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The position of the steering wheel when turning off the turn signals automatically

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Abstract: Turn signals are an important device on vehicles, with which we inform other participants about our intention when changing lanes, realigning, turning, overtaking, etc. The use of turn signals increases the safety of all road users. According to research conducted in the USA and Canada, one of the reasons why drivers do not use their turn signals is that they sometimes forget to turn off this device. In this work paper, special emphasis is placed on determining the position of the steering wheel at which the automatic turning off of the turn signal is activated when returning the steering wheel to the original "zero" position, as well as the position of the steering wheel when the automatic turning off of this device is not activated.

KEYWORDS: TURN SIGNALS, ANGLE, AUTOMATIC TURNING OFF

1. Introduction

According to the rulebook on the division of motor vehicles and trailers of the Republic of Serbia, light and light-signal devices on motor vehicles and trailers, i.e. lights, mean:

- Road lighting devices,
- Vehicle marking devices and
- Devices for giving light signals [1].

A device for giving light signals means:

- Stop lights,
- Turn signals and
- Device for simultaneously turning on all turn signals [1].

In this paper, special attention will be paid to turn signals, which are standard equipment on vehicles for a reason. By using the turn signals at any time when planning to change the direction of movement, change the traffic lane, start overtaking or going around other vehicles, other participants are informed about this intention, and thus prevent the occurrence of a potentially dangerous traffic situation.

The driver is obliged to inform other traffic participants clearly and in a timely manner about the intention to perform any of the actions in traffic (joining traffic, changing lanes, realigning, turning, U-turn, going around, overtaking, reversing, exiting traffic, stopping, parking, etc.) by giving the prescribed signal to the turn signals. But it is also important that after the action in traffic, the driver is obliged to stop giving that signal. [2].

It is a common situation in traffic accident expertise that drivers state that they turned on the turn signal before starting a certain action in traffic, and that their turn signal was still working after completing the same action. This misled other road users and contributed to dangerous traffic situations, and in some cases to traffic accidents.

In most cases, the turn signals turn off automatically when returning the steering wheel to the zero position, i.e. the position corresponding to driving in the direction. In some cases, an intervention by the driver is required to turn off the turn signal. In this paper, the angle of the steering wheel at which the turn signal automatically turns off will be analyzed.

2. Using of turn signals

The following can be achieved with the correct use of turn signals [3]:

- Greater safety for pedestrians and cyclists - the turned on turn signal warns pedestrians and cyclists that the vehicle will turn left or right and thus prevents them from entering the driver's blind spot. Otherwise, when pedestrians and cyclists are not informed about the driver's intention, they can easily find themselves in a dangerous situation.
- Safe lane change - when realigning, giving turn signals, other drivers are warned that space is needed to perform this maneuver and thus they can adjust the speed of their vehicles. If other drivers are not warned about this maneuver, potentially dangerous traffic situations would be created.

- Warning of the vehicle behind - turning on the turn signals warns the drivers of the vehicle behind them about a potential speed adjustment. If there is an intention to make a turn, it is necessary to reduce the speed beforehand and adapt it to this maneuver. By giving a signal, the drivers behind are warned in time to slow down and adjust the speed of their vehicle as necessary. If the warning did not occur, there could potentially be a delay in reaction and adjustment of movement speed and a collision could occur.



Fig. 1 The turn signal lever

In North America, a study was conducted, which showed that drivers in the US and Canada do not signal a turn at intersections approximately 25% of the time. When it comes to changing lanes, a study showed that drivers in Dayton (Ohio) failed to signal a lane change 48% of the time [4]. According to the same research, the most common reasons why people do not use their turn signals are as follows:

1. There is no one around - drivers behave better when they are in traffic with a large number of vehicles, than when they are alone or with a small number of vehicles in traffic. If the driver is on one of the local roads or smaller streets where there is less traffic, it is more likely that he will not use the turn signal;
2. It's only a right turn - a left turn is potentially a much more dangerous move than a right turn. By signaling a left turn, not only are you letting the people behind you know that you're slowing down and potentially stopping in the middle of the road, but you're telling opposing traffic know that you're about to cut across. If it's a four-way intersection with pedestrians, everyone benefits from a heads up.
3. The person in front of you did not use the signal - research has shown that drivers can be influenced by other road users and their behavior. The degree of use of turn signals is greater if following a vehicle on which this device for giving light signals was also turned on;
4. The last vehicle in the column - when the driver enters the column of vehicles in a special lane for left or right turns, it can be assumed which maneuver he will perform and often in these situations the driver does not use the turn signal;
5. Turning off the signal - a certain percentage of people stated in the research that the reason for their carelessness is that they sometimes forget to turn off this device, if it does not turn off automatically etc.

3. How the turn signals works

The turn signal circuit gets power when the ignition key is on. The power goes through a fuse panel into the thermal flasher. From there it goes to the lever on the steering column.

Depending on the position of the turn signal lever, the power either stops in the switch or gets sent to the left or right turn signal lights (including the indicator lights on the dashboard). Power flows through the filament of the lights and then is grounded.

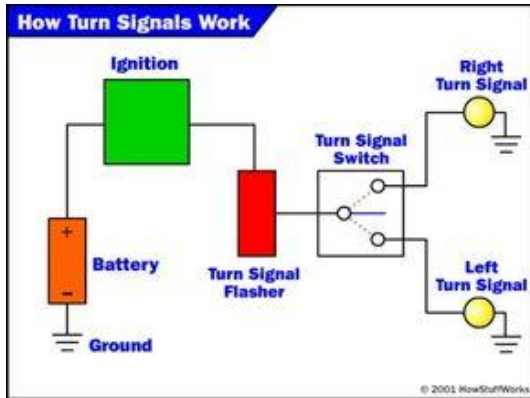


Fig. 2 Turn signal circuit [5]

The turn signal first appeared on automobiles in 1909, but the click wasn't added until the 1930s. Inventor Joseph Bell patented a small electronic device that directed electricity to the outer turn signals [6].

Buick was the first automaker to add this new technology to its cars in 1939. For the first time in history, cars had turn signals that flashed, which also added a new layer of safety. Other automakers were slow to adopt this technology, and it wasn't until the 1950s that it really caught on and the clicking turn signals became standard on practically every new car sold [7].

In many cars, the sound and flashing signals are generated by a thermal-style flasher. An electric current flows through the device, which houses a bimetallic spring, located within the dash.

When you turn the signal on, a current is sent through the bimetallic spring that heats it up. The two metals within the spring heat up at different rates, forcing them to bend in a certain way. The bending does two things: It completes the circuit, sending current to the outer light and turning it on for a split second, and it makes that distinct clicking sound as the metal pops into position.

Much newer vehicles rely on a turn signal system that is completely chip controlled. There are no moving parts, which means no bimetallic spring, yet they still make that clicking sound. It's a "fake" sound. It's just there because we expect it to be and lets us know our signal is on [8].

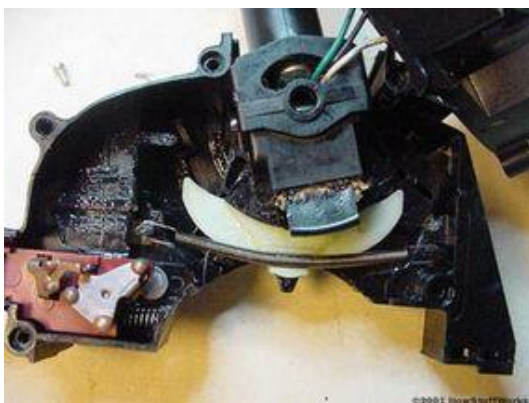


Fig. 3 Inside the turn signal switch [5]

On the steering shaft (the part that spins when you turn the steering wheel), there is a notched hub. There are four notches

equally spaced around the hub. When the turn signal is on, a plastic lever on the turn-signal switch is pushed into the path of these notches. When the turn signals are on, the black plastic tip on the white plastic lever engages the notches on the hub. When the turn signal lever is raised to signal a right turn, a spring-loaded roller drops into a notch on the switch housing, holding the lever in place. At the same time, a plastic lever thrusts out into the path of the hub.

As the hub continues to rotate clockwise, the notches hit the plastic lever, which rocks to let each notch pass. When the wheel turns back to the left, the hub turns counterclockwise, pushing the plastic lever in the other direction. This forces the spring-loaded roller out of its notch in the switch housing, so the lever springs back to its centered position.

4. Research methodology

First, it is necessary to define the zero position of the steering wheel. Reference points on the instrument panel, as well as the steering wheel itself, are marked and the position is photo-documented.

Then the experiment was started, by turning on the turn signal. The steering wheel is then rotated through the following angles: 90°, 180°, 270° and 360°, as well as a full turn of the steering wheel. The procedure was carried out separately by checking the operation of the left turn signals and the winding of the steering wheel on the left side, as well as the right turn signals and the winding of the steering wheel on the right side.

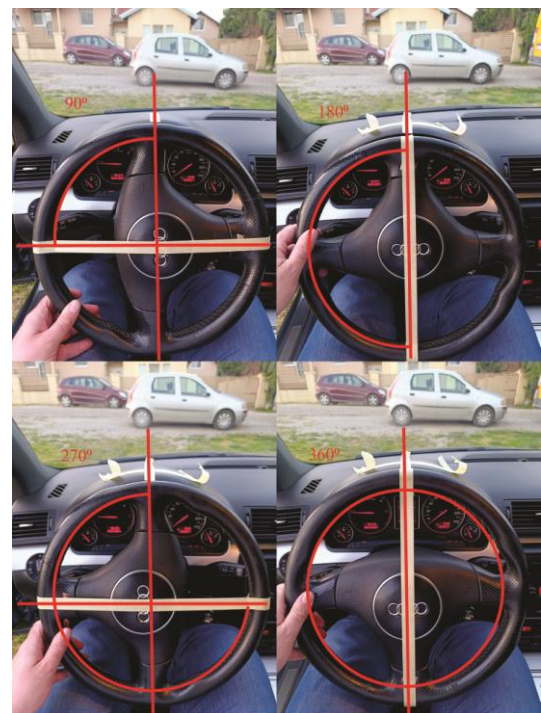


Fig. 4 Steering wheel position rotated by 90°, 180°, 270° and 360°

When the desired turning angle was reached, which is a simulation of turning the vehicle, the steering wheel was slowly returned to its zero position. It should be noted that along with the turned on turn signals, light and sound signals were also turned on to control the operation of the turn signals. The moment when the sound and light signals stop working, it means that the turn signal has also turned off. It automatically stops turning the steering wheel and records its position.

Subsequent processing determines the angle at which the steering wheel was turned when the turn signal stopped working.

In the second part of the experiment, the position of the steering wheel when the turn signal will not turn off automatically was recorded. Turning the steering wheel to this position requires the driver to manually turn off the turn signal when returning the

steering wheel to the zero position, and for each angle of rotation of the steering wheel greater than this value, the automatic turning off of the turn signal is activated.

The research was conducted on the following vehicles:

- Ford C-max, produced in 2005,
- VW Polo, produced in 2004,
- Audi A3, produced in 2013,
- Audi A4, produced in 2004.

5. Research results

Table 1 shows the positions of the steering wheel at which the automatic turn signal is activated when the steering wheel is returned to the zero position. The results are shown for each vehicle separately, when showing the left and right turn signals.

What can be concluded is that the angle at which the turn signal automatically stops working is between 20° and 30° in relation to the zero position of the steering wheel, while the average value for all measurements is 25° in relation to the zero position of the steering wheel. The results do not oscillate much for different steering wheel angles.

Turning angle steering wheel	Ford C-max		VW Polo		Audi A3		Audi A4	
	left	right	left	right	left	right	left	right
90°	25°	25°	27°	27°	25°	28°	26°	27°
180°	22°	26°	25°	26°	25°	25°	27°	26°
270°	24°	30°	29°	25°	26°	28°	28°	26°
360°	27°	29°	28°	27°	27°	26°	26°	25°
>360°	22°	24°	28°	24°	27°	28°	27°	27°

When fully winding the steering wheel, where the angle of rotation is greater than 360°, the angle at which the turn signal automatically turns off is 20-28° in relation to the vertical line, which defines the zero position of the steering wheel, but it should be noted that the driver still needs a full turn of the wheel of the steering wheel to return the steering wheels to the zero position.

Vehicle	Turning angle steering wheel
Ford C-max	42°
VW Polo	41°
Audi A3	48°
Audi A4	45°

Table 2 gives the values that define the final steering wheel turning angles where the automatic turning off of the turn signals is not activated. For these and smaller steering wheel turning angles, the driver must turn off the turn signals manually, while when turning the steering wheel for larger angles, the automatic turning off of the turn signals is activated. In the observed vehicle models, this angle is about 45°.

6. Conclusion

During many actions in traffic, such as merging into traffic, changing lanes, realigning, turning, U-turning, going around, overtaking, etc., the driver is obliged to clearly and promptly inform other traffic participants of this intention by giving the prescribed signal to the turn signals. The driver must give the prescribed signal for the entire time the vehicle is operating, and after the operation has been completed he must stop giving that signal. In most cases, the turn signal turns off automatically when returning the steering wheel to the zero position, i.e. the position corresponding to driving in the direction. In some cases, an intervention by the driver is required to turn off the turn signal.

This paper analyzes the position of the steering wheel when returning to the zero position, during which the turn signal is automatically switched off, as well as the maximum angle of rotation of the steering wheel when the automatic switch-off of this device is not activated.

The research was carried out on four vehicles, when giving the left and right turn signals, by turning the steering wheel for angles: 90°, 180°, 270° and 360°, as well as full winding of the steering wheel.

The measurement determined that the value of the angle, at which the automatic shutdown of the steering wheel is activated when returning the steering wheel to its original zero state, ranges between 20° and 30°, while the average value is 25°, regardless of how much the steering wheel was initially turned.

The value of the angle of rotation of the steering wheel when the automatic turning off of the turn signals is not yet activated and when the driver's intervention is required to turn off the same device, moves about 45° in relation to the zero position of the steering wheel.

6. References

- [1] Rulebook on the division of motor and trailer vehicles and technical conditions for vehicles in road traffic, Službeni glasnik RS no. 24/24 published 22.03.2024.
- [2] Law on Road Traffic Safety, Službeni glasnik RS no. 76/23, published 07.09.2023.
- [3] The Importance of Always Using Your Turn Signal, Return to Dulaney, Lauer & Thomas Home, <https://www.dulaneylauerthomas.com/>
- [4] 7 (Bad) Reasons Why People Don't Use Their Turn Signals, Dave Roos, <https://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/7-bad-reasons-why-people-dont-use-their-turn-signals.htm>
- [5] How Turn Signals Work, Karim Nice, <https://auto.howstuffworks.com/turn-signal3.htm>
- [6] Buick turns 110, looking back at 11 decades of innovation, TorqueNews, <https://www.torquenews.com/1080/buick-turns-110-looking-back-11-decades-innovation>
- [7] The Turn Signal: A Brief History of Communication on the Road, CARmag, <https://www.carmag.co.za/news/industry-news/the-turn-signal-a-brief-history-of-communication-on-the-road/>
- [8] A Look at the History of the Turn Signal Sound, The Unmistakable Click, <https://www.qualityplusautomotive.com/blog/2020/september/the-unmistakable-click/>

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Analysis of main feedwater pump from steam power plant at three loads

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Abstract: This paper presents results of the Main Feedwater Pump (MFP) isentropic and exergy analyses at three power plant loads. Observed MFP is a constituent component of condensate/feedwater sub-system from conventional steam power plant. In real exploitation conditions, MFP uses mechanical power higher than 3000 kW, considering all observed power plant loads. Main isentropic and exergy parameters of the MFP at various plant loads show the same general trends (increase in power plant load simultaneously increases MFP losses and efficiencies and vice versa, from both isentropic and exergy viewpoints). Analyzed MFP has high isentropic and exergy efficiencies, considering all plant loads and ambient temperatures (at any plant load MFP isentropic efficiency is higher than 85%, while the lowest MFP exergy efficiency is equal to 89.24% at the lowest observed plant load and the highest observed ambient temperature). The change in isentropic and exergy efficiency of the MFP is small if all observed plant loads and ambient temperatures are taken into consideration.

KEYWORDS: MAIN FEEDWATER PUMP, ISENTROPIC ANALYSIS, EXERGY ANALYSIS, STEAM POWER PLANT, VARIOUS LOADS

1. Introduction

Steam power plants nowadays are composed of many components and sub-systems [1]. One inevitable component in any steam power plant is a pump – at least two or more pumps (main and auxiliary) are mounted in the condensate/feedwater heating sub-system of any steam power plant [2-4].

The main goal of any condensate/feedwater heating sub-system is to increase water temperature and pressure before its return to steam generator [5]. The only possibility how water pressure can be increased is by using various kinds of pumps [6]. Without this sub-system steam generator will use notably higher fuel amount and produce notably higher harmful emissions to obtain the same steam operating parameters at the steam turbine inlet [7].

The existing literature offers various analyses of many pumps, however, it is rare to find analysis of any pump at several loads from the isentropic and exergy viewpoint, along with additional investigation related to the ambient temperature change influence on the pump exergy efficiencies and losses [8, 9].

In this paper are performed isentropic and exergy analyses of the Main Feedwater Pump (MFP) at three power plant loads. Observed MFP is a constituent component of the condensate/feedwater sub-system mounted in the existing conventional steam power plant. It is analyzed and explained did MFP isentropic and exergy losses and efficiencies show the same general trends considering various plant loads. Also, it is presented and explained how the ambient temperature change influences main MFP exergy parameters.

2. Description of the analyzed Main Feedwater Pump (MFP) and its position in steam power plant

General and simplified scheme of the steam power plant feedwater heating sub-system in which are clearly visible Main Feedwater Pumps (MFP) is presented in Fig. 1.

Fig. 1 presents that inside steam power plant are mounted three identical MFPs – one of them is in operation during the power plant running, while other two are safety pumps (any safety pump can begin with an operation at any moment if problems or possible malfunction on the currently operating MFP occurs). In various power plants nowadays it is usual to mount two or three MFPs in parallel, with an aim to avoid the whole power plant stopping if a failure of the currently operating MFP occurs. Moreover, rotational parts of any MFP wear out during a long time operation, so the parallel mounting of two or more identical MFPs allows fast, easy and safe operation continuation of the whole power plant with any other safety pump. Operation transfer to any other safety pump allows proper maintenance and parts replacement of previously operating MFP without necessity of power plant stop [10].

In Fig. 1 can also be seen that any MFP in operation takes feedwater from the deaerator [11] and delivers it to the steam generator through three closed high pressure feedwater heaters (a heating medium in each closed feedwater heater, as well as in the

deaerator, is the steam extracted from high pressure and intermediate pressure turbine cylinders).

In this paper it will be performed two different analyses of the currently operating MFP – isentropic and exergy analyses. Each of these analyses considers the different kind of losses, so it will be interesting to see will both analyses result with the same main conclusions and the same general trends. Moreover, exergy analysis of currently operating MFP will be performed not only for one, but for several ambient temperatures.

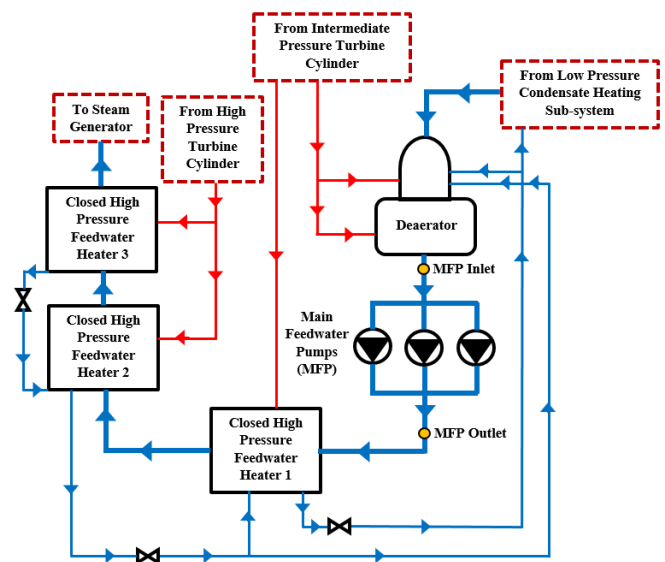


Fig. 1. General scheme of the Main Feedwater Pumps in the steam power plant feedwater heating sub-system

MFP isentropic analysis is a comparison of ideal (isentropic) and real (polytropic) water pressure increase process.

Real (polytropic) MFP pressure increase process is presented with a blue line in Fig. 2. Real process involves all the losses which are involved in water pressure increase process from the MFP inlet until the outlet (these losses are proportional to the increase in water specific entropy) [12]. Water operating parameters at the MFP Inlet and Outlet (pressures, temperatures and mass flow rates) can be determined by the measurements during the pump exploitation. If there is no water mass flow rate leakage inside the MFP, than mass flow rate at the MFP Inlet and Outlet will be the same.

Ideal (isentropic) water pressure increase process is the process between the same pressures and it uses the same mass flow rates as the real (polytropic) process, but in ideal process water specific entropy remains constant, Fig. 2 [13]. Water operating parameters at the outlet of the ideal pressure increase process are obtained by mathematical calculations at each plant load (in the ideal process at the MFP outlet are known water pressure and the same water specific entropy as at the MFP inlet). In Fig. 2 ideal (isentropic) MFP process is presented with dashed red line. Ideal MFP process

did not take into consideration any losses which occur during the water pressure increase from the inlet pressure till the outlet pressure.

MFP is a mechanical power consumer, so as any other mechanical power consumer [14] in ideal (isentropic) water pressure increase process MFP will consume the lowest possible mechanical power (due to neglecting all losses in the ideal process). In real (polytropic) process, MFP will consume more mechanical power in comparison to the ideal process (in real process additional mechanical power consumed by the MFP will be used for covering all the losses during the pump operation).

It should be highlighted that ideal and real water pressure increase processes of the MFP, presented in Fig. 2, are valid for any plant load (the change occur only in water operating parameters at different plant loads).

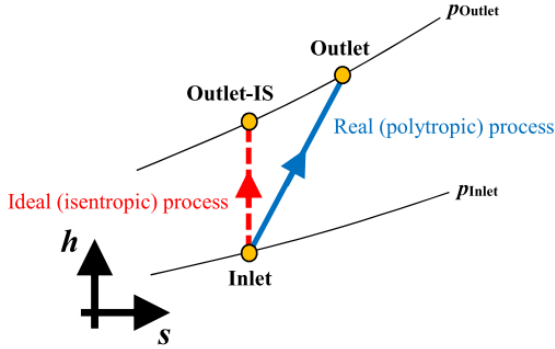


Fig. 2. Specific enthalpy/Specific entropy (h/s) diagram of water pressure increase process (both ideal and real processes)

3. Equations for the MFP analysis

MFP isentropic analysis is performed according to the recommendations from the literature [15, 16], while MFP exergy analysis is performed according to procedure from the literature [17, 18]. In the mentioned literature can be found general isentropic and exergy equations and balances related to any observed system or component.

In comparison to MFP isentropic analysis which did not consider parameters of the ambient in which pump operates (ambient pressure and temperature), exergy analysis of any system or component, as well as of the observed MFP, takes into consideration the ambient parameters [19, 20]. Therefore, in the exergy analysis can be investigated changes in the ambient parameters and the influence of that change on the component or system losses and efficiencies [21, 22] (what is performed in this analysis for the observed MFP).

Both isentropic and exergy analyses are black box” methods because they did not consider the inner structure of the observed system or component [23-25]. At each observed power plant load is not detected water mass flow leakage through MFP, so the water mass flow rate at the MFP Inlet is the same as water mass flow rate at the MFP Outlet (at each plant load independently).

MFP isentropic and exergy analysis equations are defined according to operating points presented in Fig. 1 and Fig. 2. For all equations in both analyses should be highlighted that they remain the same regardless of the power plant load (change occur in water operating parameters only). Also, in the MFP exergy analysis equations remain the same as presented regardless of the change in ambient parameters.

3.1. MFP isentropic analysis equations

Real (polytropic) mechanical power consumed by the MFP is calculated as:

$$P_{\text{real,MFP}} = \dot{m}_{\text{Inlet}} \cdot (h_{\text{Outlet}} - h_{\text{Inlet}}), \quad (1)$$

where P is mechanical power, $\dot{m}$ is water mass flow rate and h is water specific enthalpy. Mechanical power which will be consumed by the MFP in an ideal situation is calculated as:

$$P_{\text{ideal,MFP}} = \dot{m}_{\text{Inlet}} \cdot (h_{\text{Outlet-IS}} - h_{\text{Inlet}}). \quad (2)$$

MFP isentropic loss is calculated as:

$$IS_{\text{Loss,MFP}} = P_{\text{real,MFP}} - P_{\text{ideal,MFP}}, \quad (3)$$

while MFP isentropic efficiency is:

$$\eta_{\text{IS,MFP}} = \frac{P_{\text{ideal,MFP}}}{P_{\text{real,MFP}}}. \quad (4)$$

3.2. MFP exergy analysis equations

In MFP exergy analysis is considered real (polytropic) water pressure increase process only. MFP cumulative exergy inlet is calculated as:

$$\dot{E}x_{\text{Inlet,MFP}} = \dot{m}_{\text{Inlet}} \cdot \varepsilon_{\text{Inlet}} + P_{\text{real,MFP}}, \quad (5)$$

where $\dot{E}x$ is fluid total exergy flow and ε is fluid specific exergy. MFP cumulative exergy outlet is:

$$\dot{E}x_{\text{Outlet,MFP}} = \dot{m}_{\text{Outlet}} \cdot \varepsilon_{\text{Outlet}}, \quad (6)$$

while MFP exergy destruction is calculated as:

$$\dot{E}x_{\text{Destruction,MFP}} = \dot{E}x_{\text{Inlet,MFP}} - \dot{E}x_{\text{Outlet,MFP}}. \quad (7)$$

MFP exergy efficiency is:

$$\eta_{\text{Ex,MFP}} = \frac{\dot{m}_{\text{Outlet}} \cdot \varepsilon_{\text{Outlet}} - \dot{m}_{\text{Inlet}} \cdot \varepsilon_{\text{Inlet}}}{P_{\text{real,MFP}}}. \quad (8)$$

4. Water operating parameters required for the MFP isentropic and exergy analyses

Operating parameters of real (polytropic) water pressure increase process at each observed power plant load are defined on the basis of literature [26] and presented in Table 1. Mentioned water operating parameters in the real process at the MFP inlet and outlet are pressure, temperature and mass flow rate. Other water operating parameters presented in Table 1 are calculated by using NIST-REFPROP 9.0 software [27].

