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Estimation of vehicle speed based on video analysis

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Abstract: *The use of video cameras for automatic traffic management, as well as video surveillance cameras, has made it possible to visually observe traffic accidents, i.e. the manner and movement of the parties involved in the accident at the moment and immediately before it occurred. On the basis of a video of a vehicle passing through a section that can be photogrammetrically rectified and transformed into an orthogonal view, with knowledge of the dimensions of characteristic formations that are usually rectangular in shape, such as pedestrian crossings, etc., and with knowledge of the frequency of the video recordings, it is possible, using appropriate software, to determine the speed of the object under study. In this paper, the reliability of the speeds determined by rectification using the AnalyzerPro software has been compared with the target speeds of the vehicle defined by the speed limiter, measured by a handheld radar and a GPS device installed in the vehicle.*

Keywords: speed, video recording, rectification, AnalyzerPro

1. Introduction

Video cameras are increasingly present in private and public life, used for video surveillance, social media, monitoring, etc. In addition to cameras installed at crossroads to manage traffic or to detect offences and identify their perpetrators, the spread of CCTV (Closed Circuit Television) [1], i.e. video surveillance, has meant that more and more traffic accidents are being recorded on video.

In most cases, the video recording of a traffic accident is only analysed to determine how, i.e. in what way, the accident occurred. However, the video recording of the accident itself can be a very important source of information for determining the kinematic parameters relevant for a high-quality and reliable time-distance analysis of the traffic accident. One of the basic parameters for this part of the analysis is the speed of the accident participants [2].

For the videos themselves, there can be considerable variability in the quality and content of the recorded material. The parameters extracted from the videos to determine the speed of movement of the accident participants are time (s) and distance travelled (m).

Data on the time elapsed during the sequence analysed can be obtained by dividing the video into time slices (frames), using some of the professional or online video conversion tools from avi, mp4 or other codecs in jpg format, or from data recorded in the recording history. The video frequency is expressed in frames per second (fps). The most common video recording standard is 25 fps, which allows the human eye to see a clear and uninterrupted image in front of it. This means that the time interval between two successive images is approximately 0.04 s. In any case, the analysis of the time interval between two successive clips should be preceded by an analysis of whether they are repeated at identical successive intervals within one second, or whether they differ to some extent. The basic indicator of elapsed time between clips within a video, regardless of the frequency at which it is recorded, should be motion detection of the object between two successive frames.

Another parameter needed to calculate speed is the distance travelled. To determine this, the video must show the characteristic positions of the objects to be analysed in relation to stationary objects or markings in the plane of the road surface that can be subsequently identified, such as road markings, the position and dimensions of objects, road grids, etc. By means of plan photography and knowledge of the mutual distance between at least four characteristic points visible in the photograph or photographs taken during the inspection, which happen to include characteristic surface points whose mutual distance can be determined. With the aid of plan photography and the knowledge of the mutual distance between at least four characteristic points visible in the photograph or photographs taken during the inspection, which happen to include characteristic surface points whose mutual distance can be determined subsequently, it is possible to carry out rectification photography, i.e. its transformation into a plan view in one plane [3], [4], using specialised computer programmes based on

photogrammetry. On the photographs transformed in this way, the object is observed from a so-called "bird's eye view", on which it is possible to determine the distances between certain characteristic surface points contained in the photograph.

Within the AnalyzerPro (ver. 24.0) software for simulation and reconstruction of traffic accidents, a video analysis module has been developed that can be used to recognise moving objects in videos and, under certain circumstances, determine their approximate speed. After directly downloading videos from a static camera in mp4. or avi. format and defining characteristic points visible on the video, whose mutual distance is known, using machine learning algorithms, the software detects movements in the video and identifies the objects whose speed is being tracked. In order to cover as large area as possible, most security cameras have wide-angle lenses, for which there is generally no close-up data available to calibrate them [5]. As a result, the rectification process distorts the images on the selected frames, which affects the accuracy of the mathematical calculation of the distance between each feature point, which is based on triangulation. The algorithm used by the AnalyzerPro program to obtain an orthogonal image relevant for analysis is based on the detection of groups of lines whose correspondences in reality are likely to be collinear, such as pedestrian crossings, road edges and other surface markings or other surface objects.