Table 1. Water operating parameters at the MFP inlet and outlet – real (polytropic) process

POWER PLANT LOAD	POINT *	Temp. (°C)	Pressure (bar)	Mass flow rate (kg/s)	Specific enthalpy (kJ/kg)	Specific entropy (kJ/kg·K)	Specific exergy (kJ/kg) **
100%	Inlet	162.30	8.17	171.725	685.57	1.9653	104.18
	Outlet	164.92	170.00	171.725	706.30	1.9720	122.91
90%	Inlet	162.20	8.10	159.683	685.13	1.9643	104.03
	Outlet	164.84	170.00	159.683	705.95	1.9712	122.80
80%	Inlet	162.15	7.90	141.819	684.90	1.9638	103.95
	Outlet	164.84	172.00	141.819	706.08	1.9710	122.99

* In accordance to Fig. 2.

** Specific exergy at the base ambient state.

As described previously, ideal (isentropic) water pressure increase process is the process between the same pressures and it uses the same mass flow rates as real process, but specific entropy in such ideal process remains constant at each observed power plant load. Therefore, water operating parameters in the ideal MFP process are presented in Table 2.

Table 2. Water operating parameters at the MFP inlet and outlet – ideal (isentropic) process

POWER PLANT LOAD	POINT *	Pressure (bar)	Mass flow rate (kg/s)	Specific entropy (kJ/kg·K)	Isentropic specific enthalpy (kJ/kg)
100%	Inlet	8.17	171.725	1.9653	685.57
	Outlet-IS	170.00	171.725	1.9653	703.37
90%	Inlet	8.10	159.683	1.9643	685.13
	Outlet-IS	170.00	159.683	1.9643	702.93
80%	Inlet	7.90	141.819	1.9638	684.90
	Outlet-IS	172.00	141.819	1.9638	702.93

* In accordance to Fig. 2.

Exergy analysis of any component or system requires definition of the base ambient state. Base ambient state can be defined provisionally [28, 29], and in the exergy analysis of MFP base ambient state is defined by the ambient temperature of 25 °C and the ambient pressure of 1 bar.

5. Results and discussion

5.1. Results of the MFP isentropic analysis

Fig. 3 presents real (polytropic) and ideal (isentropic) mechanical power consumed by the analyzed MFP at three power plant loads.

At each power plant load real (polytropic) mechanical power consumed by the MFP is higher than ideal (isentropic) one, because real process considers all the losses which occur during the water pressure increase, while ideal process did not consider any losses.

Considering all observed power plant loads, it can easily be concluded from Fig. 3 that power plant load is directly proportional to MFP consumed mechanical power (both real and ideal) – increase in power plant load simultaneously increases MFP consumed mechanical power and vice versa.

At the power plant nominal load (Load 100%) analyzed MFP will consume mechanical power equal to 3559.86 kW in real (polytropic) and equal to 3056.70 kW in ideal (isentropic) pressure increase process.

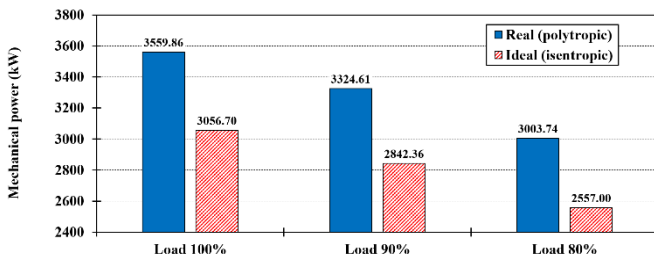


Fig. 3. Real (polytropic) and ideal (isentropic) mechanical power consumed by the observed MFP at three power plant loads

Isentropic loss and isentropic efficiency of the analyzed MFP at three observed power plant loads are presented in Fig. 4.

It is interesting that direct proportionality of power plant load in relation to MFP consumed mechanical power, Fig. 3, is also valid for the power plant load and isentropic loss as well as for the power plant load and isentropic efficiency, Fig. 4. Increase in power plant load simultaneously increases MFP isentropic loss and isentropic efficiency (and vice versa). In addition, it is also interesting that increase in isentropic loss simultaneously increases isentropic efficiency of the analyzed MFP (usually for many components from steam power plant increase in loss results with an efficiency decrease).

At the power plant nominal load (Load 100%) observed MFP has the highest isentropic loss equal to 503.15 kW and simultaneously the highest isentropic efficiency of 85.87%. From Fig. 4 can also be seen that the change in MFP isentropic efficiency during the power plant load change is quite small (change in power plant load of 20% results with MFP isentropic efficiency change of 0.74% only).

Finally, it can be concluded that in the observed MFP isentropic analysis, all presented operating parameters are directly proportional to power plant load (consumed mechanical power, isentropic loss and isentropic efficiency).

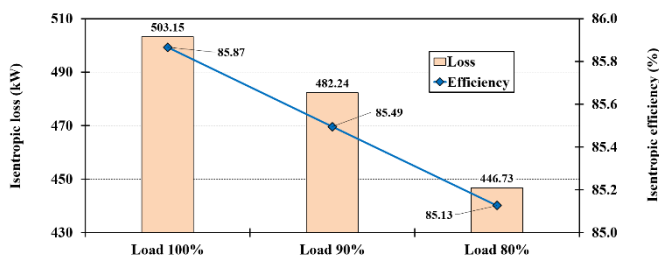


Fig. 4. Isentropic loss and isentropic efficiency of the observed MFP at three power plant loads

5.2. Results of the MFP exergy analysis

In exergy analysis of the observed MFP is varied the ambient temperature from 5 °C up to 45 °C in steps of 10 °C. The change in ambient pressure is relatively small, and it will not have a notable influence on the MFP exergy parameters. Therefore, for any observed ambient temperature, ambient pressure remains the same as at the base ambient state (equal to 1 bar).

Exergy destruction of the observed MFP during the ambient temperature change at three power plant loads is presented in Fig. 5.

From Fig. 5 is clear that power plant load and MFP exergy destruction are directly proportional – increase in power plant load simultaneously increases MFP exergy destruction and vice versa, regardless of the observed ambient temperature. Moreover, the ambient temperature is directly proportional to MFP exergy destruction – increase in the ambient temperature simultaneously increases MFP exergy destruction and vice versa, at any observed power plant load.

The highest MFP exergy destruction is equal to 365.60 kW and is obtained at power plant nominal load (Load 100%) and ambient temperature of 45 °C, while the lowest MFP exergy destruction is equal to 282.22 kW and is obtained at the lowest observed power plant load (Load 80%) and ambient temperature of 5 °C.

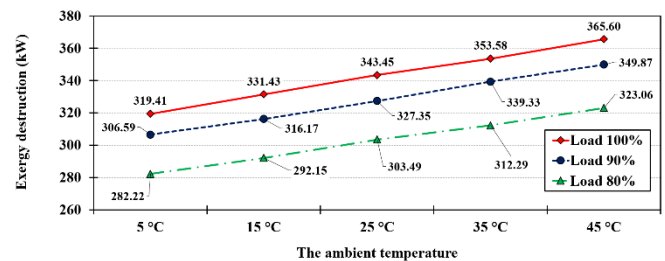


Fig. 5. Exergy destruction of the observed MFP during the ambient temperature change at three power plant loads

Exergy efficiency of the analyzed MFP during the ambient temperature change at three power plant loads is presented in Fig. 6.

From Fig. 6 can be easily concluded that power plant load and MFP exergy efficiency are directly proportional – increase in power plant load simultaneously increases MFP exergy efficiency and vice versa, regardless of the observed ambient temperature. The ambient temperature is reverse proportional to MFP exergy efficiency – increase in the ambient temperature simultaneously decreases MFP exergy efficiency and vice versa, at any observed power plant load.

The highest MFP exergy efficiency is equal to 91.03% and is obtained at power plant nominal load (Load 100%) and ambient temperature of 5 °C, while the lowest MFP exergy efficiency is equal to 89.24% and is obtained at the lowest observed power plant load (Load 80%) and ambient temperature of 45 °C. Considering all observed power plant loads and ambient temperatures, it can be concluded that the overall change in MFP exergy efficiency is low (equal to 1.79% between the highest and the lowest MFP exergy efficiency).

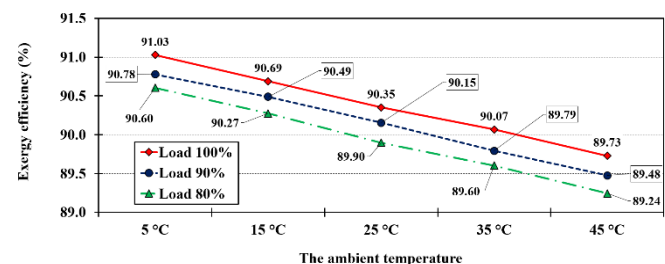


Fig. 6. Exergy efficiency of the observed MFP during the ambient temperature change at three power plant loads

6. Conclusions

This paper presents results of the Main Feedwater Pump (MFP) isentropic and exergy analyses at three power plant loads. Analyzed MFP is a constituent component of condensate/feedwater sub-system from conventional steam power plant. Along with isentropic and exergy analyses, it is shown how the ambient temperature change influences the dominant MFP exergy parameters. Main conclusions of the presented analyses are:

- In real exploitation conditions, analyzed MFP uses mechanical power higher than 3000 kW, considering all observed power plant loads.
- At various plant loads, MFP main isentropic and exergy parameters show the same general trends (increase in power plant load simultaneously increases MFP losses and efficiencies and vice versa, from both isentropic and exergy viewpoints).
- The ambient temperature is directly proportional to MFP exergy destruction and reverse proportional to MFP exergy efficiency at any power plant load (the increase in ambient temperature increases MFP exergy destruction and simultaneously decreases MFP exergy efficiency and vice versa).
- MFP analyzed in this paper has high isentropic and exergy efficiencies, considering all plant loads and ambient temperatures (at any plant load MFP isentropic efficiency is higher than 85%, while the lowest MFP exergy efficiency is equal to 89.24% at the lowest observed plant load and the highest observed ambient temperature).
- The change in MFP isentropic efficiency during the power plant load change is small (change in power plant load of 20% results with MFP isentropic efficiency change of 0.74% only). Also, considering all observed power plant loads and ambient temperatures, the overall change in MFP exergy efficiency is low (equal to 1.79% between the highest and the lowest MFP exergy efficiency).

7. Acknowledgment

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8. References

- [1] Sutton, I. (2017). Plant design and operations. Gulf Professional Publishing
- [2] Mrzljak, V., Lorencin, I., Andelić, N., & Baressi Šegota, S. (2020). Comparison of three methods for the pump energy analysis. In IV International Scientific Conference: Mathematical Modeling (pp. 5-8).
- [3] Ahmadi, G. R., & Toghraie, D. (2016). Energy and exergy analysis of Montazeri steam power plant in Iran. *Renewable and Sustainable Energy Reviews*, 56, 454-463. (doi:10.1016/j.rser.2015.11.074)
- [4] Mrzljak, V., Poljak, I., & Mrakovčić, T. (2017). Energy and exergy analysis of the turbo-generators and steam turbine for the main feed water pump drive on LNG carrier. *Energy conversion and management*, 140, 307-323. (doi:10.1016/j.enconman.2017.03.007)
- [5] Koroglu, T., & Sogut, O. S. (2018). Conventional and advanced exergy analyses of a marine steam power plant. *Energy*, 163, 392-403. (doi:10.1016/j.energy.2018.08.119)
- [6] Mrzljak, V., Žarković, B., & Poljak, I. (2017). Energy and exergy analysis of sea water pump for the main condenser cooling in the LNG carrier steam propulsion system. *Mathematical Modeling*, 1(3), 144-147.
- [7] Mrzljak, V., Poljak, I., & Medica-Viola, V. (2017). Dual fuel consumption and efficiency of marine steam generators for the propulsion of LNG carrier. *Applied Thermal Engineering*, 119, 331-346. (doi:10.1016/j.applthermaleng.2017.03.078)
- [8] Kostyuk, A., & Frolov, V. (1988). Steam and gas turbines. Mir Publishers.
- [9] Orlandi, F., Montorsi, L., & Milani, M. (2023). Cavitation analysis through CFD in industrial pumps: A review. *International Journal of Thermofluids*, 20, 100506. (doi:10.1016/j.ijft.2023.100506)
- [10] Fausing Olesen, J., & Shaker, H. R. (2020). Predictive maintenance for pump systems and thermal power plants: State-of-the-art review, trends and challenges. *Sensors*, 20(8), 2425. (doi:10.3390/s20082425)
- [11] Mrzljak, V., Prpić-Oršić, J., Musulin, J., & Štifanić, D. (2020). Energy and exergy analysis of deaerator from combined-cycle power plant. *Trans Motauto World*, 5(2), 64-67.
- [12] Mrzljak, V., Poljak, I., Jelić, M., & Prpić-Oršić, J. (2023). Thermodynamic Analysis and Improvement Potential of Helium Closed Cycle Gas Turbine Power Plant at Four Loads. *Energies*, 16(15), 5589. (doi:10.3390/en16155589)
- [13] Medica-Viola, V., Baressi Šegota, S., Mrzljak, V., & Štifanić, D. (2020). Comparison of conventional and heat balance based energy analyses of steam turbine. *Pomorstvo*, 34(1), 74-85. (doi:10.31217/p.34.1.9)
- [14] Poljak, I., Orović, J., & Mrzljak, V. (2018). Energy and exergy analysis of the condensate pump during internal leakage from the marine steam propulsion system. *Pomorstvo*, 32(2), 268-280. (doi:10.31217/p.31.2.12)
- [15] Elčić, Z. (1995). Steam turbines. ABB, Karlovac, National and University Library Zagreb.
- [16] Poljak, I., & Mrzljak, V. (2023). Thermodynamic Analysis and Comparison of Two Marine Steam Propulsion Turbines. *NAŠE MORE: znanstveni časopis za more i pomorstvo*, 70(2), 0-0. (doi:10.17818/NM/2023/2.2)
- [17] Erdem, H. H., Akkaya, A. V., Cetin, B., Dagdas, A., Sevilgen, S. H., Sahin, B., ... & Atas, S. (2009). Comparative energetic and exergetic performance analyses for coal-fired thermal power plants in Turkey. *International Journal of Thermal Sciences*, 48(11), 2179-2186. (doi:10.1016/j.ijthermalsci.2009.03.007)
- [18] Mrzljak, V., Jelić, M., Poljak, I., & Prpić-Oršić, J. (2023). Analysis and Comparison of Main Steam Turbines from Four Different Thermal Power Plants. *Pomorstvo*, 37(1), 58-74. (doi:10.31217/p.37.1.6)
- [19] Kanoğlu, M., Çengel, Y. A. & Dincer, I. (2012). Efficiency Evaluation of Energy Systems. *Springer Briefs in Energy*. (doi:10.1007/978-1-4614-2242-6)
- [20] Aljundi, I. H. (2009). Energy and exergy analysis of a steam power plant in Jordan. *Applied thermal engineering*, 29(2-3), 324-328. (doi:10.1016/j.applthermaleng.2008.02.029)
- [21] Mrzljak, V., Andelić, N., Lorencin, I., & Sandi Baressi Šegota, S. (2021). The influence of various optimization algorithms on nuclear power plant steam turbine exergy efficiency and destruction. *Pomorstvo*, 35(1), 69-86. (doi:10.31217/p.35.1.8)
- [22] Kopac, M., & Hilalci, A. (2007). Effect of ambient temperature on the efficiency of the regenerative and reheat Çatalağzı power plant in Turkey. *Applied Thermal Engineering*, 27(8-9), 1377-1385. (doi:10.1016/j.applthermaleng.2006.10.029)
- [23] Mrzljak, V., Kudláček, J., Baressi Šegota, S., & Medica-Viola, V. (2021). Energy and Exergy Analysis of Waste Heat Recovery Closed-Cycle Gas Turbine System while Operating with Different Medium. *Pomorski zbornik*, 60(1), 21-48. (doi:10.18048/2021.60.02)
- [24] Elhelw, M., Al Dahma, K. S., & el Hamid Attia, A. (2019). Utilizing exergy analysis in studying the performance of steam power plant at two different operation mode. *Applied Thermal Engineering*, 150, 285-293. (doi:10.1016/j.applthermaleng.2019.01.003)
- [25] Baressi Šegota, S., Lorencin, I., Andelić, N., Mrzljak, V., & Car, Z. (2020). Improvement of marine steam turbine conventional exergy analysis by neural network application. *Journal of Marine Science and Engineering*, 8(11), 884. (doi:10.3390/jmse8110884)
- [26] Čehajić, N. (2023). Exergy Analysis of Thermal Power Plant for Three Different Loads. *Tehnički glasnik*, 17(2), 160-166. (doi:10.31803/tg-20211214151555)
- [27] Lemmon, E. W., Huber, M. L., & McLinden, M. O. (2010). NIST Standard Reference Database 23, Reference Fluid Thermodynamic and Transport Properties (REFPROP), version 9.0, National Institute of Standards and Technology. R1234yf. fld file dated December, 22, 2010.
- [28] Mrzljak, V., Poljak, I., & Žarković, B. (2018). Exergy analysis of steam pressure reduction valve in marine propulsion plant on conventional LNG carrier. *NAŠE MORE: znanstveni časopis za more i pomorstvo*, 65(1), 24-31. (doi:10.17818/NM/2018/1.4)
- [29] Kotas, T. J. (2012). The exergy method of thermal plant analysis. Paragon Publishing.

Modern tendencies and challenges in the car industry- international and national aspect

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Abstract: *In the world today, Germany could lose its status as a superpower in the automotive industry, and the German Association of the Automotive Industry considers excessive regulation, slow political decisions and the absence of a legal framework for issues such as artificial intelligence as key problems.*

From the year 2021, the list of Chinese companies has doubled. China develops electric motor cars and has taken the lead compared to Europe, especially in battery technologies, but also subsidizes their production. At the same time, China became the world's largest car exporter in 2023 - it exported 4.91 million cars, which is an increase of 57.9% compared to the last year, becoming the world's first country according to the number of exported cars.

An additional problem for car manufacturers is created by the European Union's plans to phase out vehicles with internal combustion engines by 2035. There is also a lack of access to the raw materials needed to manufacture batteries and the slow development of electric vehicle charging infrastructure. Nevertheless, during the year 2023, 254 thousand "Tesla" models were sold in Europe, making this car the best-selling car on the continent.

From July 2024, every new car must have the most modern safety systems, having in mind that 20.400 people died on the roads of the European Union in 2023, according to unofficial data (that's 1% less than in 2022). From July 7, new cars are obliged to have 10 additional safety systems, which will contribute to increasing safety and reducing the number of accidents.

On the territory of Serbia, a license was issued to one company for test driving of automated vehicles, after tests and analysis conducted jointly by the Traffic Safety Agency and the CIAX laboratory of the Faculty of Mechanical Engineering in Belgrade. And from February this year in Serbia, the registration of those interested in state subsidies for the purchase of electric vehicles began and will continue until October. In Kragujevac, from 2024 "Stelantis" will start producing the new "Panda" hybrid. It was announced that it will be called "PANDINA". And we look forward to its production.

KEY WORDS: ELECTRIC CARS, SAFETY, WORLD, SERBIA

Introductory considerations

A high rate of growth in the number of cars between 2012 and 2022 was recorded in Central and Eastern Europe. The most cars are in Italy, followed by Luxembourg, Finland and Cyprus. Lithuania had the lowest rate.

On September 15th last year, the trade union of united Auto Workers of the USA launched simultaneous strikes in three factories owned by "Ford", "General Motors" and "Chrysler", which started the most ambitious union action in the American industry in recent decades. The strike by the "Detroit Three" stopped the production of the "Ford Bronco", "Jeep Wrangler" and "Chevrolet pickup truck" along with other popular models. It is believed that workers should have a share in the profits these companies make. It should be known that in the period between 1910 and 1920, "Ford" already produced the millionth car.

Mercedes is introducing a new era of transportation, it had the first tow truck that drives itself, and now it has the first to run on electricity. The first electric truck, the "Daimler Trak", was introduced, as well as the electric "e-actros 600" with a range of 500 kilometers¹, ready to immediately replace the diesel fleet in Europe and the world.

This year, the formula race in Monza was held without a driver for the first time.

And the world is struggling with food shortages... Nevertheless, during the year 2023, 254 thousand "Tesla" models were sold in Europe, making this car the best-selling car on the continent.

New development trends in the world

But, back in November 2019, the German chancellor of that time Angela Merkel, during a tour of the production facility for the "Volkswagen" electric car "ID-3", said that she wanted to drastically increase the number of stations for electric vehicles in Germany and wanted that till 2030 there are a million such stations in Germany. It was an incentive to replace vehicles with internal combustion engines with electric vehicles.

Today Germany could lose its status as a major power in the automotive industry and China is competing for that status. The German Association of the Automotive Industry (VDA) considers

excessive regulation, slow political decisions and the absence of a legal framework for issues such as artificial intelligence as key problems. They are asking the state to temporarily subsidize the price of electricity, in order to prevent the departure of battery and semiconductor manufacturers from Germany, and also to attract foreign companies. The Government, on the other hand, announced tax relief for companies in the amount of 32 billion euros over the next four years.

The Chinese are catching up the European automotive industry. As of 2021, the list of Chinese companies has doubled. China develops electric motor cars [1] and has taken the lead over Europe, especially in battery technologies, but also subsidizes their production. For this year 2024, the Chinese Changan E 07 (Qiyuan) fully electric SUV has been prepared. The Chinese company "Xiaomi" announced that it will officially start selling its first electric car SY7 from March 28th, and that a waiting list for the new vehicle has been opened in 59 stores in 29 cities in China.

In September 2023, along with well-known European companies, such as "Volkswagen" and "Mercedes", there were as many as 41% of exhibitors from Asian countries at the fair in Munich. Several Chinese electric car manufacturers have dominated the German market. An investigation on China's public subsidies for electric cars is also being opened. By introducing a punitive duty on Chinese vehicles, the risk of a "trade war" with Beijing can be triggered.

And at the beginning of 2024, manufacturers such as "Ford" and "General Motors" announced that they are reducing the production plans of electric vehicles. There has been a decline in the demand for electric vehicle rentals, and rent a car companies are exchanging them for gas-powered cars due to higher maintenance costs and more frequent collisions.

It is interesting that the Government in Great Britain postponed the previously announced measures within the framework of the green policy. Nevertheless, the goal remained the same, zero emissions of exhaust gases in 2050, although the end of sales of new diesel and gasoline cars was postponed for five years.

After a break of almost 5 years, caused by the covid pandemic, the 19th International car show in Geneva opened its doors and until the 3rd of March this year, visitors had the opportunity to see the latest vehicle models, more than 20 brands from various regions. "Renault" presented a new electric model and received an award for the "Senik" electric vehicle.

¹ At the presentation of the truck in Lower Saxony, the company announced that serial production will begin at the end of next year, and the factory will start receiving orders already this year.

Importance of safety issues

The Japanese company "Toyota" announced in November 2023 that it is withdrawing more than 1.8 million RAV4 vehicles manufactured between 2013 and 2018 due to the risk of fire. Some replacement batteries in these SUVs are not the correct size and could come loose and cause a fire if the car takes a sharp turn. The Japanese manufacturer is working on a repair that is free for vehicle owners. (detailed information is expected in December!)

In addition to this, "Honda" is also withdrawing 750,000 vehicles in the USA, manufactured since 2020, due to a malfunction in the air mattress systems. They speculate that the failure may have occurred after a natural disaster struck the manufacturer's production facility.

With the introduction of driverless cars, we should not forget how to drive. The goal of introducing automated cars should be to increase safety, not decrease human capabilities. However, most of the traffic accidents are caused by humans. These days in production is the Czech "Prague" bohemian sports car whose maximum speed exceeds 300 km/h and which has room for two people up to 2 meters tall.

An interesting survey was conducted in Germany to find out which drivers, of which car brands, have the most penalty points in traffic. According to "Verywatch" data (their main activity is consumer protection and price comparison of key products and energy sources in Germany) "Porsche" drivers have the most negative points with 76% above average. The drivers of "Land Rover" are in second place, and the drivers of "Yaguar" are in third place. The best participants in traffic are Mitsubishi drivers, with 40% below average, followed by Suzuki drivers.

From July 2024, every new car must have state-of-the-art safety systems, having in mind that 20,400 people died on the roads of the European Union in 2023, according to unofficial data (that's 1% less than in 2022).

New trends in serbia

On the territory of Serbia, a license for test driving automated vehicles was issued to one company, after tests and analyzes conducted jointly by the Traffic Safety Agency (ABS) and the CIAX laboratory of the Faculty of Mechanical Engineering in Belgrade.

And from February this year, the registration of those interested in state subsidies for the purchase of electric vehicles began and will continue until October. Subsidies will be provided by the Ministry of Environmental Protection of Serbia with the aim of improving air quality and the environment. The Decree on the subsidized purchase of several types of electric vehicles was adopted on February 1st, 2024, and will amount to up to 5,000 euros (for the purchase of an electric moped or light tricycle, they can count on support of 250 euros in dinar equivalent).

The National Assembly in Serbia recently adopted amendments to the Law on Road Traffic Safety [2], along with the adoption of the necessary regulations. From the 5th of April this year light electric vehicles, i.e. electric scooters, will be able to be registered, while from the 15th of June, only light electric vehicles with a valid registration will be able to participate in traffic.

There are estimates that show that the number of traffic accidents would decrease by 60% if all vehicles on the roads were autonomous. Level 3 automated vehicles have already been approved for testing on our streets.

The fact is that the majority of automated vehicles today are electric vehicles, which are associated with a greater risk of ignition in the public. This danger has nothing to do with the additional elements that automated vehicles have compared to conventional ones. It is interesting that the installation of an ignition blockade device is not currently specified in the regulation.

In Kragujevac, from 2024 "Stelantis" will start producing the new "PANDA" hybrid [3], 4 m long. It was announced that it will be called "PANDINA". And we look forward to its production. In the preparatory phase, cars are assembled every day - that's part of the process. And in addition to the "ordinary" electric panda, a mega panda will also be produced. It was announced that the future

model from Kragujevac could travel 200-320 kilometers on a single charge, depending on the car's configuration.

And in our city of cars, Kragujevac, the city government decided to build a karting track. Although in this city karting has been driven for decades on improvised tracks in the grounds of the former "Zastava" and in the Great Park. This attractive sport is nurtured in the city of great auto-moto aces, and the old masters were succeeded by the new aces R. Vukosavljević, P. Lambaša, M. Nikolić.

Conclusion

Due to war events and chaos in the Red Sea, the work of the factory was interrupted and "Tesla" stopped production in Germany. Attacks by Yemen's Houthis on the main shipping lane leading to the Suez Canal have prompted major shipping companies to avoid the area and use alternative shipping routes, which are now much longer - the corridor is an important trade link between Europe and large parts of Asia. Production at the Greenheide factory in the suburbs of Berlin resumed in February 2024.

At the same time, China became the world's largest car exporter in 2023 - it exported 4.91 million cars, what is an increase of 57.9% compared to last year, becoming the world's first country in terms of the number of exported cars.

Newer forecasts indicate that batteries for electric vehicles are expected to become cheaper in the coming years, so it can be expected that the price of electric cars will be significantly lower. It is also believed that by 2040, two out of three cars on the road will be electric.

An additional problem for car manufacturers is created by the European Union's plans to phase out vehicles with internal combustion engines by 2035. There is also a lack of access to the raw materials needed to manufacture batteries and the slow development of electric vehicle charging infrastructure.

And in the Republic of Serbia there is an opportunity to attract the world's largest manufacturers of electric cars. Nevertheless, in 2023, 131,905 used vehicles were imported into Serbia (that is 610 vehicles less than in 2022). The most imported brand is still Volkswagen.

From July, new cars must have 10 additional safety systems, which will contribute to increasing safety and reducing the number of accidents.

With the introduction of driverless cars, we should not forget how to drive. The goal of introducing automated cars should be to increase safety, not decrease human capabilities.

Literature

- [1] Hong Huo, Qiang Zhang, Michael Q. Wang, David G. Streets, and Kebin He, Environmental Implication of Electric Vehicles in China, *Environ. Sci. Technol.* 2010, 44, 13, 4856–4861 *Environ. Sci. Technol.* 2010, 44, 13, 4856–4861.
- [2] Law on Road Traffic Safety, "Official Gazette RS", no 41/2009, 53/2010, 101/2011, 32/2013, 55/2014, 96/2015, 9/2016, 24/2018, 41/2018, 87/2018, 23/2019, 128/2020, 76/2023.
- [3] Stanton, H. W. Impact of Plug-in Hybrid Vehicles on the Electric Grid; Technical Report, ORNL/TM-2006/554; Oak Ridge National Laboratory: 2006.

Exploring Transient 2D Conduction: A Practical Guide Using Ansys Mechanical

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Abstract: The present research paper examines the thermal conduction transient through a 2D model analysis using the Ansys Mechanical software product. The study focuses on the importance of time in the heat conduction process and its influence on temperature stabilization in various materials and structures. Any process related to heat transfer requires some time to reach a stable heat conduction state. In various scientific and engineering fields such as thermal engineering, electricity generation, and electronics, understanding, controlling, and analysing transient conductivity can lead to more efficient operation of machines and mechanisms, reduction of energy costs, development of more resistant materials, optimization of conditioning systems, and creation of engineering simulations and models to predict thermal behaviour under different conditions. In addition, the present study can provide new knowledge in the educational field and serve as a basis for a new approach in teaching in the field of thermal engineering regarding the clarification of the conditions under which heat exchange processes occur and related changes.

Keywords: TRANSIEND CONDUCTION, TEMPERATURE, HEAT FLUX, CFD SIMULATION

1. Introduction

Thermal conductivity is a fundamental physical process that plays a critical role in solving numerous problems in various fields such as thermal engineering, electronics, energy systems, building design, etc. In the present work, is paid attention to transient heat conduction, in which the variation and distribution of temperature and heat flux in each of the bodies changes with time. Often, in a large part of the considered thermal processes, sudden temperature changes occur, in which the process becomes unstable or transient and the bodies are subjected to thermal loads. A good knowledge and analysis of these processes can lead to the improvement of conditions for their progress and their control, to the correct setting of the accompanying initial and boundary conditions, as well as to the production of new materials with improved properties.

Sources [1, 2] were used to clarify the essence of transient conductivity and to familiarize with various problems related to determining the time dependence of the temperature distribution within solid bodies during a transient process, as well as for determining the heat transfer between the body and his surroundings.

This report presents a detailed investigation of transient 2D heat conduction using Ansys Mechanical [3]. The aim is to illustrate the practical applications and benefits of this analysis in real situations by simulating the heat transfer process.

The posed physical problem is two-dimensional and for its solution a mathematical model of Laplace's differential equation for heat conduction was used [4]. The model is solved with the ANSYS solver using the finite element method [5]. For this purpose, it is necessary to draw the geometry of the domain; to set the initial and boundary conditions of the problem, which determine the heat exchange between the object and its surroundings; to generate a computational mesh with a certain set of elements for solving the heat transfer equations; and to perform a discretization of these differential equations for their solution by the ANSYS solver [6]. Following the instructions in [7], a programmatic solution is reached for all elements making up the mesh and the results obtained are analyzed.

2. Methodology

A. Model creation in Ansys Mechanical.

The simulation process begins with the creation of a 2D model in Ansys Mechanical with Laplace's two-dimensional differential equation included, which is solved numerically (1).

$$k \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) = 0, \quad (1)$$

where: k , $W/m^\circ C$ – thermal conductivity coefficient;
 T , $^\circ C$ – temperature of the domain.

A two-dimensional domain has dimensions width $\Delta x=W$ and height $\Delta y=H$.

Since the problem under consideration is a Boundary value problem, it is necessary to introduce predefined boundary conditions. Also, for the solution of the given problem, it is necessary to simplify the mathematical model and the dimensions of the area by dimensionless. In ANSYS, the dimensionless mathematical model (2) with boundary values is introduced, which corresponds to the dimensional one (1).

$$\left(\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} \right) = 0. \quad (2)$$

Fig. 1 is shown dimensionless boundary value problem.

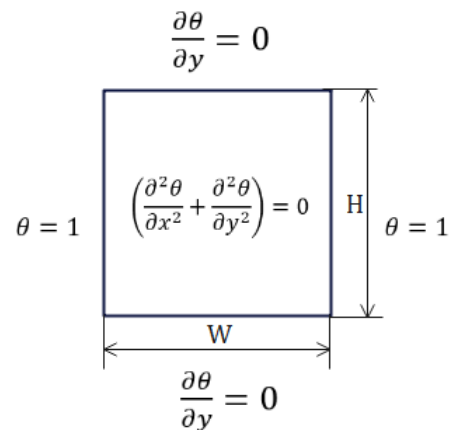


Fig. 1. Dimensionless boundary value problem

Two boundary conditions for the four faces are set for the given domain:

- ✓ 1st boundary condition: on the left and right faces the temperature must be kept constant, the surface is isothermal. In order to fulfil this condition, a temperature $T=T_0$ is set in the dimensional equation on both sides, where the dimensionless temperature is $\theta=1$;

- ✓ 2nd boundary condition – there should be no heat exchange with the environment on the lower and upper faces, the surfaces should be adiabatically insulated. This means that the heat flux must be zero in the y direction: $\frac{\partial T}{\partial y} = 0$ and T is assumed to be θ .

The initial temperature is set to 0 K .

B. Mesh generation.

The discretization of the square domain is done by setting a mesh to generate the geometry, Fig. 2. The computing mesh built around the object is a quad map, i.e., a structured mesh that consists of 100 quadrilateral elements and 341 nodes. As can be seen from the figure, the grid is fine enough for better accuracy of the numerical solution.

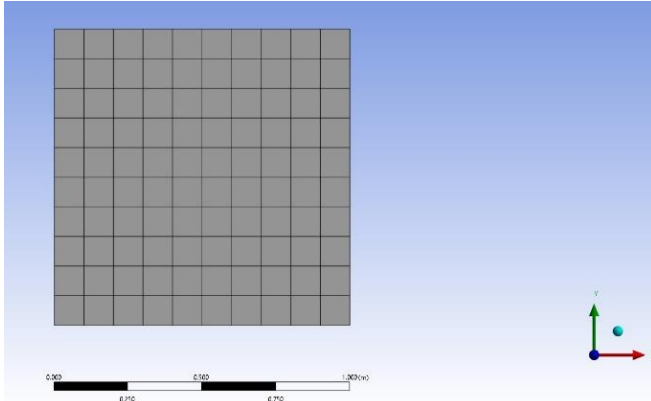


Fig. 2. View of mesh geometry

Each element in the mesh has four nodes, with each internal node shared among four neighboring elements. To determine the temperature in these elements, the ANSYS solver uses bilinear polynomial interpolation of the nodal temperatures of the cell, obtaining a weighted average of these four temperatures. The solver constructs a system of algebraic equations for all nodal temperatures, each equation relating a nodal temperature to the temperatures in neighboring elements. Thus, the temperature value of each node depends on the temperatures in the surrounding elements, allowing the determination of the temperature anywhere in the domain by interpolation, and the calculation of the heat flow accordingly.

To reduce the calculation error, it is necessary to increase the number of elements in the mesh. In this way, the number of equations for the nodal temperatures is increased, but the accuracy is significantly increased. Another method to reduce the error is to increase the order of the polynomial in each element, which is achieved by adding additional nodes between the existing ones. This results in a second-order interpolation in the x and y directions, providing a better and more accurate solution to the problem.

C. Transient analysis.

To study the temperature change over time, a thermal transient analysis is performed. It includes selection of appropriate time steps to accurately account for the temperature behavior during the process and settings of the solver algorithm to ensure numerical stability and convergence.

➤ Change in temperature in the studied domain:

Fig. 3 shows the temperature distribution in the domain. During the process, it is clear from the graph (Fig. 4) that the temperature change over time is linear. The temperature rises smoothly from 0 K

and by 0.5 s has already stabilized to near 5 K . This analysis shows that for the specific conditions set, the transient process is extremely fast and smooth in time and without any temperature fluctuations.

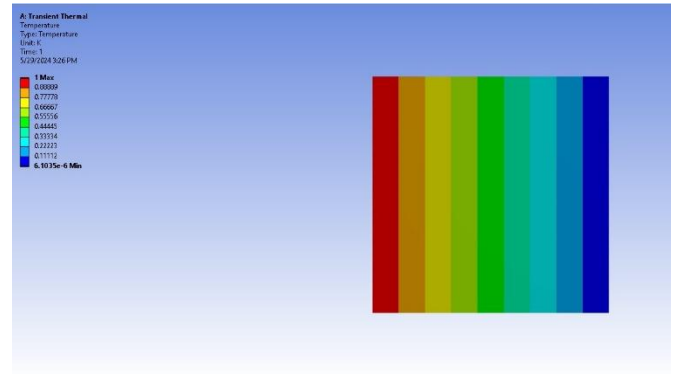


Fig. 3. Temperature variation in the domain

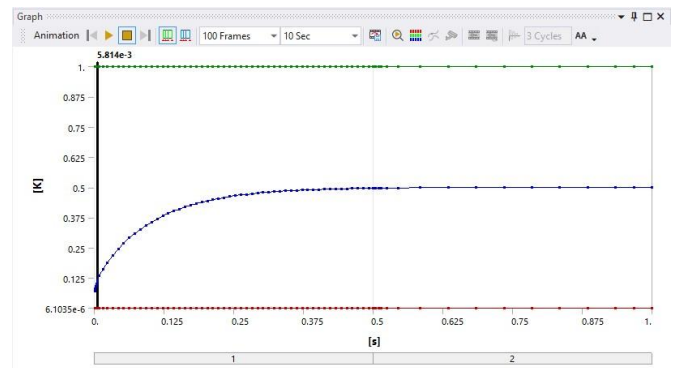


Fig. 4. Graphic representation of temperature variation

From the obtained tabular data (Table 1), it is easy to follow the temperature variations at certain moments of time.

Table 1: Temperature variation for each time step.

	Time [s]	Minimum [K]	Maximum [K]	Average [K]
1	1.00E-03	6.10E-06	1	7.21E-02
2	2.00E-03	6.10E-06	1	8.16E-02
3	3.00E-03	6.10E-06	1	9.10E-02
4	4.27E-03	6.10E-06	1	0.10146
5	6.23E-03	6.10E-06	1	0.11511
6	9.26E-03	6.10E-06	1	0.13257
7	1.53E-02	6.10E-06	1	0.16019
8	2.29E-02	6.10E-06	1	0.18858
9	3.29E-02	6.10E-06	1	0.21955
10	4.29E-02	6.10E-06	1	0.24629
11	5.29E-02	6.10E-06	1	0.26989
12	6.29E-02	6.10E-06	1	0.29098
13	7.29E-02	6.10E-06	1	0.30998
14	8.29E-02	6.10E-06	1	0.32717
15	9.29E-02	6.10E-06	1	0.34275
16	0.10291	6.10E-06	1	0.35691
17	0.11291	6.10E-06	1	0.36978
18	0.12291	6.10E-06	1	0.38149
19	0.13291	6.10E-06	1	0.39214
20	0.14291	6.10E-06	1	0.40183
21	0.15291	6.10E-06	1	0.41065
22	0.16291	6.10E-06	1	0.41868
23	0.17291	6.10E-06	1	0.42598
24	0.18291	6.10E-06	1	0.43263

25	0.19291	6.10E-06	1	0.43869
26	0.20291	6.10E-06	1	0.44419
27	0.21291	6.10E-06	1	0.44921
28	0.22291	6.10E-06	1	0.45377
29	0.23291	6.10E-06	1	0.45792
30	0.24291	6.10E-06	1	0.4617
31	0.25291	6.10E-06	1	0.46514
32	0.26291	6.10E-06	1	0.46828
33	0.27291	6.10E-06	1	0.47113
34	0.28291	6.10E-06	1	0.47372
35	0.29291	6.10E-06	1	0.47608
36	0.30291	6.10E-06	1	0.47823
37	0.31291	6.10E-06	1	0.48019
38	0.32291	6.10E-06	1	0.48197
39	0.33291	6.10E-06	1	0.48359
40	0.34291	6.10E-06	1	0.48506
41	0.35291	6.10E-06	1	0.4864
42	0.36291	6.10E-06	1	0.48762
43	0.37291	6.10E-06	1	0.48873
44	0.38291	6.10E-06	1	0.48975
45	0.39291	6.10E-06	1	0.49067
46	0.40291	6.10E-06	1	0.49151
47	0.41291	6.10E-06	1	0.49227
48	0.42291	6.10E-06	1	0.49296
49	0.43291	6.10E-06	1	0.4936
50	0.44291	6.10E-06	1	0.49417
51	0.45291	6.10E-06	1	0.4947
52	0.46291	6.10E-06	1	0.49517
53	0.47291	6.10E-06	1	0.49561
54	0.48291	6.10E-06	1	0.496
55	0.49291	6.10E-06	1	0.49636
56	0.5	6.10E-06	1	0.4966
57	0.505	6.10E-06	1	0.49676
58	0.51	6.10E-06	1	0.49691
59	0.515	6.10E-06	1	0.49706
60	0.525	6.10E-06	1	0.49732
61	0.545	6.10E-06	1	0.49776
62	0.585	6.10E-06	1	0.4984
63	0.635	6.10E-06	1	0.49893
64	0.685	6.10E-06	1	0.49928
65	0.735	6.10E-06	1	0.49952
66	0.785	6.10E-06	1	0.49968
67	0.835	6.10E-06	1	0.49978
68	0.885	6.10E-06	1	0.49986
69	0.935	6.10E-06	1	0.4999
70	0.9675	6.10E-06	1	0.49993
71	1	6.10E-06	1	0.49995

➤ **Temperature variation through a point in the y direction:**

Fig. 5 and Fig. 6 shows the change in temperature at a point where, during the flow of the heat flux through the material, it increases smoothly until it reaches a steady state again in about 5 s. Here too, the transition is smooth and a steady state is quickly reached where the temperature settles down to about 0.5 K.

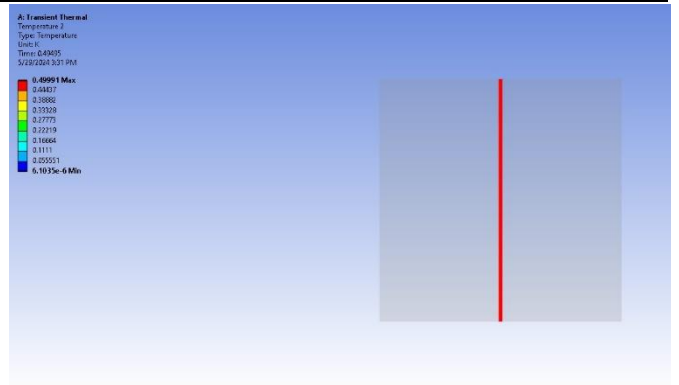


Fig. 5. Temperature variation along a line

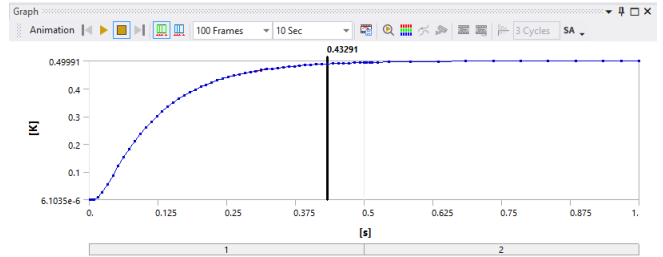


Fig. 6. Graphic representation of temperature variation along a line

➤ **Heat flux distribution in the studied domain:**

From the results obtained in Fig. 7 and Fig. 8, the stability of the process is again seen. At the beginning of the process, the heat flux is the largest, after which the heat smoothly spreads over the entire domain and by 0.2 s a steady state is reached, where the value of the heat flux is slightly above 1 W/m². After the further progress of the process, it is kept constant at 1 W/m². As with the temperature, based on the obtained tabular data (Table 2), it is possible to track the heat flux at each point in time.

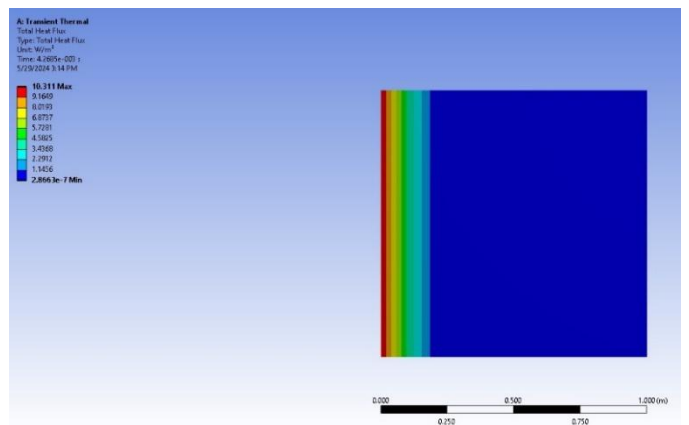


Fig. 7. Heat flux distribution in the domain

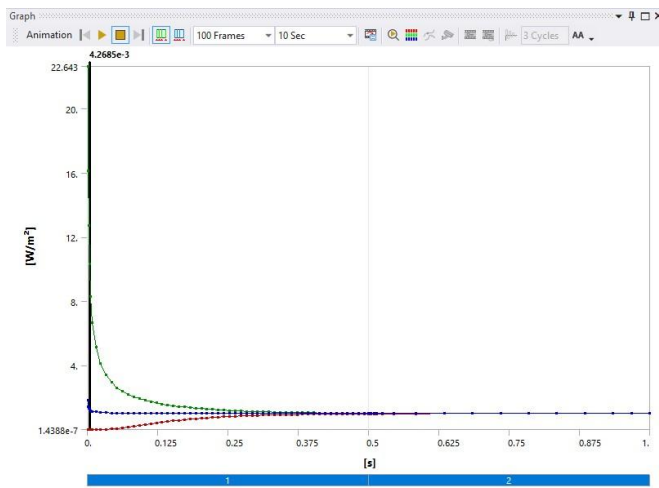


Fig. 8. Graphic representation of heat flux distribution in the domain

Table 2: Heat flux distribution for each time step.

	Time [s]	Minimum [W/m²]	Maximum [W/m²]	Average [W/m²]
1	1.00E-03	4.77E-07	22.643	1.8435
2	2.00E-03	1.44E-07	16.153	1.4359
3	3.00E-03	3.30E-07	12.732	1.3305
4	4.27E-03	2.87E-07	10.311	1.2559
5	6.23E-03	7.41E-07	8.2883	1.1936
6	9.26E-03	2.38E-07	6.647	1.1431
7	1.53E-02	3.26E-04	5.117	1.096
8	2.29E-02	2.79E-03	4.1207	1.0654
9	3.29E-02	1.32E-02	3.3964	1.0434
10	4.29E-02	3.30E-02	2.9372	1.0299
11	5.29E-02	6.27E-02	2.618	1.021
12	6.29E-02	0.10086	2.3815	1.0149
13	7.29E-02	0.14573	2.1979	1.0106
14	8.29E-02	0.19504	2.0505	1.0076
15	9.29E-02	0.24673	1.929	1.0054
16	0.10291	0.29908	1.8267	1.0039
17	0.11291	0.35077	1.7394	1.0028
18	0.12291	0.40085	1.6637	1.002
19	0.13291	0.44868	1.5976	1.0014
20	0.14291	0.49386	1.5393	1.001
21	0.15291	0.53615	1.4876	1.0007
22	0.16291	0.57555	1.4415	1.0005
23	0.17291	0.61205	1.4002	1.0004
24	0.18291	0.64572	1.363	1.0003
25	0.19291	0.6767	1.3296	1.0002
26	0.20291	0.70514	1.2993	1.0001
27	0.21291	0.73119	1.272	1.0001
28	0.22291	0.75502	1.2473	1.0001
29	0.23291	0.7768	1.2248	1.0001
30	0.24291	0.79669	1.2045	1
31	0.25291	0.81484	1.186	1
32	0.26291	0.83138	1.1692	1
33	0.27291	0.84647	1.1539	1
34	0.28291	0.86022	1.1401	1
35	0.29291	0.87274	1.1274	1
36	0.30291	0.88415	1.116	1
37	0.31291	0.89454	1.1055	1
38	0.32291	0.904	1.0961	1
39	0.33291	0.91261	1.0874	1
40	0.34291	0.92046	1.0796	1
41	0.35291	0.9276	1.0724	1
42	0.36291	0.9341	1.0659	1
43	0.37291	0.94	1.06	1
44	0.38291	0.94539	1.0546	1
45	0.39291	0.95029	1.0497	1
46	0.40291	0.95476	1.0452	1
47	0.41291	0.95882	1.0412	1
48	0.42291	0.96251	1.0375	1
49	0.43291	0.96588	1.0341	1
50	0.44291	0.96894	1.031	1
51	0.45291	0.97173	1.0283	1

52	0.46291	0.97427	1.0258	1
53	0.47291	0.97657	1.0235	1
54	0.48291	0.97867	1.0214	1
55	0.49291	0.98059	1.0194	1
56	0.5	0.9818	1.0181	1
57	0.505	0.98266	1.0173	1
58	0.51	0.98347	1.0165	1
59	0.515	0.98425	1.0157	1
60	0.525	0.9857	1.0143	1
61	0.545	0.98806	1.0119	1
62	0.585	0.99143	1.0086	1
63	0.635	0.99426	1.0057	1
64	0.685	0.99616	1.0038	1
65	0.735	0.99742	1.0026	1
66	0.785	0.99826	1.0018	1
67	0.835	0.99882	1.0011	1
68	0.885	0.99921	1.0008	1
69	0.935	0.99946	1.0006	1
70	0.9675	0.99954	1.0004	1
71	1	0.99969	1.0003	1

3. Conclusion

This model for investigating transient heat conduction in two-dimensional systems through ANSYS Mechanical has significant potential for practical application in various industries and scientific fields. For example, in the field of heat engineering, this type of model would help to optimize heat exchange processes in engineering systems, leading to more efficient use of energy and cost reduction. In electronics, knowledge and control of thermal processes is critical to the development of electronic devices that must operate under optimal temperature conditions to avoid overheating and component damage. The method can find a place in energy systems when analyzing their thermal efficiency, including power plants and heating installations, thereby increasing their efficiency and sustainability. To create sustainable and ecological buildings in the field of construction design, the use of the model can lead to improved thermal insulation and energy efficiency already in their design. In the field of materials science, the analysis of transient thermal processes would contribute to the development of new materials with improved thermal insulation, corrosion and other properties, which can be applied in many engineering fields. Last but not least, this model can provide new knowledge and teaching approaches in the field of thermal engineering, facilitating the understanding of the conditions under which heat exchange processes occur and the accompanying changes.