These groups of lines are corrected and then a new error function calculation is performed to estimate the remaining amount of distortion. The process is repeated iteratively until the optimal distortion parameters are found. However, due to the mostly unknown parameters of the cameras used for the recording, i.e. not knowing the frequency of the video recording, the low resolution of the recording and the dispersion during the rectification process, the speeds of the objects included in the recording can vary significantly from frame to frame. The AnalyzerPro programme partially solves this problem by fitting a polynomial curve which, at the usual video frequency of 25 fps, allows the speed and mode of movement of the object in the recording to be determined with reasonably satisfactory accuracy.

2. Video analysis module in the AnalyzerPro program

The video analysis module of the AnalyzerPro programme contains useful tools which, under certain conditions, can be used to determine the speed of movement of the vehicles in the video of the event being analysed.

After importing the video into the module (step 1), the top right corner of Figure 1 shows the basic video clip, while below is approximately the same clip, but from a slightly different perspective, with an orthogonal view of the section where the measured speed of the object will appear after rectification.

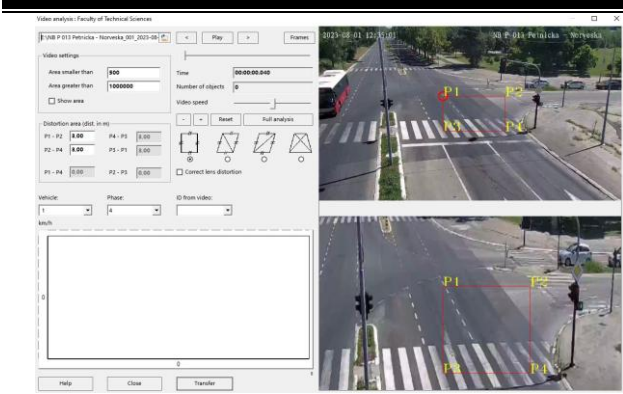


Fig. 1 Analyzer Pro desktop after video import

In the upper right figure appears the rectangle with the corners marked by points P1, P2, P3 and P4. By dragging these points to the corners of the quadrilaterals visible in the video, whose distances are known or can be determined later, in the lower right figure of the basic workspace, an approximate orthogonal representation of the section to be analysed is obtained.

In order to perform a video rectification, it is first necessary to define the way in which the known dimensions of the surface to be recorded are entered (step 2). These can be rectangular shapes, such as marked pedestrian crossings on the road for which it is sufficient to know the length of their sides, parallelograms, for which it is necessary to know the length of all four sides as well as the length of one diagonal, and irregular tetragons, for which it is necessary to know the length of all four sides as well as the length of both diagonals (step 3).

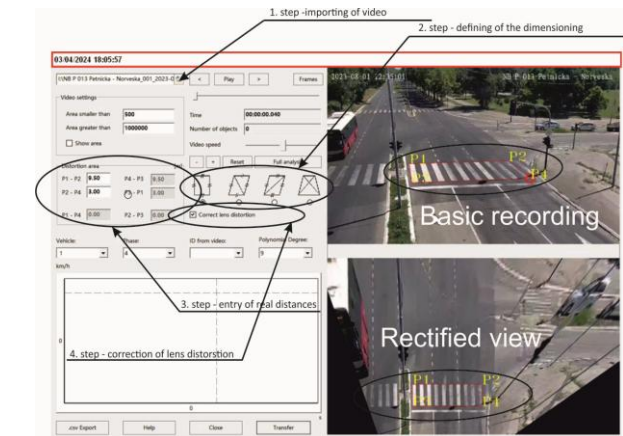


Fig. 2 Video rectification process in the AnalyzerPro software

After entering the parameters necessary for the rectification, depending on the position and characteristics of the video camera, whose parameters are mostly unknown, the optimisation of the orthogonal image is carried out using an algorithm based on the recognition of rectangular or collinear shapes, and in this way the image is calibrated in order to reduce as much as possible its distortion caused by the position of the camera and the ignorance of its parameters.

By activating the "play" command, the procedure for determining the speed of the vehicle on the basis of the rectified video is started and the monitor display shows the speeds of the vehicles included in the video, together with their identification by serial number (ID).