4. References

1. T. L. Bergman, A. S. Lavine, F. P. Incropera and D. P. DeWitt, Introduction to Heat Transfer, Ch. 5 Transient Conduction, Copyright 2011, 2007, 2002 by John Wiley & Sons, Inc., **6th Edition** (2011), pp. 279-376, ISBN 13 978-0470-50196-2.
2. Y. A. Çengel and A. J. Ghajar, Heat and mass transfer: Fundamentals & Applications, Ch. 4 Transient Heat Conduction, Copyright © 2015 by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121, **5th Edition** (2015), pp. 237-306, ISBN 978-0-07-339818-1.
3. Cornell University. (Dec 19. 2018). 2D Steady Conduction – Mesh. Simulation Wiki, <https://confluence.cornell.edu/display/SIMULATION/Transient+Conduction+-+Numerical+Results>.
4. W. H. David and Özisik M. N, Heat Conduction, John Wiley & Sons, Inc., Hoboken, New Jersey, **3rd Edition** (2012), ISBN 9780470902936.
5. J. N. Reddy and D. K. Gartling, The Finite Element Method in Heat Transfer and Fluid Dynamics, CRC Press, Taylor & Francis Group, **3rd Edition** (2010), ISBN 9781420085983.
6. Y. Jaluria and K. Torrance, Computational Heat Transfer, Published December 19 by CRC Press, **2nd Edition** (2002), ISBN 9781560324775.
7. ANSYS Inc. (2021). *ANSYS Mechanical User's Guide*. ANSYS Inc.

Policy of shipbuilding development in Bulgaria in the second half of the 20th century. Successes and shortcomings

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Abstract: Regardless of the fact that all the prerequisites exist for the development of maritime business and shipbuilding in Bulgaria, a purposeful state maritime policy has not been implemented for a long time. Although there are registered beginnings of our shipbuilding already at the end of the 19th century, and the first serious orders were made during the Second World War, one can speak of a Bulgarian state policy of shipbuilding only in the 2 ½ of the 20th century. Until 1962, the development of the shipbuilding industry was at an average level for the capabilities of our country. In the following decades until the end of the socialist period, shipbuilding emerged as a sub-branch of machine-building of strategic importance for the entire industry, and the scale of its development was comparable to the scale of countries with developed shipbuilding. It is characteristic of the entire period that the majority of shipbuilding production is not created for internal needs, but is dictated by external orders, structural changes are constantly made in the management, there is a lack of continuity, and the construction of capacities for the construction of large-tonnage ships takes a very long time is a debatable issue. Nevertheless, the development of the shipbuilding industry brings enormous positives to the country. During this period, Bulgaria was recognized as a maritime country; builds a production and technical base that is not small for the scale of our country; puts the work on a scientific basis and gives an opportunity for the appearance of a whole constellation of engineers, according to whose projects dozens and hundreds of ships that sail under the Bulgarian and foreign flags have been built.

Keywords: HISTORY, MARITIME, SHIP-BUILDING

1. Introduction

The aim of the proposed study is to present some significant moments from the creation and development of shipbuilding in Bulgaria in the second half of the 20th century. The chronological framework in which the subject is traced suggests the disclosure of the epoch-specific politics directly directed by the top of the state apparatus. Ideologically burdened and declared wrong today, the policy for the development of Bulgarian shipbuilding leads to results that bring substantial positives for the state and society in the second half of the 20th century. These results are evidenced in the rich documentary legacy left by both the business organizations directly involved in shipbuilding, as well as the administration and state bodies managing the national economy, monitoring and directing the development of the industry. The documents are a constituent part of various funds stored in the State Agency "Archives". For the purposes of this article, the work of Tremol Ivanov "Pages from the history of Bulgarian shipbuilding" was used.

2. Solutions

The history of modern Bulgarian shipbuilding begins at the end of the 19th century and the beginning of the 20th century, when several vessels were built and successfully launched. These successes should be attributed to the first Bulgarian shipbuilders, who were driven by pure enthusiasm, rather than to any state policy. Compared to the development of railway transport, it can be said that shipbuilding was not on the agenda of the state policy of Bulgaria, until the threshold of the Second World War. Tsar Boris III's passion for railways has been repeatedly witnessed at that time, his negative attitude towards shipbuilding is less known. Nevertheless, there was no lack of supporters of the policy of shipbuilding development in our country. Unfortunately, without solid state support, systematic shipbuilding appeared in our country only after the establishment of foreign companies, such as the German "Koralovag". Its appearance is connected with the economic and political orientation of Bulgaria to the orbit of Germany in the middle and second half of the 1930s - the years of the 20th century. After the outbreak of the Second World War, the German High Command commissioned the construction of 12 amphibious ships to a small shipyard in Varna. For this first major order, expansion and reconstruction of the production base is required. A German specialized enterprise arrives with all the necessary technological park to fulfill the order and supervises the work. Construction of an entirely new shipyard began, which was not completed until the end of the war. For the period 1939 - 1944, a total of 86 vessels were built there, with only 17 designated for

Bulgaria, and the remaining 69 built for the needs of the German fleet. The Varna Shipyard employs 1,450 workers, and three of the four production manager engineers graduated in mechanical engineering in the Czech Republic. An extremely valuable document proving the technological readiness of the Bulgarian society for the development of shipbuilding is Todor Delistoyanov's concept for the expansion and reconstruction of the Varna shipyard, developed as early as 1939 and presented to the attention of the Directorate of Water Communications at the General Directorate of Railways and Ports. [1]

The development of machine, forge, foundry, welding and compressor departments, according to the concept, was supposed to ensure the construction of ships up to 6000 tons. Without being strictly followed, this plan was implemented at variable rates only towards the end of 1949. After the change, carried out on 9.IX.1944, the development of shipbuilding passed under the direction of the Directorate of Water Communications under the Ministry of Railways and Water Transport. The production base - property of the German fleet in Bulgaria, was handed over to the USSR after a law was passed in the National Assembly. The production of ships did not cease, but began to serve the interests of the new owner. This situation was preserved until 1950, when an agreement was signed for the formation of the Bulgarian - Soviet parity shipbuilding company - KORBSO. [2]

In the same year, an inspection of the Maritime Register of the USSR was opened in Varna, which began monitoring ship production. For the period 1945 - 1949, 41 vessels with a carrying capacity of 9216 tons were built in the shipyard in Varna. The classification documents issued by the Maritime Register are the first international recognition of Bulgaria as a shipbuilder. Renovation of the machine park begins, a new foundry and tool shop, oxygen and compressor stations were built. The report of the shipyard for 1951 indicates that the goods industry is performed at less than 50%, and the cost price of some of the vessels is too high. The reason for this is the low qualification of the staff. For the solution of this problem, a new specialty "Shipbuilding" was opened at the Mechanical Engineering School in Varna, and the following year - a shipbuilding department at the Faculty of Engineering and Construction of the State University. An important moment in the development of Bulgarian shipbuilding is the election of our country as a permanent member of the shipbuilding section of the Permanent Commission on Mechanical Engineering within the Committee for Mutual Economic Assistance in 1956. According to the contracts to which Bulgaria is a party, it specializes in the production of four groups of ships: 1. cargo - from 3,000 to 5,000 tons of carrying capacity; 2. cargo from 10,000 to

15,000 tons; 3. tankers with a carrying capacity from 4000 to 5000t, 4. passenger - from 500 to 2000t. [3]

For the absorption of the new production, the Ministry of the Shipbuilding Industry of the USSR provides Bulgaria with working documentation for the construction of ships and the production of articles of ship's furniture. (ibid., p. 263)

During this period, the construction of an extremely successful series of 4000t tankers began. Then the passenger ship designed by the Bulgarian engineer L. Veselinov for near and far coastal navigation was completed and handed over to the Bulgarian Navy (BMF). Engineer Atanas Yordanov designs 150 and 300 ton marine cargo motor ships for close and coastal navigation. Under the guidance of engineers Hristo Naydenov and Georgi Tashev, a project for a floating workshop with a reinforced concrete body was developed. The USSR alone received about 200 such workshops by the end of the period under review. (ibid, p. 89)

In 1957, at the technical council at the Shipbuilding and Ship Repair Plant (KKZ) "G. Dimitrov", Varna, a project assignment for the construction of a 10,000 t dry cargo ship is being discussed, which is not being implemented. In 1959, engineer Todor Ganchev presented a project for a 5000 t dry cargo motor ship, in the construction of which low-alloy steels were used for the first time and an electrical network with alternating current was designed. (ibid, p. 91)

The inclusion of Bulgarian shipbuilding in international specialization increased production several times during the period 1955 - 1960. Compared to the previous five-year period, the volume of production jumped 2.7 times, commodity production 1.6 times, and labor productivity was three times higher. The reason for the increase in indicators is the successful transition to the construction of more expensive medium-tonnage ships. However, at the end of the 1950s, there was an increasingly frequent fall behind the requirements required for the economic and operational planning of production, the annual plans could not be fulfilled, and this led to non-compliance with the deadlines for the handover of the objects. The industry is lagging behind in terms of technological level as well – the transition to the mechanization of manual labor is taking place too slowly, and the available equipment is outdated. (ibid, p. 95)

An essential reason for stopping the development of shipbuilding in our country during the period is the delay in the expansion of the plant in Varna, which should provide opportunities for the construction of ships with large tonnage. Already with the undertaking of the commitments to the SIV on the specialization for the construction of ships of 10,000 and 15,000 tons, a task was approved for the preparation of a master plan for the reconstruction of the KKZ - Varna, but the project was not implemented due to the transfer of the plant to the Ministry of Heavy industry. [4]

A significant development in Bulgarian shipbuilding is provided by the signed long-term agreement with the USSR providing for the construction of 95 vessels within 5 years. Of interest to the guarantor are the possibilities of KKZ - Varna for the construction of 6,500 tons of reinforced concrete docks. During the negotiations, the plant in Varna prepares a comprehensive concept for the development of reinforced concrete shipbuilding, but on the condition that the existing facilities are reconstructed. With the signing of the agreement, "Zavodproekt" renews the development of a master plan for the reconstruction of the plant. [4] By Decree of the Council of Ministers No. 1608 of 30.08.1961, a deadline of March 1, 1962 was set for the conceptual project for reconstruction to be completed.

In the meantime, at the invitation of KKZ - Varna, three representatives of the Soviet shipbuilding industry arrive in our country, who prepare a competent assessment of the state of Bulgarian shipbuilding. The assessment is critical, but true. It is emphasized that the general development of ship engineering is lagging behind. There is no reconstruction plan for the shipyard in

Varna, the construction of the shipyard in Ruse is going slowly, and the ship repair base in Burgas is in a hopeless state, cooperation with other factories in our country is weak, there is no technological institute for shipbuilding.

On February 13, 1962, the Council of Ministers approved the XXII Resolution of the Central Committee of the BKP on the development of shipbuilding. [5]

The document considers shipbuilding as one of the important branches of heavy engineering with great importance for the development of other industrial branches. As the first task, the need to complete the reconstruction of the KKZ - Varna by the end of 1964 and the complete construction of the KKZ - Ruse by the end of 1963 was indicated in order to expand the possibilities for the production of sea and river ships and, of course, to prepare the production for the construction of ships with a carrying capacity of 10,000 tons. Bearing in mind the assessment given by Russian shipbuilding specialists, the decree emphasizes the need to create a scientific and research base in Varna and to strengthen cooperation between enterprises in the shipbuilding system by specializing and profiling.

With a delay of five months, on 13.8.1962 the Council of Ministers approved with Resolution No. 1295 a conceptual project for the reconstruction and modernization of the KKZ "G. Dimitrov", Varna. The project is worth BGN 120 million and only Bulgarian design companies, institutes and construction associations are working on it - "Zavodproekt", "Mashelectroproekt", "Transproekt", "Transstroy" and many others. The execution of the project is close to the average world level of shipbuilding production. Complex hydrotechnical facilities are planned for construction - dock chambers, each of which absorbs 100,000 tons of concrete steel and 110,000 cubic meters of concrete. The late approval of the conceptual design causes the object not to be completed on time and the commitments to the guarantor are not fulfilled on time. Regardless of this, during the period of intensive construction for the reconstruction and modernization in KKZ - Varna until 1965, 54 vessels were built and handed over to the customers. Then, for the first time, a project for the construction of a 5,000-ton dry cargo ship was completed with engineer Todor Ganchev as designer.

In 1967, it was agreed to receive from the Soviet Union specifications for four types of ships of interest to us. The following year, a program was specified for the construction of 61 vessels with a total carrying capacity of 1,300,880 tons in the period up to 1975, thus ensuring full utilization of the new facilities built. (Ivanov, T., Shipbuilding, p.164 – 165) The highest rates of development of Bulgarian shipbuilding were realized in the period 1965-1969. Then the production funds were increased nearly three times, the total industrial and commodity production jumped 3 times, and the tonnage of vessels amounted to 601,000 tons of deadweight for 377 ships, according to a report of the Minister of Mechanical Engineering Mariy Ivanov to the Chairman of the Council of Ministers Todor Zhivkov. [6]

In 1969, the first deals were concluded for the export of ships "in the second direction", i.e. for developed countries that are not part of the SIV. The contracts with these countries amount to BGN 24.4 million. The total export of vessels for the period 1966-1970 is in the amount of BGN 178,781,000 (ibid.) The high values reached by shipbuilding cause even higher goals to be set in the next decade. At the end of 1975, the production of a 75,000-ton tanker and a 75,000-ton coal carrier is expected to be mastered, which will constitute the main type of production until 1980. (ibid)

The scale of this scope and self-confidence, which is demonstrated by Bulgarian engineering, is due to the qualitative changes that occurred in the industry during this period. New technological methods are used in shipbuilding, the degree of process mechanization has been increased, new technical equipment has been provided, and a scientific organization of labor has been introduced. The modernization of the production base and the new

production methodology bring Bulgarian shipbuilding closer to the achievements in this industry of developed countries. An example of this is the pursuit of higher productivity by shortening construction cycles. In 1971, a 23,500 ton coal carrier was produced in an average of about 260 days, which was close to the achievements of other shipbuilding countries. The aspiration leads the Bulgarian shipbuilders to shorten this time to 140 days. (ibid)

The main obstacle to the realization of these goals is the existing huge dependence in our country on the import of materials and equipment. All shipbuilding countries complete the ships with locally produced equipment, and their import varies between 5% and 10%, while in Bulgaria the import is 75% [6].

The import of ship equipment and main engines places the Bulgarian shipbuilding industry in great dependence on the suppliers, which negatively affects the duration of the construction of the ships, the cost of production and the foreign exchange return. In a technical-economic report developed by KKZ, Varna, it is stated that imports can be reduced if the plant adopts the production of main ship engines. The Ministry of Mechanical Engineering proposes to purchase from the USSR a sublicense for the production of marine engines from the Western company "Burmeister & Wein" in line with international cooperation, or to purchase a license directly from a Western company producing marine engines. (ibid) A desire for cooperation with the West was also demonstrated by the visit of a delegation of Bulgarian shipbuilders to Japan, at the invitation of the Association of Japanese Shipbuilders and the Hitachi Zosen company, which took place at the end of 1970 [7]. The purpose of the visit is to study the achievements of Japanese shipbuilding and to establish scientific and technical cooperation with one of the largest shipbuilding companies in the world. An agreement was reached for the conclusion of an agreement for technical assistance from the Japanese side, which is expressed in: training of 5 of our engineers and 20 workers in the shipyard in Inoshima, which is close in profile to KKZ "G. Dimitrov", Varna; training of 2 Bulgarian specialists in the implementation of electronic - computing technology in management, organization and production; consultations on the plan for the modernization of the plant in Varna; consultations for the implementation of progressive technologies and modern equipment for the mechanization and automation of production processes; delivery of a project for the construction of a 70,000-ton tanker and preparation for the mastering of the construction of such constructions in Varna, etc. (ibid)

The aspiration of the Bulgarian shipbuilding industry to specialize in the construction of ships with large tonnage is clearly visible. This production is economically more profitable, but also requires higher technological capabilities, for which Bulgarian shipbuilding is not sufficiently prepared. This is evident from a report prepared in 1972 by specialists from "Vneshtekhnika", Moscow, who follow the state and our opportunities in this industry[8]. According to the report, the relative share of Bulgarian production, with which the ships being built in our country are completed, is still too low - 15-25%, and the technological level of the factories, excluding those in Ruse and Varna, is low. There is also still a lack of capacity to produce marine engines. In this connection, in 1974, the "Mayak" machine-building plant in Tolbukhin was handed over to DSO "Shipbuilding", which is planned to be converted into a plant for the production of marine diesel engines under the license of the Swiss company "Sulzer" [9]. In the 1970s, the development of the scientific service of shipbuilding was observed. An Electronic - computing center for shipbuilding was built in Varna, where work is being done on the automation of engineering work and on the development and implementation of automated production management systems. In 1973, the Institute of Ship Hydromechanics was built, approved by RMS No. 11 with 14.7 million BGN capital investments, of which 2.5 million were aid from the United Nations. This is the year in which shipbuilding is designated as a subsector of particular importance to the national economy. The previous year, 1972, the production of ships with a total carrying capacity of 1 million tons

was reached, which gave reason to plan for 1985 a volume of 2 million tons, and in 1990 - 3 million tons deadweight (Report No. M - 1964/30 of the Ministry of Mechanical Engineering) . It was decided, at the highest state level, to build a material and technical base for scientific research and development by 1976, to build a plant for ship engines by 1978, and to create conditions for the construction of a ship engine by 1980 in Burgas large-tonnage ships [10]

A significant problem, besides this circumstance, is that these decisions were not discussed and agreed with the executive bureau and the business council of DSO "Korabostroene". The complex program for the development of shipbuilding until 1990, which was drawn up by the planners at the highest levels of power, sets unattainable goals for our capabilities, one of which is for Bulgaria to increase its relative share in world shipbuilding from 0.2% to 2%, and the other - to achieve in 7 years such a development of ship engineering as was achieved in Poland in a period of 20 years. [11] Regardless of the failure of the megalomaniac aspirations (or precisely thanks to them, *my note.*) in the period 1970-1985, the goods production of DSO Korabostroene increased 2.5 times, and the value reached BGN 303.7 million (T. Ivanov, p. 231) A total of 29 new projects of self-propelled and non-self-propelled ships were mastered in the three main shipyards. The most significant drawback of the production policy during the period is that the majority of the ships created in our factories were not included in the national ship park, but filled the foreign ones. This applies with particular force to the output of the shipyard in Ruse, 90% of which goes to the Soviet Union. The absurd situation arises in which we have a factory specializing in the production of ships for bulk cargo, and at the same time the "Bulgarian River Navigation" Shipping Company is in dire need of tugs and pushers, because after 1974 the shipyard does not fulfill its orders at all. (T. Ivanov, p. 228)

Conclusions

The review of some literature on the subject and the available archival material testify to the discovery of many opportunities for the development of shipbuilding in Bulgaria in the second half of the 20th century. First of all, the fact that shipbuilding managed to establish itself, moving from a non-priority position in the Bulgarian economy to a strategic industrial sub-sector of particular importance for the development of the national economy, deserves attention. This is due to the implementation of a policy of permanent state support, expressed in a constant increase in capital investments, thanks to which the technological park and the material base manage to stay within the current world level. Placing shipbuilding on a scientific basis is not without importance for this development, which, again we must admit, is state policy. Apart from the debate on whether this was carried out in the most economically expedient way, we must calculate the benefits of this development, which are generally expressed in the inclusion of Bulgaria in the world list of shipbuilding countries. The policy of shipbuilding development in our country is a consequence of the perceived impossibility of Bulgaria filling the necessary ship tonnage from imports alone, in order to be recognized as a maritime country. Although led with all the shortcomings of the planned economy, constantly suffering from the lack of adequate staffing and technological renewal in production, the policy of developing its own shipbuilding guarantees the country more opportunities for independence in maritime trade and transport. With a lot of effort during the considered period, the foundations of a specific machine-building branch were laid in our country, borrowing the example of other maritime countries, thanks to which a whole generation of shipbuilders grew up, whose completed projects served various foreign fleets for many years. The names of dozens of Bulgarian engineers and specialist shipbuilders are evidence of a technological step forward, which was prematurely interrupted by the powerful tectonic tremors in world politics from the end of the 20th century.

References

1. SA Varna, f.11 K, des. 1, a.u. 80, p. 400
2. SA Varna, f.21, des.3, a.u. 1, p. 1
3. T. Ivanov, Pages from the history of Bulgarian shipbuilding, Varna, 1998, p. 88
4. SA Varna, f. 21, des. 6, a.u. 94, p. 19
5. Government Gazette, No. 16/23, February 1962
6. CSA, F. 531, des. 3, a.u. 57, p. 48
7. CSA, F.531, des. 4, a.u. 67, p. 45
8. SA Varna, f. 928, des. 3, a.u. 409
9. SA Varna, f.928 , des. 2, a.u. 100
10. Transcript from Protocol No. 292 of the PB of the Central Committee of 24.04.1973, SA - Varna, f. 928, des. 2, a.u. 4, p. 1-2
11. SA Varna, f. 928, des. 3, a .u. 143, p. 46

Passenger intensity prediction as a tool for effective management of regional rail transport

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Abstract: Regional rail transport is a key part of the transport process, and its importance is growing every year. Suburban rail forms the backbone of the regional transport system and is widely regarded as a sustainable form of mobility with societal benefits. On the other hand, the costs associated with operating rail transport are significant and it is essential to design cost-effective and efficient transport solutions. This paper takes a closer look at the prediction of passenger volumes and the associated options for effective management of regional rail transport when travel demand is known. A practical application is developed in the conditions of suburban rail transport in the vicinity of Ostrava in the Czech Republic. It analyses the available data on transport supply and travel demand of which passengers can be assigned to specific directions and time slots in relation to daily and weekly variations of travel demand. Based on the data provided, a model for assigning passengers with respect to public transport supply was proposed. The prediction is harmonised with local specific conditions. The results obtained were used to design a new operational concept for the suburban railway in the assessed area. On the basis of the data obtained, a modelled composition of vehicle units and frequency of services on individual sections was proposed. An appropriately set capacity of the vehicle units enables a significant reduction of operating costs and leads to an economical and efficient transport solution.

Keywords: TRAVEL DEMAND, SUBURBAN RAILWAY, PASSENGER RAILWAY, SUSTAINABILITY, VEHICLE CIRCULATION, TIMETABLE, VEHICLE UNITS

1. Introduction

The area is located in the Czech Republic, in the Moravian-Silesian Region. The task of prediction of future passenger intensity was solved for line No. 323 between Ostrava and Valasske Mezirici.

The right moment for the consideration of a new operating concept is a significant qualitative improvement of the infrastructure. If a new operating concept is to be introduced within a few years, a thorough analysis of travel patterns and future demographic development of the region is necessary. This is especially the case for public transport organizers and carriers. On the basis of the feasibility study and the infrastructure project, a transport model for the future use of suburban rail is based. At the same time, the developed models often do not provide sufficient input data for the preparation of the operating concept, in particular data for determining the number of train routes per hour and train capacity.

As inputs for the design of the operating concept, it is necessary to know travel demand in individual hours, the distribution of demand in the relevant line sections and the origins and destinations of the trips. Based on these decisions, it is possible to assess the introduction of additional trains or new segment of trains, i.e. fast trains connecting important sessions.

Finally, it is desirable to consider the variation in travel demand during the day, week and year. All calculations are essential for the design capacity and the required number of multiple vehicle units needed to support the operational concept. The chosen arrangement of vehicle units, in particular their capacity and number of coaches, are key elements for the efficient operation of a suburban railway.

2. Methods

2.1. Current passenger movement data

2.1.1. Origin-destination matrix for stations

The starting point of the prediction of the future development of the number of passengers is the analysis of the current situation which will serve as an input to this prediction. For a comprehensive picture of the existing transport relations, authors drew on various publicly available sources, whose data were put into context as far as possible. It is important to take into consideration that the authors do not have a comprehensive transport model, which doesn't exist for this area, but only fragments. They do not have exact current data on the number of passengers on trains either, as obtaining this data is demanding.

Data from the National Population and Housing Census (2011) [1] were taken into account to determine daily commuting. All

municipalities in the reasonably considered neighborhood of each station were taken into account. This allows the authors to create a origin-destination matrix. However, it is not possible to determine a modal split from the census [2]. The authors prepared a procedure for making a qualified estimate, which consists in assessing the attractiveness of the connection for the major transport modes for the purpose of determining the modal split. The attractiveness of the connection by individual car transport, the possibility of using the bus service (frequency of connection, travel time, average walking distance) and the possibility of using the railway transport (frequency of connection, travel time, average walking distance) were assessed. The result was a qualified estimate of modal split for regional rail transport for all pairs origin-destination municipality of the assessed municipalities [3].

The product of an absolute number of trips in the origin-destination matrix for each relation and the coefficient corresponding to the modal split of the regional rail transport in the given relation we get the potential in rail transport for the given relation. Subsequently, the potentials in rail transport from the origin-destination matrix were assigned to the network. A station usually includes data for more than one municipality because it provides services to several municipalities. On the other hand, there is no case on the track No. 323 where there is more than one station in one municipality. The result of this procedure is the origin-destination matrix for stations containing the potentials of relations between them.

2.1.2. Daily variation of passengers

The demand for transport is uneven at certain times of the day. The course of demand for transport within one day is expressed by a curve, which is defined as a daily demand variation. The actual course depends on many factors, the most important ones are usually the type of day (workday / weekend), the daily routine of the region and local customs and specifics. It also depends on the punctuality of the timetable, which is very closely related to its robustness [4].

The daily routine is often based on the type of municipality. Nowadays, small municipalities are not the centre of the inhabitant's life because of sub-urbanization. They are mostly used frequently for overnight stay. The morning trip to bigger towns and the afternoon return predominate. There are also medium-sized towns where the citizens of small municipalities commute, but at the same time the citizens of these cities commute to larger cities. Passengers from small municipalities approximately correspond to the number of passengers from these towns. The last category include the core cities of the agglomeration or centers of the metropolitan area, where dominate commuting from the surroundings in the morning and coming back in the afternoon [5].

2.1.3. Weekly variation and other influences

At present, there is a relatively significant share of trips on weekends and public holidays. The Beskydy Mountains, which is an important local touristic region, can be considered the main destination of the trips. Tourists at weekends with favorable weather use the track No. 323 mostly in the opposite direction than on working days. The number of passengers on Saturdays is often higher than on a working day, the section between Frydek-Mistek and Frydlant nad Ostravici is used tens of percent higher. Another influence on weekly variation is week-long commuting to schools in more distant destinations, which is the most apparent on Friday afternoons and Sunday afternoons, but with comparison to every day commuters it has a marginal affect on predicted demand (in this case) [6].

2.2. Future passenger movement data

2.2.1. Growth coefficient for stations

The authors utilized variations described in Section 2.1. for the determination of the number of passengers per day. Recent data due was not available at this time due to limited availability.

The load values from „Beskydy“ feasibility study [7] were compared with the diploma thesis [8] and other censuses carried out in the following years and were subsequently standardized because a constant decrease in the number of passengers was identified over the years. Subsequently, the standardized number of passengers corresponds to the year 2010, from which the most valid dataset comes from.

Furthermore, the authors used relevant data for the period after the modernization of the track No. 323. These data come from the study [7] and describe passenger section load after the completion of the track modernization. The period after modernization corresponds to the year 2025. These data are available to the authors only in the form of loading of individual sections, therefore it is necessary to perform the conversion below.

On the basis of these data, an increase in the number of passengers at the relevant stations and adjacent sections was determined. The calculation was performed according to the following eqn (1).

$$k = \frac{z_{2025}}{z_{2010}} \quad (1)$$

,where k is the coefficient of the passenger number growth, z_{2025} expresses the predicted passenger section load according to the transport model for 2025 after the modernization and z_{2010} expresses the standartized passenger section load according to 2010.

Using the eqn (2), the values for the estimated movements (boardings and gettings off) at all stations were received.

$$p_{2025} = p_{2010} \frac{(k_p + k_n)}{2} \quad (2)$$

,where p_{2025} expresses the predicted passenger movements at station in 2025, p_{2010} expresses the passenger movements at station in 2010, k_p represents the passenger growth coefficient immediately preceding the assessed station and k_n represents the passenger growth coefficient immediately following the assessed station [9].

2.2.2. Passengers per hour and direction

Based on the passenger data at individual stations on the track No. 323 and data describing the section load, it is possible to determine the estimated demand for transport for the given direction and specific hour. For the allocation of passengers to the network, data on the daily variation of passengers at the station was used, divided into individual directions and their movements (boardings / gettings off) [10]. The result of this procedure is an indication of the number of passengers for each hour, their direction of travel and movement (boarding / getting off) at the station.

After assigning the values of the anticipated demand for transport to the respective direction and hour, the obtained values were aggregated and tables with the expected section load in the respective direction and hour could be compiled. The validation of the section load was carried out in the vicinity of important nodes Frydek-Mistek and Frydlant nad Ostravici. The verification was carried out on data obtained during the field survey carried out in April 2019.

3. Results and discussion

By applying the procedures described in the Section 2, the authors gradually reached the expected output – the number of passengers load in each section for a given hour and direction. Partial outputs are presented below.

3.1. Origin-destination matrix output

Table 1 shows the station potentials for the respective directions to the initial or terminal station of the track. Looking at Table 1 on the obtained slope coefficients, it is clear that boarding passengers predominate in the direction to Ostrava, the direction to Valasske Mezirici is less preferred. The endstations of the monitored section have potentials of 1 in the appropriate direction, since it is an entry into the solved area and other travel relations in the node are not considered. For the stations Frydek-Mistek and Frydlant nad Ostravici, data from the authors' survey was used as a validation of predicted data.

Table 1: Proportion to directions per station (section Ostrava – Frydlant n. O.).

Station	Total number of commuters [-]	proportion to direction Valasske Mezirici [-]	proportion to direction Ostrava [-]
Ostrava-Kuncice	-	1,00	0,00
Vratimov	351	0,28	0,72
Paskov	226	0,40	0,60
Liskovec u Frydku	82	0,62	0,38
Frydek-Mistek	887	0,33	0,67
Baska	266	0,15	0,85
Przno	108	0,21	0,79
Frydlant n. Ostr.	468	0,11	0,89

3.2. Comparison of daily variations

A daily variation of passenger movements at the stations Paskov and Frydek-Mistek was prepared to determine the actual course of the curve. The Paskov station represents a station near a small municipality, the Frydek-Mistek station represents a station in a medium-sized town.

The available data on the 2011 and 2014 from Paskov Census and in 2019 from authors' survey were used for Paskov Station. For Frydek-Mistek Station the data on the 2019 from authors' survey were used [6]. All surveys took place on an average workday in the middle of the week, with an emphasis on the passengers' boarding and getting out the trains and their assignment to directions.

The rules described in Section 2.1.2 in the above cases were applied. The suburbanization trends and the prevalence of morning commuting to larger cities are apparent from the Paskov station data and balanced boarding and gettings off confirm the rule for medium-sized towns in the case of the Frydek-Mistek station. When comparing the daily variations at the stations Paskov and Frydek-Mstek, it can be concluded that the variations are comparable.

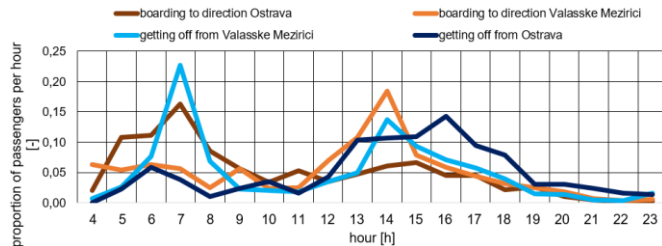
The daily variation of passenger movements for the Paskov station was applied to stations connected with small and daily variations of passenger movements for stations Frydek-Mistek and Frydlant nad Ostravici were applied for stations in larger settlements, where similar development of the number of passengers is expected and commuting from surrounding municipalities is noticeable.

3.3. Future movement of passengers

The method described in Section 2.2 was applied for the determination of future passenger movements. Based on the data of passengers movements at stations and data describing the load of track sections, it was possible to determine the estimated travel demand for the given direction and specific hour. For each station, passengers' boardings and gettings off have been computed. Furthermore, the direction in which the passenger is boarding or getting off has been taken into account. The existing division of passengers into directions according to Section 2.1.1 was used for routing.

The data collected from 2010 to 2019 were used for this purpose and daily variations of passenger movements were created. Subsequently, the daily variation of the respective station was applied to the absolute number of passenger movements, and values were obtained for specific hours of the average working day.

Figure 2: Daily variation at station Frydek-Mistek – proportion to directions



Tables with an estimated number of passengers in respective directions and sections per hour were created from the data analyzed so far on transport demand by their synthesis. The validation of the section load was carried out in the vicinity of transport nodes with the quarry of transport demand, it was performed on data obtained during the authors' survey in April 2019.

Table 2 below shows the expected section load in the direction to Ostrava per hour, values are rounded up to tens. The authors are aware of some inaccuracies stemming from the insufficient volume of data obtained and the difficulty of predicting travel behavior. However, given the design horizon and feasibility study submission, a more accurate analysis is possible only on the basis of a complete transport model with significantly larger data inputs. For the purposes of designing the operational concept, timetable and vehicle circulation, it is possible to be satisfied with the values obtained and their possible deviations.

Table 2: Expected passenger section load per hour in the direction to Ostrava

from	to	hour									
		4	5	6	7	8	9	10	11	12	
Valasske M.	Hostasovice	20	20	20	20	10	20	10	10	30	
Hostasovice	Morkov	20	20	20	20	10	20	10	10	30	
Morkov	Verovice	30	30	30	30	20	20	10	10	30	
Verovice	Frenstat p. R.	30	50	50	50	30	30	20	20	30	
Frenstat p. R.	Kuncice p. O.	30	50	130	110	20	30	50	50	50	
Kuncice p. O.	Celadna	40	80	160	150	40	40	50	50	60	
Celadna	Frydlant n. O.	50	120	210	200	60	60	60	60	70	
Frydlant n. O.	Przno	110	210	430	460	150	100	110	90	170	
Przno	Baska	120	240	470	500	160	110	110	100	180	
Baska	Frydek-Mistek	130	290	520	550	190	130	120	110	200	
Frydek-Mistek	Liskovec u F.	80	490	660	820	410	250	200	230	180	
Liskovec u F.	Paskov	80	500	670	850	410	250	190	230	170	
Paskov	Vratimov	90	530	700	880	420	260	190	230	180	
Vratimov	Ostrava-K.	110	570	750	930	450	270	200	230	190	

Table 2 shows the stations at which there is a significant refraction of demand for transport and a change in the frequency of the offered connections or vehicle capacity can be expected.

3.4. Application in regional rail transport management

Table 2 shows the passenger load on each track section at the appropriate hour. This output makes it possible to determine a

suitable operational concept for track No. 323. It is obvious that the utilization of the sections is variable, in the part of the track between Frenstat pod Radhostem and Valasske Mezirici the number of passengers is usually up to 50 passengers per hour and the differences between the peak and saddle hours are minimal. In this section it is about ensuring a minimal transport service, which corresponds to a one train connection hourly.

On the other hand, in the section between Frydek-Mistek and Ostrava, the estimated number of passengers is almost 1,000 passengers per hour. It is necessary to consider the capacity strengthening of the trains, as well as shortening the interval. It is also apparent from the outputs that there is a significant change in the number of passengers in Frydek-Mistek and Frydlant nad Ostravici [11]. These passengers are heading to Frydek-Mistek or Ostrava. This implies the need to introduce fast suburban trains for this large group of passengers [12]. Conversely, there is no need for such a number of trains during the saddle period. In relation to the number of passengers, it is also possible to determine the optimal train capacity, capacity coverage during the morning rush hour is crucial.

In addition, the outputs allow to determine the range of periods of the rush hour and transport saddle, the extent of periods with shorter intervals or additional train lines could be determined accordingly.

An important contribution is also the consideration of current trends on the market of railway vehicles. While the designing of infrastructure project starts usually about 10 to 15 years before its construction, the vehicle production and operation competition are organized approximately three to five years before the start of operation. It is possible to modify the original operating concepts and introduce, for example, vehicles with alternative propulsion - typically BEMUs (battery electric multiple units). These vehicles open up new application possibilities, allowing direct connections even where a transfer was necessary due to the absence of overhead lines. These unconventional solutions open space for even more efficient operating concepts and at the same time highlight the importance of suburban rail transport management. [13]

4. Conclusion

Effective regional rail transport planning is based on analysis of available data and forecasting for the future. The anticipated major infrastructure upgrades and the associated major changes in the organisation of transport are an opportune moment to forecast future passenger volumes. Based on the original origin-destination matrices, predictions and expected passenger numbers after the infrastructure upgrade and the introduction of new trains were compiled. Forecasts have been made for individual directions and time periods. Demand growth coefficients for individual stations were used. Daily variations in travel demand, weekly variations in travel demand and other influences were also taken into account. In accordance with the procedure described in Section 2, a daily variance was determined for each station type. The data was aggregated and an output describing the number of passengers in each direction and time period was obtained. Subsequently, the future passenger loads for the line segments and stations were obtained.

Based on the outputs, it is possible to determine an appropriate operating concept on the suburban railway line. The integrated periodic timetable is a suitable tool for meeting the requirements of suburban railways. Given the extent of infrastructure capacity and future travel demand, it is possible to determine the appropriate vehicle unit for train services on the railway line.

There are two basic criteria for the design of the service, the minimum frequency of service and the capacity aspect of the service offered. In the case of line No. 323, there is a minimum frequency of service at the level of 1 train per hour in rural areas and 2 trains per hour in agglomeration areas. In terms of train capacity, it is important to compare the vehicle unit capacity with

the predicted passenger movement data and the capacity margin for any increase of travel demand. If more trains need to be introduced, the introduction of fast suburban trains for passengers commuting between major cities is suggested. Operating concepts can be designed for peak, off-peak and weekend periods.

In conclusion, the authors would like to state that for projects developed with a longer time interval it is necessary to assess the impact of new technologies, especially the possibility of alternative propulsions. Methodologies with a detailed analysis of usage alternative propulsions are still emerging, the design of an operating concept using these vehicles in the case of modernization of railway lines is unique. With the successful implementation of this methodology, it is possible to introduce a different operating concept on the railway line that will be more efficient and sustainable than originally expected.

5. References

- [1] Sčítání lidu, domů a bytů 2011 (ČSÚ), <https://www.czso.cz/csu/sldb>, 12.01.2024
- [2] Kraft, S., M., Marada: Delimitation of functional transport regions: Understanding the transport flows patterns at the micro-regional level, *Geografiska Ann. Ser. B Human Geograph.*, vol. 99, no. 1, pp. 79-93, 2017, doi: 10.1080/04353684.2017.1291741
- [3] Janoš, V.; M., Kříž: PRAGMATIC APPROACH IN REGIONAL RAIL TRANSPORT PLANNING, *Zeszyty Naukowe Politechniki Śląskiej*. 2018,(100), 35-43. ISSN 0209-3324, doi: 10.20858/sjsutst.2018.100.4
- [4] Solinen, E., C.W., Palmqvist: Development of new railway timetabling rules for increased robustness, *Transport Policy*, Pages 198-208, Volume 133, 2023, ISSN 0967-070X, doi: 10.1016/j.tranpol.2023.02.003.
- [5] Wardman, M., W., Lythgoe, G., Whelan: Rail Passenger Demand Forecasting: Cross-Sectional Models Revisited. In: *Research in Transportation Economics*, vol. 20, 2007, Pages 119-152, [https://doi.org/10.1016/S0739-8859\(07\)20005-8](https://doi.org/10.1016/S0739-8859(07)20005-8)
- [6] Fridrisek, P.: *New Operating Concept on the Track Ostrava - Valašské Meziříčí*, master thesis, Praha: CTU. Faculty of Transportation Sciences, 2019.
- [7] Composite authors: *Studie proveditelnosti Beskydy*, feasibility study; SUDOP Brno, AF CITYPLAN, Brno, 2015.
- [8] Solansky, S.: *Assessment of the extent of infrastructure and its capacity on track Valašské Meziříčí - Ostrava for current and prospective operation*, master thesis, Univerzita Pardubice, 2011.
- [9] Pekel, E., S.S., Kara: Passenger flow prediction based on newly adopted algorithms, In: *Applied Artificial Intelligence*, 31:1, 64-79, DOI: 10.1080/08839514.2017.1296682
- [10] Milenković, M., L., Švadlenka, V., Melichar, N., Bojović, Z., Avramović: SARIMA modelling approach for railway passenger flow forecasting, *Transport*, 33 (5), 1113-1120, 2018. doi: 10.3846/16484142.2016.1139623
- [11] Zhu, Y.T., F.Z. Wang, X.H., Shan, X.Y., Lv: A Model for Seat Allocation of Railway Passenger Transport Based on OD's Priority. In: *Advanced Materials Research 2014*; 989–994:2344–8. doi:10.4028/www.scientific.net/amr.989-994.2344.
- [12] Janoš, V., R. Vávra: Comparison of Different Conceptions of Suburban Railway Transport In: *2019 Smart City Symposium Prague*. New York: IEEE Press, 2019, ISBN 978-1-7281-0497-3, doi: 10.1109/SCSP.2019.8805699
- [13] Dedík, M., L. Čechovič, J. Gašparík; Methodical Process for Innovative Management of the Sustainable Railway Passenger Transport, *Transportation Research Procedia*, 305-

312, Vol. 44, 2020, ISSN 2352-1465,
doi:10.1016/j.trpro.2020.02.038.

Specific features of cargo insurance

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Abstract: *In any economic system, the transportation of goods is critical to the functioning of commerce and industry. In the world of international trade and transportation of goods, the risks associated with the transportation of goods are inevitable. Although technological logistics systems are developing at an extraordinary pace thus ensuring the efficiency and safety of transportation, factors such as natural disasters, technical problems, theft and damage can lead to serious losses for both carriers and cargo owners.*

Keywords: INSURANCE, INFRASTRUCTURE, TYPES OF INSURANCE COVERAGE, FREIGHT

1. Introduction

One of the means to deal with these risks is to insure the cargo during its transportation. This not only offers security of commercial operations and minimization of financial losses in case of accidents or damage during transport, but also provides psychological peace of mind to all participants in the supply chain. This area of the insurance industry is dynamic and constantly changing, adapting to new technologies, legislative requirements and geopolitical conditions. However, the core principle of cargo insurance during transportation remains unchanged - to provide security and protection for traders and their goods, ensuring the smooth and trouble-free functioning of the global trade.

The study aims to study and analyze the main aspects of cargo insurance in transit. The presentation of the historical development of insurance, as well as an analysis of contemporary methods, products and services in the field, will provide a deep understanding of the importance and influence of insurance in this social and economic sphere. The analysis includes an overview of the main types of insurance that are used to cover risks during transportation, from traditional marine insurance to air and land cargo insurance. The specific risks associated with each of these forms of transport will also be analysed, as well as methods for risk assessment and risk management [1,4].

2. Types of cargo insurance coverage and types of risks during the transportation of goods

When it comes to transporting goods, regardless of the mode of transport – by land, air, sea or rail, it is essential to secure the right type of cargo insurance cover. Different modes of transport expose goods to different risks, and having the right insurance cover helps to provide the right protection and security when transporting goods.

A. Marine Insurance Coverage

Marine insurance cover is like a safety companion for goods traveling by sea. In view of the vastness of the oceans and unpredictable weather conditions, having marine insurance coverage provides protection against potential damage or loss.

As a general rule, marine insurance cover includes cover for damage or loss caused by loading/unloading incidents, weather-related incidents and other perils of the sea. It can also be extended to cover storage periods in ports and any land transit transportation associated with the sea voyage.

The unpredictability of the sea transport is associated with the possibility of storms, collisions or even piracy. Having marine insurance cover ensures that if a potential risk materialises, significant financial losses will be avoided. This makes marine insurance coverage mandatory when shipping goods by sea, especially over long distances. This type of insurance is essential for importers, exporters and manufacturers who deal with international ocean freight [2,3].

B. Air Insurance Coverage

Air insurance coverage is specifically intended for goods transported in the sky, protecting cargo from the unique risks associated with flights, such as changes in air pressure and rapid changes in temperature. It mainly covers damage or loss caused by accidents, turbulence or improper handling during loading and unloading. Depending on the covered risks included in the policy, cargo may be protected against damage caused during storage at the airport. The speed and efficiency of air transport for international shipments of goods, especially perishable goods or high-value products, contribute to indispensable air insurance coverage, reducing financial losses from unforeseen events during flights or cargo handling problems at airports.

C. Land Insurance Coverage

Land insurance coverage, also called commercial vehicle insurance, is coverage for goods transported by trucks or other vehicles on the road. Because of the diverse range of risks present on highways and roads, ground insurance coverage typically covers damage or loss caused by accidents, theft, or ambient conditions affecting the cargo. Specific policies may also cover damages incurred during the loading and unloading process. Road transit exposes goods to risks of accidents related to weather conditions as well, ensuring insurance security against the financial consequences of such unfortunate events.

D. Railroad Insurance Coverage

Railroad insurance coverage provides protection for cargo carried by rail, ensuring protection against loss or damage caused by accidents, collisions and other rail-specific incidents. The cover also includes insurance against theft or fire while the goods are on the train. Rail transit is preferred for its efficiency and lower environmental footprint, but does not negate rail insurance as a safeguard against possible damage and loss.

Types of risks during the transportation of goods: The transportation of goods is associated with various types of risks that may occur during transportation and lead to loss or damage for traders and transport companies, and for the prevention of which the necessary management measures are applied. Below are some of the main types of risks during cargo transportation that are covered by insurance law and can be caused by various circumstances, intentional or unforeseen, at individual stages and moments of transportation operations.

Damages during loading and unloading: This type of risk includes damages occurring during the process of loading and unloading the goods from and into the vehicle, which are due to improper handling of the goods, mechanical shocks or poor handling conditions of the cargo. For example, incorrect lifting or carrying of heavy goods can cause deformation or breakage of the load.

Loss of goods: This risk includes cases of loss of goods or goods fallen off during transport caused by a vehicle accident, incorrect marking and identification of goods. Loss of goods leads to supply chain disruption and financial losses.

Fire and explosion: This type of risk includes the danger of fire or explosion during the transportation of the goods, related to both technical problems of the vehicle and non-compliance with the

storage conditions during transportation or chemical reactions of certain types of goods and cargo, endangering the life and health of people involved in transport.

Theft and vandalism: This type of risk includes the risk of theft, loss or vandalism both during the transportation of the goods and during their stay in certain places, for example in warehouses or in the means of transport themselves during transit through risk areas or high crime areas.

Damage during transportation: This type of risk includes damage as a result of the transportation of the cargo itself, such as possible deformations, breaks, leakage of liquids, damage to the packaging of the goods due to uneven distribution and sorting of the cargo or instability during transportation.

Loss of information or documentation: This risk includes the possibility of loss or destruction of important information or documentation related to transport processes due to data leakage, loss of transport documents and other documents to identify the goods. The loss of such information can in some cases also lead to legal problems.

Adverse weather conditions: This type of risk includes adverse weather conditions such as storm, snowfall or flooding, which may cause delays or damage to the cargo during transportation, as well as may lead to difficulties in the movement of vehicles.

Violation of legal and regulatory requirements: This type of risk includes violation of legal and regulatory requirements during the transportation of the goods, related to non-compliance with transport regulations or lack of necessary permits and licenses. Such violations lead to legal problems and penalties, as well as disruption of transport operations.

3. Insurance products and services for cargo in transit and types of risks during the transportation of goods coverages and exclusions for cargo insurance during transportation

Main types of cargo insurance during transportation

- **All Risk Insurance:** This is a general insurance coverage that provides insurance against all risks except those expressly excluded in the policy. This type of insurance offers broad coverage and is generally used to protect goods against any type of damage or loss during transit.

- **Basic Risk Insurance:** This type of insurance provides coverage only against certain basic risks that are specifically listed in the policy. These typically include fire, explosion, theft, and shipping damage. This type of insurance is more limited than All Risks insurance, but may be more suitable for certain situations or budget constraints.

- **Natural Disaster Insurance:** This type of insurance provides coverage for damage caused by natural disasters such as floods, earthquakes, hurricanes, and others. Because these events can cause serious damage to goods in transit, natural disaster insurance can be important to protect investments and prevent financial losses.

- **Theft and Vandalism Insurance:** This type of insurance provides coverage for losses caused by theft or vandalism during the transportation of the goods. As theft and vandalism can be serious threats to the safety of goods, insurance against these risks is essential for traders.

- **Catastrophe and Accident Insurance:** This type of insurance provides coverage for loss or damage caused by catastrophic events or accidents during transportation. It may include such situations as accidents, collapse of the vehicle or other unusual and unexpected events.

- **Third Party Liability Insurance:** This type of insurance provides coverage for damage caused to third parties during the transportation of the goods. This includes damage caused to property or to people who are not part of the carrier or owner of the goods, but suffered losses as a result of the transport activity.

- **Delivery Interruption Insurance:** This type of insurance provides coverage for loss or damage caused by interruption of delivery due to various reasons such as accidents, strikes, problems with the means of transport or other unexpected situations.

- **Extra Expense Insurance:** This type of insurance provides coverage for additional expenses that may occur during the transportation of the goods due to unexpected events such as accidents, crew illnesses or other factors that may lead to delays or supply interruptions.

Coverages and exclusions for cargo insurance during transportation

A. Coverages:

- **Fire and Explosion:** Generally, the insurance policy covers loss or damage to goods caused by fire or explosion during transportation.

- **Theft and Vandalism:** Covers losses caused by theft or vandalism during the transport mission.

- **Damages during loading and unloading:** This insurance can cover damages that occur during the handling of the goods during loading and unloading from/on the means of transport.

- **Damage in transit:** This insurance usually offers coverage for damage to goods during transit itself, including deformation, breakage or spillage.

- **Natural Disasters:** Some insurance policies may cover losses caused by natural disasters such as floods, earthquakes and hurricanes.

4. Regulatory and legal context, International conventions and agreements. Innovations in in-transit cargo insurance

Normative requirements for cargo insurance during transport

Regulatory requirements for cargo insurance during transportation may vary depending on the jurisdiction in which the transportation takes place, as well as the type of transportation and the characteristics of the goods. However, there are some general regulatory requirements and standards that may apply in many countries.

- **Minimum carrier liability coverage:** In many jurisdictions, legislation requires that carriers must have a minimum level of insurance coverage for their liability to shippers. This is important to ensure that customers are compensated in the event of loss or damage to goods in transit.

- **Specific requirements for certain types of transport:** For certain types of transport, such as the international transport of dangerous goods (ADR), specific insurance coverage may be required in accordance with international conventions and national legislation.

- **Financial Licensing Requirements:** Insurance companies that offer in-transit cargo insurance are generally subject to financial licensing requirements and regulations from regulatory authorities. This may include capital and solvency requirements, as well as compliance with certain standards for the insurance business.

- **Information and documentation compliance:** In order to comply with regulatory requirements, insurance companies must generally provide information and documentation about the insurance coverage they offer, as well as comply with their obligations to provide fair and accurate information to their customers.

These are some of the general regulatory requirements for in-transit cargo insurance that may apply in many countries. However, it is important to check with your local legislator or insurance expert to understand the specific requirements that apply to your business and region.

International conventions and agreements

In the insurance of cargo during transport, international conventions and agreements play an important role in regulating the rights and responsibilities of the parties involved in the transport, as

well as in determining the general standards for insurance coverage. Some of the most important international conventions and agreements in this area include:

- The International Convention for the Carriage of Goods by Road (CMR): The CMR is an international treaty that regulates the rights and responsibilities of carriers and consignors during the international carriage of goods by road. It includes provisions for the insurance of goods and sets a minimum level of liability for carriers.

- The International Convention for the Carriage of Goods by Rail (COTIF): COTIF is an international convention that regulates the carriage of goods by rail in some European countries. It includes provisions for the insurance of goods and defines the rights and responsibilities of carriers and consignees.

- The International Convention for the Carriage of Cargo by Air (Montreal Convention): This convention regulates the carriage of goods by air and includes provisions for cargo insurance and the liability of airlines for loss or damage to goods.

The International Convention for the Protection of Goods (ISC): This convention aims to ensure the protection of goods during transport and includes provisions for the insurance of goods against various risks that may arise during carriage.

These international conventions and agreements aim to standardize the rules and procedures for the carriage of goods and to ensure the protection of the interests of carriers, shippers and insurers. These may include various provisions regarding the insurance of the goods and the rights and responsibilities of the parties in the event of loss or damage.

Innovations in in-transit cargo insurance

1. Technological innovations and technological platforms

Technological innovations and platforms are playing an ever-increasing role in insuring cargo in transit, providing more efficient and innovative solutions for insurers and customers alike. Some of the major technological innovations and platforms in this area include:

- o Digitization of insurance processes: Digitization of insurance processes enables faster and more efficient issuance of insurance policies, claims processing and insurance portfolio management. This includes the use of electronic documents, online quoting and coverage platforms, and automated claims management systems.

- o Use of sensors and IoT (Internet of Things): Sensors and IoT devices can be used to continuously monitor and control cargo conditions during transport, such as temperature, humidity, vibration and shock. This helps insurers assess risks more accurately and provide more personalized insurance solutions.

- o Blockchain technologies for data management: Blockchain technologies provide a secure and transparent way to manage data and transactions at any point in the supply chain. They can be used to ensure the authenticity of documents such as insurance policies and contracts, and to automate claims settlement processes.

- o Artificial intelligence and machine self-learning: Artificial intelligence and machine self-learning can be used to analyze large volumes of data and predict risks. They can help insurance companies better understand their customers' behavior, offer personalized insurance products and optimize pricing and coverage.

- o Mobile applications and online platforms for customer service: Mobile applications and online platforms provide a convenient way of communication between insurance companies and their customers. They allow customers to quickly access information about their insurance, submit claims and get help from customer service teams.

These technological innovations and platforms not only streamline the processes of insurance companies, but also improve transparency, efficiency and customer satisfaction in insuring cargo in transit.

2. New approaches to risk assessment and risk management

New approaches to risk assessment and management in in-transit cargo insurance focus on using advanced technology, data and analytics to protect insurance companies from unforeseen losses

and improve the precision and efficiency of the risk management processes [5].

- Use of Big Data and analytics: The collection and analysis of large volumes of data (Big Data) from various sources, such as sensors, social media, weather data and historical risk data, allow insurance companies to make a more accurate risk assessment and offer customized insurance solutions.

- Use of predictive models: Predictive models based on machine learning and statistical analysis can predict the probability of occurrence of various risks during the transportation of goods. These models can help insurance companies identify potential problems and take proactive measures to reduce risk.

- Use of sensors and IoT devices: The integration of sensors and IoT devices in the transport infrastructure and on vehicles enables continuous monitoring and control of transport conditions such as temperature, humidity and vibration. This allows insurance companies to react quickly to potential risks and take action to reduce them.

- Improved risk modeling: Advanced risk modeling models allow insurance companies to more accurately estimate the potential loss and damage that may occur as a result of various risks during transportation. This helps them determine the appropriate amount of insurance coverage and manage risk more effectively.

- Advanced risk assessment methods: New risk assessment methods, such as scenario analyses, stress tests and dynamic risk management models, enable insurance companies to deal with the complex and dynamic risks associated with the transportation of goods. These new approaches to risk assessment and management in in-transit cargo insurance allow insurance companies to be more flexible, innovative and efficient in meeting the challenges of the market today.

3. Development of multimodal insurance products

The development of multimodal insurance products in insuring cargo in transit represents a significant innovation in the insurance industry. These products offer comprehensive cover for the risks associated with the carriage of goods by various modes of transport and routes, enabling insurers and customers to deal with the complexities of international trade and logistics. Here are some of the main aspects of the development of multimodal insurance products:

- Integration of coverages for different modes of transport: Multimodal insurance products enable customers to obtain cover for the risks associated with the transportation of goods by air, land, water and rail. This provides comprehensive insurance cover for the entire transport route and reduces the risk of unforeseen loss or damage.

- Appropriate insurance services for the entire supply chain: Multimodal insurance products focus not only on the coverage of goods transportation, but also include insurance services for the entire supply chain, including warehouses, transit points and processing centers. This ensures greater security and protection of the goods throughout the transport process.

- Flexibility and customization: Multimodal insurance products offer flexible and customized solutions that meet the specific needs and risks of customers. They allow insurers to choose different types of coverage, limits and services depending on the characteristics of their shipments and business models.

- Integrated technology solutions: Multimodal insurance products use advanced technologies such as IoT devices, digital platforms and analytics tools to provide better risk monitoring, management and analysis. This allows insurers to offer more efficient and innovative solutions to their customers.

- Partnerships and collaborations: The development of multimodal insurance products often involves collaborations and partnerships between insurance companies, carriers, logistics operators and other actors in the transport chain. This allows all parties to share the risk and work together to reduce loss and damage during the carriage of goods. In conclusion, multimodal insurance products represent an innovative approach to freight risk management that provides comprehensive and customized

insurance coverage for customers and improves the efficiency and security of transportation operations.

5. Conclusion

Cargo insurance during transportation is an indispensable part of the effective and efficient development of business and the protection of the personal interests of participants in global trade and logistics. Transporting goods by various modes of transport presents a significant risk of loss and damage, which is why having the right insurance cover is essential. Different modes of transportation expose cargo to a variety of risks, including collisions, theft, fires, natural disasters, and more. Insurance coverage is designed to provide financial protection in the event of such mishaps while ensuring business continuity.

The main types of cargo insurance in transit include marine insurance, air insurance, land insurance and rail insurance. Each of these insurances offers different levels of coverage tailored to the specific risks associated with the type of transport and route. With the development of technology and new approaches to risk management, insurance companies are offering innovative solutions for insuring cargo in transit. Technological innovations such as IoT devices, Big Data analytics and predictive models help in more accurate risk assessment and better management of insurance products.

Also, the development of multimodal insurance products provides complex solutions to cover risks during transport, which is of particular importance for companies that use different modes of transport to deliver their goods.

In conclusion, in-transit cargo insurance is vital to ensuring the security and continuity of the global supply chain. With the right insurance coverage, businesses can protect themselves from unforeseen losses and continue their business operations successfully, while insurance companies provide the most appropriate innovative and customized solutions to ensure protection, ensuring peace of mind for their customers.

6. Literature

- [1]. Bergstrom, V, *Measuring and Interpreting Business Cycles*. Clarendon Press, 1994.
- [2]. Gancheva, Y., *Some Problems Related To The Exploitation Of Automated Container Terminals*, *Pedagogika-Pedagogy*, Volume 93, Number 7s, 2021.
- [3]. Hirsch, Seev. 1967. *Location of industries and international competitiveness*. Oxford, UK: Oxford University Press
- [4]. Stefanova, M., *Integrating Quality and Risk Management in Logistics*, ISBN 978-1-80356-534-7, 03.2022.
- [5]. Transportu, P., *The Concept of Organizing Transport and Logistics Processes*, 2013.

Risk Assessment and Functional Safety Management in Air Traffic Control and Automated Air Traffic Control

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Abstract: Risk assessment is a crucial aspect of functional safety. As many of the safety development methods define the development process and applicable procedures based on the required risk reduction (safety level or tolerable hazard rate). System development, including hardware and software development requires special measures to reduce the dangerous effects of random hardware failure as well as systematic developer-made errors that can lead to dangerous situations during operation. This set of measures is known as safety management.

In air traffic management there are international and European legislation and industry-specific standards that mainly focus on software issues. Additionally, general functional safety standards offer more complex hardware and software solutions to achieve the desired level of safety for newly developed systems.

This paper discusses on the risk assessment challenges posed by new, highly automated air traffic control systems. These systems rely on hardware and software components to perform safety-critical control functions without human intervention or human supervision. The paper identifies the relevant legislative entities and compares a domain-specific risk assessment method for air traffic control with widely used general risk assessment methods. An example Air Traffic Control function is analysed according to EUROCAE ED153 ("Guidelines for ANS Software Safety Assurance"), according to 2017/373/EU ("Commission Implementing Regulation laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight...") and in comparison, according to general functional safety standard IEC 61508 ("Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems").

Keywords: AIR TRAFFIC MANAGEMENT, AUTOMATED AIR TRAFFIC CONTROL, RISK ASSESSMENT

1. Introduction

It is indispensable to conduct a comprehensive risk assessment in order to guarantee the safety of complex systems, particularly in the domain of Air Traffic Management (ATM), where failures can have severe consequences. Standardized approaches to safety assessment universally guarantee acceptable safety risks through adherence to international regulations, in addition to specific industry standards. Table 1 summarizes these main standards applicable in the industry.

However, with the rise of highly automated air traffic control systems, new challenges have emerged for current risk assessment methodologies. These systems rely heavily on technology and to a lesser extent on humans, thus necessitating a comprehensive examination of both hardware and software. This paper compares specific risk assessment methods for air traffic control with broader safety standards in order to identify the most effective approach.

By examining a typical air traffic control function based on relevant regulations and standards, such as EUROCAE ED-153 [1] and ED-109A [2], IEC 61508 [3], EU 2017/373 [4] in section 3, this paper aims to explore differences in risk assessment techniques. Through this comparison the goal is to identify ways to make safety methods in the ATM domain better suited to the changing needs of automated Air Traffic Management.

Table 1: ATM/ANS safety standards and regulations. [4]

Document title	Reference	Date
Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems.	EUROCAE ED-109A/ RTCA DO-278A	2012
Guidelines for ANS Software Safety Assurance	EUROCAE ED-153	2009
Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements	IEC 61508 – Part 3	2010
Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/ electronic/programmable electronic safety-related systems	IEC 61508 – Part 2	2010
Software Considerations in Airborne Systems and Equipment Certification	EUROCAE ED-12C/ RTCA DO-178C	2012

2. Comparing Definitions

EU 2017/373 has presented a revised form of the basic definitions used in risk assessment. The definition of hazard, as stated in the document, is "any condition, event, or circumstance which could induce a harmful effect." However, the term "harmful effect" is not defined directly in 373. Instead, it is commonly understood to be personal injury. This leaves a gap where no harmful effect is identifiable. This is commonly defined as the potential hazard, which could result in a safety occurrence. This definition of "hazard" previously in force (e.g. under 1035/2011 [5] and 482/2008 [6]; hazard is any condition, event, or circumstance which could induce an accident) covered both of these cases through accident severities.

The distinction between the definitions of hazard from IEC 61508, as a potential source of harm, and the standard's clarification of this definition in the form of a note is to be outlined. The term encompasses dangers to persons that arise within a short time scale, such as fire and explosion, as well as those that have a long-term effect on a person's health, such as the release of a toxic substance. In contrast to the definition set out in 2017/373, this definition does not limit the term "hazard" to human injury. IEC 61508 also defines both "hazardous event" as an event that may result in harm and "harmful event" as an occurrence in which a hazardous situation or hazardous event results in harm. In the above definitions, harm is defined as physical injury or damage to the health of people or damage to property or the environment, which makes it a broader term than the hazard of 2017/373.

IEC 61508 permits the implementation of risk reduction measures through the use of E/E/PE (Electrical/Electronic/Programmable Electronic) systems in the form of safety functions, which are designed to achieve or maintain a safe state in relation to a specific hazardous event. The standard distinguishes between overall safety functions, which are considered from a high-level perspective in relation to a specific hazardous event, and elementary safety functions, which are implemented at a low-level and are comprised of individual elements. The probability that the E/E/PE system performs the safety-related function within the given conditions is the safety integrity, where a higher safety integrity results in a lower probability of failure. Safety integrity can be expressed in a discrete level (1-4) as Safety Integrity Level (SIL). Since IEC 61508 applies to the whole system, different types of safety integrities are distinguished:

- software safety integrity (systematic failures of the software),

- systematic safety integrity (systematic failures),
- hardware safety integrity (random failures of the hardware).

ATM-relevant software safety standards ED-109A and ED-153 address these definitions from a software perspective. In ED-153, software failure is defined as the inability of a program to perform a required function, whereas software malfunction is defined as the inability of a program to perform a required function correctly. ED-109A introduces a chain of error – fault – failure – failure condition, as shown in Figure 1. The term "error" is defined with respect to software as a mistake in requirements, design, or code. The term "fault" is defined as a manifestation of an error in software, where failure is the inability of a system or system component to perform a required function within specified limits. A fault, if it occurs, may cause a failure. The effect on a CNS/ATM (Communication, Navigation, Surveillance) system or equipment, both direct and consequential, caused or contributed to by one or more failures, which may be attributed to, for example, a latent software error in the executable code or data, considering relevant adverse operational and environmental conditions, is the failure condition.

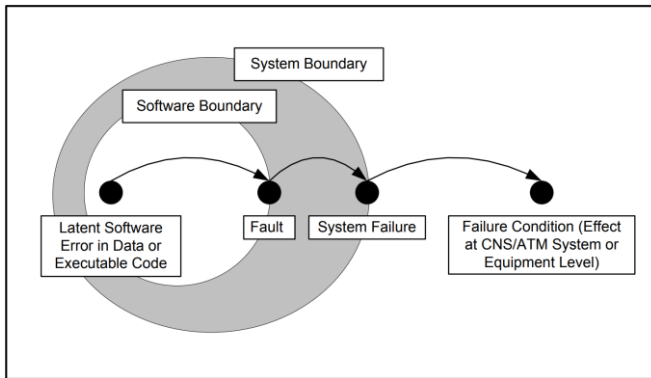


Fig. 1 Event sequence of Software Error leading to a Failure Condition. [2]

3. Methodological Comparisons

As demonstrated in the preceding chapter, there is a distinction between risk assessment methodologies. To elucidate this divergence, an example function is analysed in this section.

3.1 Function Overview

The selected function for the assessment comparison is the presentation of TOC (Top of Climb) on the screen in front of the controller. TOC is a point and time data pair that marks the end of the climb phase of flight. It is analogous to TOD (Top of Descent), which marks the beginning of the descent phase. In the case of commercial flights, both points are computed by the FMS (Flight Management System) on board the aircraft. As new technological advancements, such as ADS-C (Automatic Dependent Surveillance – Contract), enable the direct downlink of TOC and TOD data, this new information will be presented to the air traffic controller.

The integration of the TOC display enhances controllers' ability to accurately estimate climb performance, which may result in a number of potential benefits. These include the possibility of earlier direct routings, reduced mileage, prompt clearances to requested flight levels (subject to traffic conditions), and continuous climbs to preferred flight levels instead of step climbs. This optimisation can also result in fuel saving. Furthermore, the display of TOD and optimal descent profile enables controllers to authorise a later descent initiation and facilitate the execution of optimal descent profiles. This enables aircraft to maintain cruising levels for a longer duration and perform more efficient descent profiles, thereby reducing the frequency of step descents (subject to traffic conditions) and also resulting in fuel savings. [7]

The majority of risk assessment frameworks necessitate an operational concept description (OCD) or scoping, which is not addressed in this example further than establishing the operational

environment of the function as the ADS-C data link service in en-route control. Although the example is based on TOC data, it should be noted that TOD would similarly result in the activation of a comparable mechanism. The outcome of hazard identification in this example is simplified and includes the following hazards:

- HZ-1: Detected corruption of TOC data.
- HZ-2: Undetected corruption of TOC data.
- HZ-3: Unacceptable delay of TOC data.
- HZ-4: Total loss of TOC data.

Although other hazards do exist for this application, further analysis treats HZ-3 as HZ-1. Similarly, HZ-4, which is barely noticeable and eventually leads to HZ-1, is treated as such. The analysis of human factors (HF) is a mandatory requirement of IEC 61508, as well as ED-153 and 373. However, in this instance, the HF analysis has not been conducted. Nevertheless, it should be noted that HF aspects cannot be overlooked and must be included in the Safety Case, as required by 373.

3.2 Risk Assessment Based on ED-153 and ED-109A

ED-153 [1] adopts a methodology of assigning Software Assurance Levels (SWALs) to software, delineating a series of objectives to guide the software lifecycle process. SWALs are not intended to replace Safety Requirements; rather, they offer a derived Software Safety Requirement stemming from the risk assessment and mitigation procedures. The criteria for SWAL allocation hinge on the potential consequences of anomalous software behaviour as determined by the system safety assessment process.

While quantitative failure rate objectives for the combination of hardware and software may be established through the risk assessment and mitigation process, and these rates may be validated quantitatively or qualitatively, their achievement cannot be claimed solely through the application of a process. A specified SWAL does not justify a failure rate or reliability figure for the software.

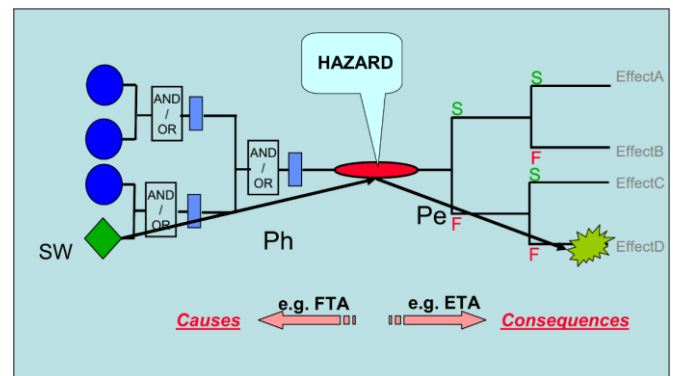


Fig. 2 Relationship between Software malfunction or failure, hazard and effects. [1]

ED-153 employs a bow-tie methodology, as depicted in Figure 2. Here, Ph represents the likelihood that when software malfunctions or fails, this malfunction or failure triggers a hazard. Ph is proportional to the capability of the remaining architectural elements to mitigate the software malfunction or failure. On the other hand, Pe signifies the likelihood that the hazard gives rise to an effect of a certain severity.

The SWAL allocation process in ED-153 considers only one likelihood, representing the Worst Credible Effect for each hazard, i.e., software behavior. Acknowledging the method's sensitivity to quantification requirements, ED-153 specifies an acceptable level of confidence but offers suggestions rather than precise quantifications, drawing on common sense, expert judgment, knowledge bases, lessons learned, incident reports, and equivalent field service experiences.

ED-153 also acknowledges the challenge of providing a failure rate for software. While it is acknowledged that software failures can occur and that a target failure rate objective may be established

for the hardware-software combination through the Risk Assessment and Mitigation process, it may only be feasible to claim the failure rate for the hardware-software combination with a certain level of accuracy.

The identification of failures is guided by the bow-tie approach outlined above. Potential failures are identified by considering various ways in which software may fail and by analysing the sequence of events leading to the failure occurrence. A list of single, consequential, and common modes of failure is compiled. ED-153 regards hazard identification as an outcome of the System Safety Assessment process, relying on EUROCONTROL's SAM (Safety Assessment Methodology) applicable at the time. External and internal mitigation measures are then considered. External mitigations influence the likelihood of a hazard contributing to or causing an end effect (right side of the bow-tie), while internal mitigations affect the likelihood of an event contributing to or causing a hazard (left side of the bow-tie).

The System Safety Assessment process established external and internal mitigations as outlined in Table 2. It should be noted that the P_e values introduced here are solely for analytical purposes regarding the risk assessment method. Internal mitigations for HZ-1 involve reducing the frequency of detected corruption (e.g., through system tests, verification, etc.), although these mitigations are not evaluated here.

Table 2: Risk mitigations in the existing system.

HZ	ID	Description
HZ-2	EMM1	Data is independent from other means of surveillance (e.g. primary and secondary radar), enabling HZ-2/EMM2 and HZ-2/EMM3.
	EMM2	Observation of human controller reveals undetected corruption of information, $P_e = 0.8$
	EMM3	Controller applies separation after Short Term Conflict Alert (STCA), $P_e = 0.9$,
	EMM4	On-board collision avoidance (ACAS/TCAS). <i>Not included in P_e as suggested by ED-125 [8].</i>

The severity of the hazard's effects varies depending on the effectiveness of the mitigation measures applied. These effects are classified into Severity Classes: Class 1 (e.g., mid-air collision), Class 2 (serious incidents such as significant loss of separation), Class 3 (major incidents such as a substantial reduction of separation with air traffic control (ATCO) or aircrew managing the situation), and Class 4 (significant incidents such as a notable increase in workload for aircrew and ATCO). To establish a Safety Objective for this hazard, either the severity of the Worst Credible Effect, considering risk mitigations, is determined, or P_e is evaluated for each hazard-effect pair, taking into account the effectiveness of risk mitigation. ED-153 recommends the former approach.

The severity of the Worst Credible Effect from HZ-2 would fall in Severity Class 1 as separation can be based on TOC data. The external mitigations are identified in Table 2 based on their likelihood of successfully mitigating a hazard (P_e). As these barriers are independent, this yields a probability of P_e^* for unsuccessful collision avoidance as $P_e^* = 0.2 \cdot 0.1 = 0.02$. $P_h = 1$ as no internal mitigations were identified. Consequently, the $P_e \times P_h$ value equals P_e^* , which corresponds to the "Possible" category in the SWAL allocation likelihood categories, as presented in Table 3. The TOC data presentation function would be allocated SWAL 2.

Table 3: SWAL allocation matrix. [1]

Effect Severity Class	1	2	3	4
Likelihood of generating such an effect ($P_e \times P_h$)				
Very Possible	SWAL1	SWAL2	SWAL3	SWAL4
Possible	SWAL2	SWAL3	SWAL3	SWAL4
Very Unlikely	SWAL3	SWAL3	SWAL4	SWAL4
Extremely Unlikely	SWAL4	SWAL4	SWAL4	SWAL4

Higher SWALs, represented by numerically lower values, impose more stringent requirements throughout the system life

cycle, thereby potentially imposing financial burden. Conversely, SWALs can be reduced by implementing mitigations within the system to decrease either the severity or the likelihood of the Worst Credible Effect, leading to a higher numerical value. Additional mitigation measures can be formulated for this purpose and outlined in Table 4. As additional risk mitigation measures are not part of the current system, these will have to turn into Safety Requirements for the software.

Table 4: Additional risk mitigation measures.

HZ	ID	Description
HZ-1	EMM1	Procedures are implemented to obtain TOC information from flight crew via voice communication or other means of communication.
	EMM2	Procedures are implemented to execute departure procedures without TOC data, as it is only a supplementary information.
	EMM3	Capacity reduction shall be applied in the affected airspace if the hazard persists.
	IMM1	Credibility of the information is assessed by the human controller.

Assessing the effectiveness of the new mitigation measures outlined in Table 4 would typically involve determining their P_e and P_h values. However, such assessment is omitted in this example. It is assumed, however, that the newly calculated P_e^* would result in a $P_e \times P_h$ falling into the "Very Unlikely" category, leading to a decrease in SWAL to SWAL 3. ED-153 mandates SWAL allocation process for all effects of a malfunction to ensure comprehensive coverage. Only the most stringent SWAL should be allocated as the final SWAL for the software.

In contrast, ED-109A [2] adopts a more developer-oriented approach, offering a detailed description of the software life cycle compared to the operator-oriented ED-153. ED-109A utilizes Assurance Levels (ALs), which are based on the contribution of software to potential failure conditions as determined by the system safety assessment process. AL does not imply the assignment of a failure rate to the software. Software reliability rates based on assurance levels cannot be used in the same manner as hardware failure rates.

ED-109A does not define failure condition categories but refers to applicable regulations and guidance material issued or recognized by the relevant authority. It provides a mapping between example failure categories and defined ALs, as software whose anomalous behaviour, as shown by the system safety assessment process, would cause or contribute to a failure of a CNS/ATM system function

- resulting in a catastrophic failure condition (AL1),
- resulting in a hazardous (AL2),
- resulting in a major (AL3),
- resulting in a minor (AL5),
- with no effect on aircraft operational capability or pilot workload (AL6).

Where AL4 is not associated with any failure condition category.

Based on this approach, the function would initially be categorized under AL3, based on their classification within Severity Class 3 of ED-153, including risk mitigations. However, ED-153 suggests an equivalence between different software safety standards, as depicted in Figure 3. According to this correspondence between assurance levels, software categorized under AL4 would be deemed partially compliant with SWAL3.

IEC 61508 [3] introduces a distinct method for safety requirement allocation, reflecting its broader scope compared to ED-153/ED-109A. While the latter documents focus solely on the software aspect of the Air Navigation Services (ANS) system (specifically the ground segment of ANS) and the Communication, Navigation, and Surveillance/Air Traffic Management (CNS/ATM) system, the scope of IEC 61508 encompasses all life cycle phases of E/E/PE systems utilized to perform safety functions. Safety functions are carried out by an E/E/PE system with the objective of

achieving or maintaining a safe state of the system with regard to a specific hazardous event. The process for the development of Safety Requirements is depicted in Figure 4.

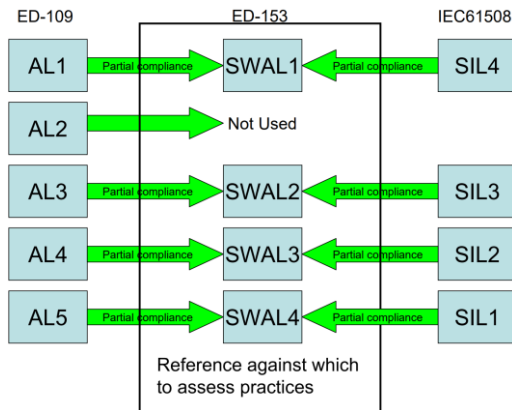


Fig. 3 Relationship between Software Safety Standards. [1]

3.3 Risk Assessment Based on IEC 61508

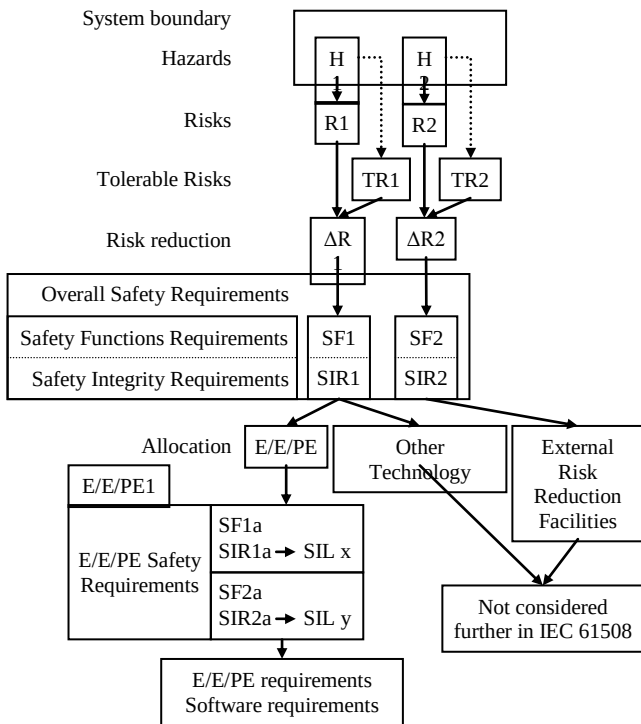


Fig. 4 Process of Safety Requirements Development [9]

To begin the process, a hazard and risk analysis must be carried out, including

- the event sequences leading to the hazardous events,
- the likelihood of the hazardous events,
- the consequences associated with the hazardous event,
- the risk of each hazardous event.

This is followed by the determination of the tolerable risk (TR) for each hazardous event and the measures taken to reduce or remove hazards and risks. This results in a set of all necessary safety functions, which constitutes the specification for the overall safety functions requirements. Then a target safety integrity requirement is to be determined in a way, that the tolerable risk is met for each overall safety function, which includes the determination of the target safety measures and the associated safety integrity levels. Safety integrity requirements can be specified in terms of either the risk reduction required to achieve the

tolerable risk, or the tolerable hazardous event rate so as to meet the tolerable risk.

The overall safety functions, as outlined in the specification for the overall safety requirements (both the overall safety functions requirements and the overall safety integrity requirements), are allocated through the designated E/E/PE safety-related systems and/or other risk reduction measures in order to meet the tolerable risk. IEC 61508 only concerns systems where compliance is at least partially achieved by an E/E/PE safety-related system. Each overall safety function, in conjunction with its associated overall safety integrity requirement, is to be allocated to one or more of the designated E/E/PE safety-related systems and/or other risk reduction measures, with the objective of achieving the tolerable risk for the safety function. This allocation is an iterative process. The decision to allocate a specific overall safety function across one or more E/E/PE safety-related systems or other risk reduction measures will depend on a number of factors, with the overall safety integrity requirement being of particular importance.

In this example, the separation process can be based on the TOC value presented to the controller. Therefore, providing the correct TOC data is considered a safety-related function. IEC 61508 distinguishes between three modes of operation. In the low demand mode, the safety function is only activated upon request, which occurs no more than once per year, without affecting the system otherwise. High demand mode is defined by demands occurring more than once per year. In continuous mode, the safety function is responsible for maintaining safe state as part of normal operation. Based on these definitions, the example function falls under the high demand mode of operation.

Table 5: Specification of Risk Classification Scheme.

Severity Class	Safety Target (/ flight hour)	Safety Target (/ year), traffic 50.000 hours/year
SC ₁ (Accidents)	1E-08	0,0005 (once each 2.000 years)
SC ₂ (Serious Incidents)	1E-05	0,05 (once each 20 years)
SC ₃ (Major Incidents)	1E-04	0,5 (once each 2 years)
SC ₄ (Significant Incidents)	1E-02	50 (50 times per year)
SC ₅ (No immediate effect on safety)	n/a	n/a

Table 6: Target failure measures for a safety function operating in high demand mode or continuous mode of operation.

Safety integrity level (SIL)	Average frequency of a dangerous failure of the safety function [h ⁻¹]
4	$\geq 10^{-9}$ to $< 10^{-8}$
3	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-6}$ to $< 10^{-5}$

The exact method of risk analysis is at the discretion of the user. Hence, for this example, the risk analysis based on ED-153 will be considered. The tolerable risk can be addressed using ED-125 (Process for Specifying Risk Classification Scheme and Deriving Safety Objectives in ATM), which aims to establish industry-wide safety risk levels based on the ESARRs (EUROCONTROL Safety Regulatory Requirement) formerly applicable. Table 5 presents the safety targets for this example. It is important to note that these values represent suggested national regulatory safety targets; values for ATM service providers may differ due to what is termed an ambition factor. These values can then be multiplied by the annual flight hours to calculate the occurrences per flight hour. According to the recommendations in ED-125, if an ATM provider's traffic volume is less than 50,000 controlled hours per year, this value should be used for the conversion. Table 6 presents the SIL values based on the frequency of failure.

Table 7 illustrates the SIL allocation. The Severity of HZ-1 is SC₃, which leads below SIL 1, requiring no SIL. However, the severity of HZ-2 in itself would be SC₁, as separation can be based

on TOC data. IEC 61508 allow the consideration of already existing risk mitigations in the system. This means, that according to Table 2, the SIL to be allocated on the new system can be lowered as $1E-08 / 0.02 = 5E-07$, which is only SIL 2. SIL can be further lowered by allocating part of the safety target to external risk mitigation. Since SIL is assigned to Safety Functions, so if from all the functions of the system only a few get higher SILs, then those are often partitioned to a separate system. Note that the values numerically are reversed compared to SWAL and AL.

Table 7: Deriving Safety Functions and Safety Integrity Levels

HZ	Sev.	ST (pfh)	Safety Requirement	Safety Function	SIL
HZ-1	SC3	1E-04	The frequency of the detected corruption of TOC data shall be no greater than 1E-04 pfh.	Procedures are implemented to obtain TOC information from flight crew via voice communication or other means of communication.	No SIL
				Procedures are implemented to execute departure procedures without TOC data, as it is only a supplementary information.	No SIL
				Capacity reduction shall be applied in the affected airspace if the hazard persists.	No SIL
				Credibility of the information is assessed by the human controller.	No SIL
HZ-2	SC3	5E-07	The frequency of undetected corruption of TOC shall be no greater than 5E-07 pfh.	Data is independent from other means of surveillance (e.g. primary and secondary radar).	2

3.4. Risk Assessment Based on EU 2017/373

The implementation of ADS-C technology and the provision of TOC data to the controller represent changes to the current functional system. Consequently, EU 2017/373 [4] applies to all EU member states.

The steps of a safety assessment (development of the safety case) are prescribed by ATS.OR.205 as follows:

- definition of scope,
- identification of hazards,
- determination and justification of the safety criteria applicable to the change,
- risk analysis of the effects related to the change,
- risk evaluation, and if required, risk mitigation for the change such that it can meet the applicable safety criteria,
- verification that the assessment corresponds to the scope of the change and that the change meets the safety criteria,
- specification of the monitoring criteria necessary to demonstrate that the service delivered by the changed functional system will continue to meet the safety criteria.

GM1 ATS.OR.205(b)(1) provides a framework for hazard identification, outlining various potential sources of hazards and methods for their identification. These methods include functional analysis, what-if techniques, brainstorming sessions, expert judgment, and literature searches (e.g., accident and incident reports).

The concept of safety criteria is analogous to that of tolerable risk in IEC 61508, which may be regarded as a risk acceptance criterion. The distinction lies in the fact that TR is predominantly

expressed in numerical form. According to ATS.OR.205(b)(2), safety criteria may be represented entirely by safety risks or by other measures, which, according to AMC1 ATS.OR.210(a), are:

- proxies,
- recognized standards and/or codes of practice,
- the safety performance of the existing functional system or a similar system elsewhere.

According to GM1 ATS.OR.210(a), a proxy is a measure of a certain property along the causal trajectory between the hazard/event and the harmful effects of the hazard/event in question.

AMC2 ATS.OR.210(a) prescribes the conditions under which safety risk proxies may be used as safety criteria:

- There must be a justifiable causal relationship between the proxy and the harmful effect. For example, if a proxy increases or decreases, this must result in an increase or decrease in risk,
- the proxy must be sufficiently isolated from other proxies to be treated independently,
- the proxy must be measurable, either quantitatively or qualitatively, to an adequate degree of certainty.

According to 373, risk analysis can be conducted in terms of risks or in terms of proxies. Safety criteria may be expressed in terms of proxies at the level of the hazard, or the mitigations between the hazard and the accidents, or the incidents that might occur from the success of the risk reduction measure. In contrast, safety criteria can be expressed in terms of risk at the level of accidents or harmful effects occurring from accidents. The default safety strategy is the "as safe as before" (also known as GAME/GAMAB), which is required by ATS.OR.210(c)(2) in most cases. This clause also supports improvements to safety whenever reasonably practicable, provided that the change clearly aims for safety improvement. However, a reduction in safety can also be exceptionally allowed, either on a temporary or permanent basis.

The methodology employed in risk analysis differs according to whether the analysis is conducted in terms of risk or in terms of proxies. As the example risk analysis is conducted in terms of risk, the objective is to identify the harmful effects of the identified hazards, followed by the classification of the severity of the harmful effects and the evaluation of the risk contributions of all hazards, as shown in Table 8.

Table 8: Deriving Safety Functions and Safety Integrity Levels

HZ	Barriers	Effect	Severity
HZ-1	Procedures for control without TOC	Workload increase	C
	Capacity reduction in affected airspace		
	Controller applies separation upon STCA		
HZ-2	Controller applies separation upon STCA	Separation minima infringement (Harmful effect)	B
	On-board collision avoidance (ACAS/TCAS)		

In the event of detected corruption, the data can be disregarded, as the controller must be able to provide separation without this supplementary information. In contrast, in the case of undetected corruption, the data cannot be disregarded, and separation might be based on corrupted data, which means that the harmful effect cannot be dismissed. The classification of the severity of the harmful effect is not standardised by 373, but is preferably based on accident and incident classification schemes to enable linkage between databases. Such a classification scheme is used by EUROCONTROL's RAT (Risk Assessment Tool) [10] for ATM-specific occurrences, as follows:

- AA: total inability to provide safe ATM services,
- A: serious inability to provide safe ATM services,
- B: partial inability to provide safe ATM services,
- C: ability to provide safe but degraded services,
- E: no effect on ATM services,

• D: not determined.

Based on this classification, the detected corruption of TOC data is in severity class C, while undetected corruption is in severity class B. Since undetected corruption of TOC data has been identified to have a harmful effect, risk mitigation measures are established in Table 4 to fulfil the Safety Criteria. The Safety Criteria can be defined as a proxy, e.g. the frequency of STCA occurrences from separation based on TOC shall be no greater than 0.5 per year. Note that this value is based on Table 5.

4. Discussion

The ED-153 standard has remained unchanged since 2009. At that time, it was consistent with the then-applicable regulations (such as 1035/2011 and 482/2008) and requirements (e.g. ESARRs). The 2017/373 standard introduced a change in the way consequences of hazards are assessed, as shown in Figures 6 and 7. In the traditional sense, severity classes are no longer assessed; only the harmful effect is determined. However, ED-153 remains recommended by 373 (in GM4 to AMC4 ATS.OR.205(a)(2)). In order to utilise ED-153 (or any of the safety standards discussed in this paper), a mapping between severity classes and harmful effects is required. Such a mapping is not necessarily straightforward and is not provided in a standardised form, which compromises the underlying idea of SWAL (and AL and possibly SIL). This results in the loss of the standardised, industry-wide meaning and the need for locally defined mapping.

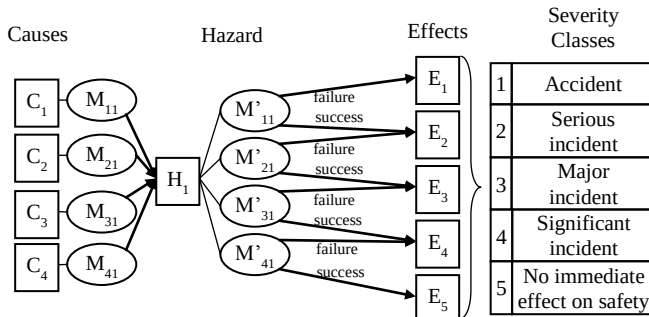


Fig. 6 Former bow-tie approach (based on 1035/2011)

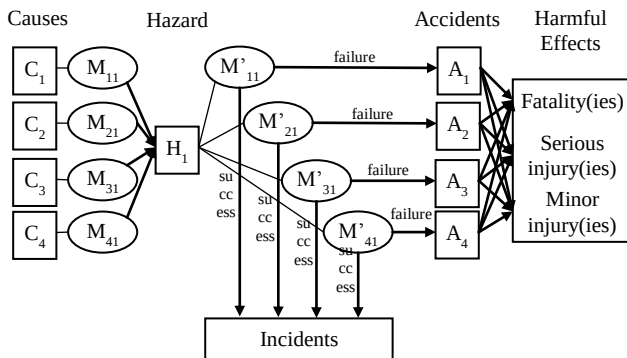


Fig. 7 Current bow-tie approach (based on 2017/373)

A notable difference is in the way the various standards and regulations interpret the term "likelihood." For example, in both EU 2017/373 and ED-153, likelihood refers to the failure generating the effect, not the failure occurring. This allows for the consideration of risk mitigation measures in this likelihood. In contrast, IEC 61508 requires the determination of the likelihood of hazardous events. This implies that the likelihood on the right side of the bow-tie is no longer the focus of attention, and that the likelihood of the left side of the bow-tie is now the subject of discussion.

The disparity between SIL, SWAL and AL makes it challenging to assess the relative merits of these standards. These levels typically indicate a high level of rigour in the life cycle processes. ED-109A permits greater flexibility in the allocation of AL between the user of the standard and the oversight authority, with only

recommendations provided. The assignment of AL to a software component is based on the severity of the failure condition, as ED-109A acknowledges that the likelihood of the software containing an error cannot be quantified in the same way as for random hardware failures. This allows the use of a risk matrix (e.g. the one provided by ED-125) to establish a Safety Target (occurrences per flight hour) for risk severities and thus form safety requirements. Furthermore, SWAL considers the likelihood of the hazard generating the worst credible effect. Both AL and SWAL extend to the software life cycle. SWAL does so by considering the confidence in fulfilling the safety requirements, while AL does so by considering the variations of the life cycle contained in ED-109A.

SIL is assigned to potentially abstract safety functions, and only becomes assigned to software when a certain safety function is covered by software. This allows the standard to be more universally applicable and to form the basis of industry-specific standards. SWAL is assigned to software components, which means it is lacking hardware coverage, similar to AL. This leaves the ATM industry without a safety standard of hardware scope. It is presumed that the rationale behind this is that it is not anticipated that hardware failure will result in any malfunction other than complete hardware failure. Furthermore, hardware malfunctions, such as faulty calculations, are not addressed. The rationale behind this can be found in the operational characteristics of the ATM industry, as outlined in [11]. In accordance with the principles of IEC 61508, functional safety is contingent upon the behaviour of the system, which has the potential to precipitate an accident. For instance, if an aircraft fails to respond to pilot input in accordance with expectations, an accident may ensue. In contrast, in ATC, the stream of bits cannot directly cause an accident, as the agents behind the operation are humans. For instance, in the event of a complete loss of functionality in an operational display, procedures are still in place to ensure the safe emptying of the airspace via voice communication alone. The safety of ATC does not derive from the effect of the bits traversing, but rather from the meaning of the bits and the information conveyed to the human operators. This means that ATM industry safety standards currently can rely on the human operator, however this contradicts with the aim of creating technical systems, which is to alleviate the human responsibility. This implies that in the future, as automation levels in ATC increase and the possibility of automatic control arises, a more IEC 61508-like approach may become necessary.

4. References

1. European Organisation for Civil Aviation Equipment (EUROCAE). "ED-153: Guidelines for ANS Software Safety Assurance." EUROCAE, (2009).
2. European Organisation for Civil Aviation Equipment (EUROCAE). "ED-109A: Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems." EUROCAE, (2013).
3. International Electrotechnical Commission. "IEC 61508: Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems." 2nd ed., International Electrotechnical Commission, (2010).
4. "Commission Implementing Regulation (EU) 2017/373." March 8, 2017. OJ L 62, 8.3.2017, p. 1–62
5. "Commission Implementing Regulation (EU) No 1035/2011." October 17, 2011. OJ L 271, 18.10.2011, p. 23–41
6. "Commission Implementing Regulation (EU) No 482/2008." June 3, 2008. OJ L 143, 31.5.2008, p. 5–10
7. EUROCONTROL. "Automatic Dependent Surveillance-Contract (ADS-C) operational at MUAC." (2023).
8. European Organisation for Civil Aviation Equipment (EUROCAE). "ED-125: Process for Specifying Risk Classification Scheme and Deriving Safety Objectives in ATM." EUROCAE, 2010.
9. Brown, Simon. "Overview of IEC 61508 Design of electrical/electronic/programmable electronic safety-related systems." *Computing and Control Engineering Journal* 11.1 (2000): 6–12.
10. European Aviation Safety Agency. "Annex to ED Decision 2014/035/R." European Aviation Safety Agency, (2014).
11. Ladkin, Peter Bernard. "Comparing software safety standards EUROCAE-ED-153 and IEC 61508." 11th International Conference on System Safety and Cyber-Security (SSCS 2016). IET, (2016).

Ecological audits and green office in road transport company

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Abstract: At the beginning of the third millennium, environmental audit acquired new importance, especially for the sustainable development of business activities, including transport companies. The triple planetary crisis refers to the three main interlinked issues that humanity currently faces: climate change, pollution, and biodiversity loss. The research pays special attention to the development of the “green office” concept in the sustainable development of a transport company. The goal of the research is the inclusion in the environmental audit of economic indicators of a transport company that affect the country’s CO₂ emissions. The subject of the research is environmental audit indicators. Based on a method of partial least squares structural equation modeling (PLS-SEM) approach additional criteria for the environmental audit of company are evaluated.

Keywords: ECOLOGICAL AUDITS, TRANSPORT COMPANY, GREEN OFFICE

1. Introduction

The 17 UN sustainable development goals [1] announced in 2015 presented a challenge to the global economy. Solving the problem of reducing carbonization requires a new rethinking of solving economic problems and searching for tools for their implementation. The EU adopts the document “A Sustainable Europe by 2030”, in which it sets ambitious goals for the implementation of environmental policy: the increase in CO₂ emissions by 2030 should reach no more than 1.5% compared to the post-industrial period, and by 2050, the formation of a climate-neutral society [2]. To achieve the stated goals, it is necessary to identify the causes and factors influencing the speed of implementation of policy documents of the UN, EU, etc., and, in general, environmental policies in states. However, the achievement of these goals is impossible, according to the author’s opinion, without the involvement of the business environment. The adoption of regulatory documents and development directions without the involvement of areas of entrepreneurial activity will not have a positive result. One of the tools for regulating CO₂ emissions into the atmosphere is environmental auditing in transport companies [3]. Taking into account the company’s vehicles, driving range will affect CO₂ emissions into the atmosphere; however, another important area for reducing emissions into the atmosphere is the introduction of a company environmental audit system and the concept of a green office.

2. Green office concept in environmental audit

Many scientists, even before the pandemic, assumed reducing working hours, for example, in the form of a four-day working week. It is presented as a means to help solve current and upcoming global problems. In Germany, the largest trade union, IG Metall, is currently suggesting to its members to introduce a four-day week to limit job cuts due to the Covid-19 pandemic [4,5].

The carried-out analysis of macroeconomic indicators by the Organization for Economic Cooperation and Development (OECD) showed that reducing employee working hours by 25% will lead to a reduction in individual CO₂ emissions by an average of 36.6% [6]. However, as a similar analysis of EU-15 countries between 1970 and 2010 shows, this correlation is not the same for all countries but rather depends on the interaction of working hours and income levels and how newly generated income is used in free time [8]. However, in the deep conviction of the author, not all countries in the near future, for economic reasons, can afford the transition to a four-day working week in the country. This is a burden on the employer and possibly on the fiscal policy of the entire country as a whole. Considering the postulate that the sustainable development of a country depends on the interaction of three factors: Planet, people, and profit [9], profit, as the basis of business for people, the country, and the planet as a whole, is very important in this trinity.

To achieve the goal set by the author, we suggests including in the environmental audit of the company a transition to 4 days of work in the office and one day of work from home, or *green office 4/1*.

This will provide benefits over the course of a year in reducing CO₂ emissions associated with the use of transport to work. However, another result is also important: the formation of environmental consciousness of employees as a whole. Concentration on the environmental problems of the company will generally influence the environmental consciousness of employees and manifest itself as a chain reaction in other areas of their lives: green energy, green food, etc.

At the World Economic Forum in Davos in 2023, eight directions were formulated to reduce carbonization in the business environment: Integrate sustainability into the core business strategy, Address energy use and associated financial barriers, Leverage technology and implement advanced sustainability data management systems, Track emissions across the supply chain, Stay informed on regulations and adapt, Avoid greenwashing, Develop skilled professionals to drive sustainability transformations, Get buy-in from stakeholders and staff [10].

The thesis “Track emissions across the supply chain” in transport companies is implemented on the basis of environmental audit and employee involvement, through the formation of a green office concept or supporting employees to work remotely for one day.

The authors point out as the advantages of a green office not only a reduction in atmospheric emissions, but also a reduction in food delivery costs, a reduction in plastic, a reduction in energy costs. However, according to the author, reducing delivery costs, correspondingly, reducing CO₂ emissions into the atmosphere and using plastic as a lunch box is a controversial thesis. An employee working from home can also order food delivery at home in plastic boxes. This is unlikely to affect the reduction in carbonation.

Therefore, the author, as an inclusion in the environmental audit indicators of a transport company, suggests including a reduction in air emissions from the travel of office employees or the possibility of working one day a week online or in a *green office (4/1)*.

3. Road freight transport in Latvia

Thus, in Latvia, the following number of employees engaged in road freight transport is registered (table 1)

Table 1. Freight transport by road: number of employees from 2018 to 2023 [11]

Type of company	2018	2019	2020	2021	2022
2–9 employees	6388	6116	5577	5319	5502
10–19 employees	4787	4339	4723	5150	4774
20–49 employees	6296	6184	6501	6678	6177
50–249 employees	5271	5715	5517	5049	4849
250 and more employees	3559	3396	2964	3687	3833
Total	26301	25750	25282	25883	25135

As we can see from the data presented in the table, the bulk of the employees in road freight transport are small and medium-sized businesses. Thus, in 2022, 16 453 employees worked for micro and small businesses, 4849 for medium-sized businesses, and 3833 employees for large businesses.

Considering the goal of our research, the author suggests analyzing freight transport by road in the period from 2018 to 2023 (figure 2) [11].

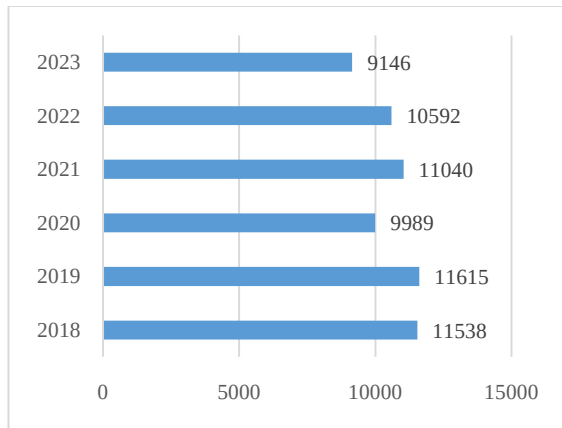


Figure 1. Analysis of Latvian road freight transport in million tons, developed by the author.

As we can see in figure 2, Latvian carriers has been a decrease. In author opinion this is due to both the pandemic and the geopolitical situation in Europe.

An interesting trend, in the author's opinion, is the declining trend in Latvia in reducing the number of hours of work remotely. The author presents a comparative analysis of the remote work time of employees employed in the transport industry, and on average, in the country's economy, Figure 2 [11].

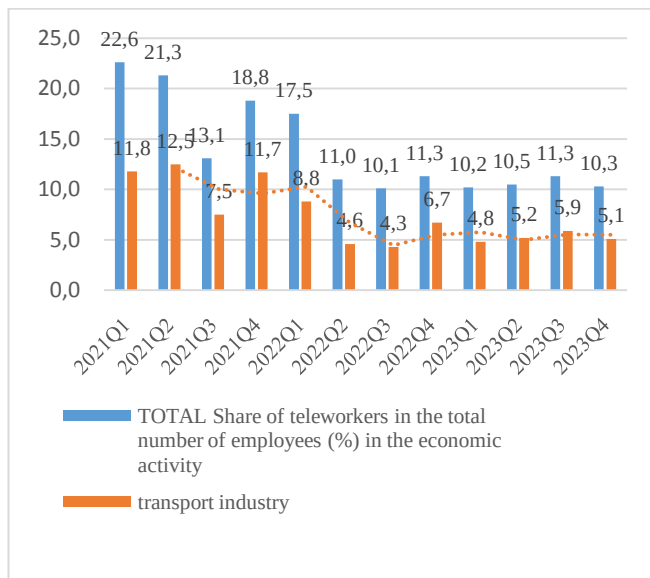


Figure 2. A comparative analysis of the number of hours of remote work in general in the Latvian economy and the transport industry, in %, developed by the author.

The graph shows that in 2023, on average, those employed in the labor market worked between 10% (1 quarter 2023) and 11% (3 quarter 2023), while the transport industry uses only half of the opportunities to work remotely: about 5.0%.

Thus, according to the author's opinion, there is a potential in the transport industry to increase the working time of office employees remotely. This means there is potential to reduce carbonization in the country. Considering the impact of the transport industry on climate change and air pollution, the transport industry should be

interested in carrying out activities and inclusion in the environmental audit *green office indicator: 4/1*.

The amount of CO₂ emissions into the atmosphere of Latvia is presented by the author in figure 3.

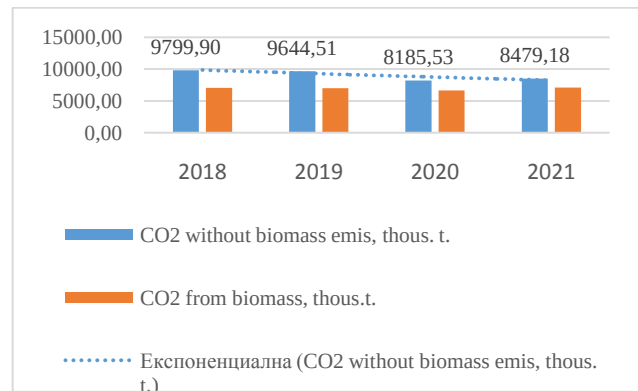


Figure 3. Air pollution in Latvia: CO₂ from and without biomass, developed by the author

In the figure, the author displayed the volume of CO₂ emissions in the air, both from and without biomass (transport industry).

As we see in Latvia during the period under study, there is a trend towards a decrease in CO₂, and it is worth noting that the number of "green investments" aimed at improving the environment has also increased.

In the presented research, the author suggests assessing the relationship between the number of employees of transport companies working online and the number of transported goods based on a partial least square's structural equation modeling (PLS-SEM) approach.

4. Research methodology

To assess the empirical relationship between latent variables, the authors use the PLS-SEM method. This method was suggested by [12]. The evaluation method is based on the consistent use of orthogonalization and PLS-regression, and according to a number of scientists [13,14,15] has the following advantages, such as: conditions related to the object under study, volume, correlation, and normal distribution. This method processes a small amount of data, which increases statistical power. PLS-SEM tests complex theories using empirical data [16], which indicates that an important characteristic of PLS-SEM is that it provides latent variable scores as specific linear combinations of their manifestations. Schubring and others [16] show that the success of PLS is due to its ability to estimate the parameter of complex models without many of the distributional and other limitations of traditional econometric models. PLS-SEM has become a common statistical method in many scientific fields [13, 14].

In the first procedure, latent variables are determined by the manifest indicators:

$$Y_i = \sum_{h=1}^p (w_{jh} * x_{jh}) \quad (1)$$

The following equation illustrates a measurement model using composite indicators, where Y is a linear combination of indicators x_j , each of which has a weight of w_j .

In the second stage, each latent variable was estimated by other latent variables using the following formula:

$$Z(j) = \sum_{i=j}^p (e_{ij} * y_i) \quad (2)$$

$$\text{Where } e_{ij} = \text{sign cor}(y_i y_j) \quad w_{yh} = \text{cor}(Z_j, x_{jh})$$

Then, we perform the previous steps until the algorithm converges. Finally, we have determined coefficients from least squares regression.

The structural model was then assessed as reliable and valid. An R^2 estimate is required for each endogenous latent variable. Pages J. and Tenenhaus M. [15] define R^2 as:

$$R^2 = \sum_{k=0}^n a_j * \text{correl} (Y_j x_j) \quad (3)$$

A higher indicator of R^2 indicates a higher degree of prediction accuracy [16,17].

Results and discussion

To achieve the goal, the authors put forward the following hypotheses:

H1: The number of transport industry employees working online affects the volume of goods transported.

H1: The amount of goods transported affects CO2 level.

The calculation data is presented in tables №2- №4.

Table 2. Assessment results of the measurement model in Latvia.

Latent variable	Indicator	Loading	CR	AVE
On line hours	Remote employees, %	-0.583	- 0.814	- 0.787
Freight volume	Freight traffic by road, ml.t-km	-0.656	0.043	0.043
CO2	Air pollution	0,546	0.834	0.773

Table 3. Discriminant validity assessment

Fornell-Larcker Criterion			
	On line hours	Freight volume	CO2
On line hours	0.298		
Freight volume	-0.123	1.000	0.639
CO2	0.191	0.697	1.000
Heterotrait-Monotrait Ratio (HTMT)			
	On line hours	Freight Volume	
On line hours	0.231		
Freight volume	-0.148	1.000	0.782
CO2	0.223	0.703	1.000

Table 4. Structural relationships and hypotheses testing

Hypotheses	Path coeff.	Stan. Error	T-Statistic	P-Value	Result
On line hours and Freight volume	- 0.423	0.0995	3.635	0.072	Not Supported (H1)
CO2	0.748	0.0995	3.114	0.002	Supported (H2)

Thus, hypothesis H1 is rejected, which means that the number of hours worked online by transport industry employees doesn't affect the volume of freight transportation.

However, the hypothesis H2 is fully confirmed, since calculations show that the volume of freight traffic in ton-kilometers affects CO2 emissions, which is quite natural.

5. Conclusions.

The results obtained are a powerful argument for the management of transport companies, since, as we said earlier, sustainable development is the interaction of three Ps. The calculations obtained by the author prove that

the transport business is not affected by the employee's place of work, whether it is an office or a remote mode (home).

This means that to conduct an environmental audit of a transport company, you can enter the green office 4/1 indicator: counting the number of hours of work that a company employee worked remotely.

6. References

- [1]. The Sustainable Development Goals, <https://unstats.un.org/sdgs/report/2023/>
- [2]. European Commission, A Sustainable Europe by 2030, https://commission.europa.eu/publications/sustainable-europe-2030_en
- [3]. Inna Stecenko, Galina Reshina, Anna Stecenko, Promotion of Environmental Audit for Transport Companies in Latvia, International Conference on Reliability and Statistics in Transportation and Communication, 2021, Riga Pages 546-555, Publisher Springer, Cham, Scopus
- [4]. Edmond, C. (2020). Germany Eyes a Four-Day Week to Help Prevent Mass Layoffs. World Economic Forum. https://www.weforum.org/agenda/2020/08/germany-four-day-week-industry-covid-19/?fbclid=IwAR3nw99Tj70vybWuNKOi_aAuU6l0JXf7zZKXhOsCWlr_7mDEK-ttNkrftw
- [5]. Gilchrist, K. (2020). Finland's New 34-Year-Old Prime Minister Wants Her Citizens on a Four-Day Workweek. CNBC <https://www.cnbc.com/2020/01/07/flexible-work-finlands-pm-sanna-marin-wants-citizens-on-a-four-day-workweek.html>
- [6]. Knight, K. W., Rosa, E. A., & Schor, J. B. (2013). Could working less reduce pressures on the environment? A cross-national panel analysis of OECD countries, 1970–2007. *Global Environmental Change*, 23(4), 691-700.
- [7]. Shao, Q., & Shen, S. (2017). When reduced working time harms the environment: a panel threshold analysis for EU-15, 1970–2010. *Journal of cleaner production*, 147, 319-329.
- [8]. John Elkington (1999) The triple bottom line: *Cannibals with forks: the triple bottom line of 21st century business*. Oxford: Capstone
- [9]. Sayam Aroonsrimorakot, Meena Laiphrakpam, Chamlong Arunlertaree, Chonticha Korattana Green office, its features and importance for sustainable environmental management: A comparative review in search for similarities and differences, 2019, Interdisciplinary Research Review, p. 31-38 DOI: [10.14456/jtir.2019.46](https://doi.org/10.14456/jtir.2019.46)
- [10]. Daniel Schmid, Sustainable Development Impact Meetings , 2023 https://www.weforum.org/agenda/2023/09/8-steps-towards-achieving-net-zero-in-your-organization/?gad_source=1&gclid=CjwKCAjwr7ayBhAPEiwA6EIGxAKjtQoVCFiqZWgG8F0RcbDMp7pFhQfPrdXwDVApk3Z5v0aSW8YlVxoCfAIQAvD_BwE
- [11]. Central Statistical Bureau of Latvia https://data.stat.gov.lv/pxweb/en/OSP_PUB/
- [12]. Wold, H. (1982). Soft modeling: the basic design and some extensions. In K.G. Jöreskog & H. Wold (Eds.) *Systems under indirect observations: Causality, structure, prediction. Part 2*, Amsterdam, North-Holland, pp.1-54.
- [13]. Becker, Jan-Michael, Arun Rai, Christian M. Ringle, and Franziska Völckner. (2013). "Discovering Unobserved Heterogeneity in Structural Equation Models to Avert Validity Threats." *MIS Quarterly* 37, 665–94
- [14]. Hair, Joe F., Marko Sarstedt, Christian M. Ringle, and Jeannette A. Mena. 2012. "An Assessment of the Use of Partial Least Squares Structural Equation Modeling in Marketing Research." *Journal of the Academy of Marketing Science* 40, 414–33
- [15]. Pages, Jérôme, and Michel Tenenhaus. 2001. "Multiple Factor Analysis Combined with PLS Path Modelling. Application to the Analysis of Relationships between Physicochemical Variables, Sensory Profiles and Hedonic Judgements." *Chemometrics and Intelligent Laboratory Systems* 58, 261–73.
- [16]. Schubring Sandra, Iris Lorscheid, Matthias Meyer, and Christian M. Ringle. 2016. "The PLS Agent: Predictive Modeling with PLS-SEM and Agent-Based Simulation." *Journal of Business Research* 69, 4604–12.
- [17]. Sarstedt, Marko, Christian M Ringle, Donna Smith, Russell Reams, and Joseph F Hair. 2014. "Journal of Family Business Strategy Partial Least Squares Structural Equation Modeling (PLS-SEM): A Useful Tool for Family Business Researchers." *Journal of Family Business Strategy* 5, 105–15.

Improvement of environmental and economic indicators in marine vehicles using various fuel additives

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Abstract: The paper will discuss and analyze the values of ecological and efficient indicators of standard fuels used in marine vehicles, and their negative impact on the surrounding environment. Reasons for the deterioration of environmental indicators, considering the processes that occur in the engine and the properties of the fuel. The paper also discusses environmental and economic indicators by using various fuel additives. Marine internal combustion engines' most important operational characteristics are reliability, fuel efficiency and environment safety indicators, which depend on complex design and operational factors. One of the most important factors is the quality of diesel fuel. The physical and chemical properties of fuel affect the mixture formation and combustion processes in diesel cylinders, the completeness of the combustion of the fuel mixture, fuel efficiency, the content of harmful substances in engine exhaust gases, fuel supply equipment and cylinder parts - (piston group) and others. The most common way to ensure diesel fuel's required properties is to bring multifunctional additives into practice. An overview of the most modern diesel fuel additives will be presented based on the results of the patent search, which ensures improved formation of the mixture and complete combustion of fuel. The article will also present information about the chemical composition of additives and the effectiveness of their mechanism of action. Dependence on ignitability and structure of air-fuel mixture is described in the paper. Foreign manufacturers of diesel fuel additives are indicated. Tests conducted on four-stroke high-speed diesel engines made it possible to determine that the use of an additive ("Nagro Boost") provides a reduction in effective fuel consumption by 3-7% and does not increase harmful effects in the exhaust gases of internal combustion engines when the engine operates with load and screw characteristics. A conclusion is made about the perspectives of using these and other additives to increase the fuel efficiency and environmental friendliness of internal combustion engines.

KEYWORDS: INTERNAL COMBUSTION ENGINES, DIESEL FUEL, ADDITIVES, COMBUSTION ACTIVATORS, FUEL CONSUMPTION, COMBUSTION PROCESS.

1. Introduction

The growing trend of caring for the environment has spread to all areas of life. Changes are constantly happening in the transportation industry. More and more hybrid engines are being produced and a new grade of biofuels and alternative energy are being developed. More efficient engines and new, stricter environmental fuel standards have become commonplace. Compliance with these standards can not always be achieved only by engineering solutions, as some properties can be improved by using various additives.

How can we improve fuel ecological characteristics?

First of all, it is necessary to improve the environmental characteristics of the fuel during the production process. Moreover, care for the environment is expressed not only in the quality of fuel but also in the preservation of energy resources and the long life of equipment. For example, using depressant additives for petroleum and fuel oil allows saving energy during their subsequent change. It also prevents corrosion and protects equipment, ensuring safety in the enterprise. Neutralizing agents extend the service life of equipment in the oil industry, reduce corrosion of internal parts and allow for less scheduled maintenance.

-What kind of additives help to improve the ecological characteristics of vehicles?

Generally, all additives can improve some properties of the fuel. Modern fuel systems require using of high-quality fuel, they are sensitive, and the formation of soot and deposits in them is unacceptable. Detergent additives effectively solve this problem, as a result, the completeness of fuel combustion increases and the toxicity of emissions into the atmosphere decreases. A similar effect can be achieved in fuel industries, but few enterprises can afford expensive technologies to improve product properties. The additives can be added directly to petroleum products at storage or service stations. In many cases, additives are not enough - to produce fuel that meets Euro standards (4-5), it is necessary to improve many parameters. The content of aromatic hydrocarbons like benzene, sulfur and others is regulated in the fuel. There are various complex additives whose effect is aimed at immediate improvement of several fuel parameters. In general, the effectiveness of additives in

any case improves the final performance of the fuel, which also affects the environment [1].

2. Main part

- What is the issue with diesel fuel?

The multifunctional properties of diesel fuel should be improved. By providing cetane booster additives, the fuel meets the Euro standard. They increase the completeness of combustion, make it easier to start the engine in winter conditions and reduce the smokiness of exhaust gases. Stop-smoke additives help restore lubricity. Petroleum fuels can also meet the requirements and be improved with the help of additives: for marine fuels. There are environmental requirements and standards for sulfur content. Nowadays liquefied gas is widely distributed, which is useful economically and environmentally. The question is asked in general, how does this trend develop for improving the environmental characteristics of fuel? More and more attention paid to this, and it is indeed time to finally think that the planet's resources must not be used only, but also be protected. A resource is not only a raw material but an environment suitable for all life because it is also diminishing. Where we can improve the situation and prevent further pollution, we must and there is every opportunity to do so, all stakeholders in the fuel and energy sector must be involved - engine manufacturers, fuel equipment manufacturers, developers, petrol stations, government and regulations [2].

On the other hand, additives are widely used and it is already impossible to produce high-quality fuel without them. What can be done to improve the situation? -To offer the market high quality and the latest products. For instance, the Difron line of additives is a great example of how to show care for the environment in an enterprise. Additives should be made by competent personnel, only on modern equipment. A high level of industrial safety also ensures greater environmental friendliness; product formulations are constantly changing to meet new environmental requirements. Using specific raw materials and energy as effectively as possible is a step towards ecology. Now it can be said that the economy and ecology are developing with the production of petroleum products.

Only environmentally friendly fuel will meet the accepted standards, and the higher its quality, the easier it will be to improve environmental indicators.

The paper deals with the issues of improving the ecological characteristics of marine diesel engines using different fuel additives. The work was carried out based on the base of the results of experimental studies of diesel using domestic and imported additives.

Due to the increasing rate of shipping and further pollution of the seas and atmosphere by ship emissions, environmental protection has become important. Therefore, the most widely used stop-smoke additives increase the combustion efficiency and reduce the soot in the exhaust gases. Some additives do not change the power and economical operation of diesel engines and do not cause wear of fuel system parts.

The additives used were ADX-3S50, ADX-3S80 (manufacturer LÜBPJZOL, UK) and PARAD YNE 668 (manufacturer Infinium, USA), POD oil purified according to TU 2433-016-00205311-99 "CuJibyshevov". The analysis of the test results of three SMT samples shows that the amount of harmful substances in the exhaust, especially soot, is significantly reduced.

Air pollutant emissions from vehicles are increasing by an average of 5.5% annually. As a result, the annual environmental damage from the operation of the transportation complex is more than 10.5 billion dollars, and this amount is increasing every year.

Vehicles contribute 60–90% to air pollution, and internal combustion engines emit more than 95% of carbon monoxide, about 65% of hydrocarbons, and 30% of nitrogen oxides into city air.

When we burn 1 kg of gasoline, 465 g of carbon monoxide, 25 g of hydrocarbons and 15 g of nitrogen oxides are emitted into the atmosphere. In addition, 1 kg of gasoline requires 14.5 kg of air to burn completely. So, an internal combustion engine (ICE) consumes about 200 liters of air per hour - 2.5 times more than a person breathes in a day. In total, the share of spark-ignition engines is 93-95%, diesel engines - 5-7%, in air pollution caused by toxic emissions by vehicles. True, the level of soot emission from the latter is 5-6 times higher [3].

It is possible to improve fuel properties in terms of ecological indicators:

1. Use of liquid additives to fuel.

Adding certain additives to fuel significantly reduces the formation of carbon monoxide, hydrocarbons, aldehydes and soot. In order to improve environmental features, they include detergents and multifunctional additives. An effective way to combat deposits in the fuel intake system is to use special detergent additives for fuel.

Additives are added to the fuel in such a low concentration that they practically do not affect the physicochemical and operational characteristics.

"FUTURA" gasoline additive was developed in Finland, which does not contain lead and increases the octane number to 95. The additive effectively cleans the engine and reduces pollution, protects the fuel system from corrosion, increases freeze resistance, ensures steady burn of fuel, and reduces the release of harmful substances.

2. Use of gas additives on fuel

The analysis of the results of experimental studies showed that the pre-saturation of the fuel with air reduces the concentration of the liquid phase in the central part of the jet, mixes it with the oxidizer and increases the lateral transfer of the droplet suspension. All these factors contribute to the formation of the mixture and the improvement of combustion processes, however, the presence of gas in the fuel harms the compression of the liquid and distorts the regularity of the fuel supply. In addition, gas additives into the fuel require a thorough modernization of the fuel equipment and the diesel engine.

To improve the performance of marine diesel engines, it is proposed to use hydrogen-containing synthetic gas additives, which are produced by catalytic conversion of hydrocarbon fuels directly

on the machine. This process ensures that the benefits of hydrogen fuel are realized without significant design changes. Catalytic conversion is proposed. Synthetic gas is produced using generators, the principle of operation of which is based on pre-evaporation and subsequent oxidation of hydrocarbon fractions of diesel fuel. As a result, a gas is formed, which includes hydrogen and carbon monoxide. The analysis of the results of experimental studies of the effect of hydrogen-containing synthetic gas additives on the environmental characteristics of diesel engines was carried out with generator sets 1Ch 8.2/7.5 and 4ChN 95/115, at idle and at speed modes, with an electrical load on the generator. Synthetic gas is supplied to the intake manifold of the engine. It is established that hydrogen fuel additives are appropriate only when the engines operate under load conditions. During the research, it was established that synthetic gas additives containing hydrogen make it possible to reduce harmful substances in exhaust gases (including carbon monoxide, hydrocarbons, nitrogen oxides and soot particles) and also cause a decrease in exhaust gas temperature. It is established that the optimal value of hydrogen-containing synthetic gas supply should be a percentage of the main fuel mass (5-10%).

3. Conclusion

I would also like to emphasize all the data we collected and the results of the experiments obtained in 2020-2023: we used the so-called liquid additive on gasoline fuel under the name of "MANNOL" (intended for gasoline), which was added to 25-30 liters—300 g of gasoline fuel. The engine was operated at idle speed and a partial load of 2000-2050 rpm.

We have obtained the following data: compared to standard gasoline, the experimental fuel gave us an increase in the minimum idle speed from 750 to 850-900 min⁻¹; The amount of carbon dioxide (CO) in the exhaust in idle mode has decreased by 20-25%; Hydrocarbons (CH) are reduced by 15-18%, carbon dioxide is reduced by 30-35% in partial load mode, and hydrocarbons are not recorded. The same experiment was conducted on a diesel engine, where the same proportion of "MANNOL" (intended for diesel) additive was used on diesel fuel, which allowed us to reduce soot in the exhaust by 18-22% in the transient mode of the partial load, and in the nominal power mode, soot is reduced by 20-28%. The experiment was repeated three to three times at different periods, with the data changing in approximately the same range as above.

Reference:

1. R. Topuria, M. Lezhava, Z. Shubladze, J. Sharadze, A. Katsadze. The prospects for the use of liquefied gas in maritime transport. VIII INTERNATIONAL SCIENTIFIC CONFERENCE. HTGH TECHNOLOGIES BULGARIA. YEAR –VIII, ISSUE- 1(11), 2023. P 97-99.
2. Дугиева А.Я., Гайтукаева Б.А., Арчакова Р.Д., Султыгова З.Х. ПРИСАДКИ ДЛЯ ЭКСПЛУАТАЦИИ ТОПЛИВ ПРИ НИЗКИХ ТЕМПЕРАТУРАХ // Фундаментальные исследования.— 2012. — № 9-2. — С. 450-454;
3. Присадка к топливу, топливо для систем сгорания, способ улучшения полноты сгорания, экономии топлива и уменьшения количества вредных загрязняющих веществ. <https://patents.google.com/patent/RU2114898C1/ru>