By selecting the identified vehicle from the video, a "fitted" curve can be obtained that represents the speed of its movement in time slices (frames) during the observation period of several seconds. The higher the frequency of the video recording, the lower the deviation of the current calculated values of the speed of the vehicles per frame from the curve showing their approximate average speed.

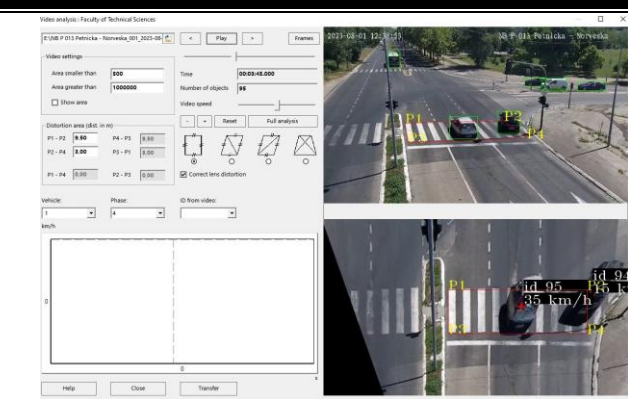


Fig.3 Rectified view of the pedestrian crossing with identified vehicle speed

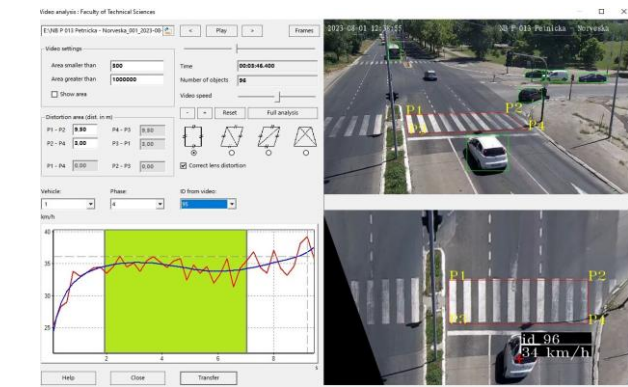


Fig.4 Diagram of the speed of movement of the identified vehicle included in the video

3. Reliability analysis of the speed of vehicle movement determined by video rectification

In order to determine the reliability of the speed of vehicle movement based on video analysis using the AnalyzerPro software, an experimental study was carried out in which the recorded speeds of the vehicle moving through the polygon created, obtained by rectification, were compared with its speeds measured in different ways. To do this, a speed limiter installed in the vehicle was used for each of the specified speeds, so that it could not exceed the speed defined by the threshold of the maximum set value. In addition, a hand-held Buschnel speed radar was used in the research.

The tests were carried out in city traffic at target speeds of 30, 35, 40, 45, 50, 55 and 60 km/h. It is important to note that even the target speeds set by the limiter and those measured by the handheld radar did not give absolutely identical results, so that at the target speeds mentioned there was a certain difference between the speeds set by the limiter in the car and those measured by the handheld radar.

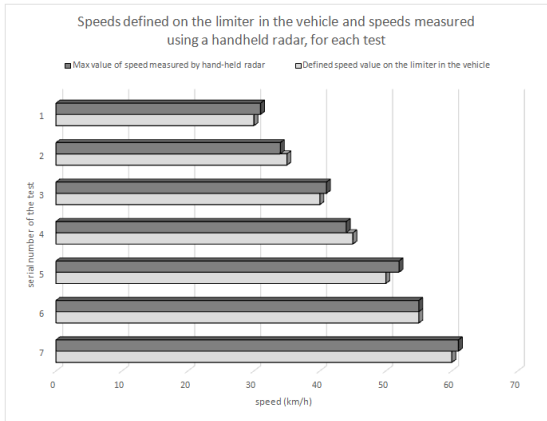


Fig. 5 Relationship between the target speeds defined by the speed limiter in the vehicle and the speeds measured by the handheld radar

The movement of the vehicle through the training ground was recorded with a Canon G7x camera installed on a fixed mount. The Racelogic Performance Box Data Logger (V Box), installed in the vehicle, which functions on the principle of GPS technology and records current data at a frequency of 10 Hz, was used as the device responsible for accurately determining the speed, route and mode of movement of the vehicle.

In order to achieve the best resolution of the video and the accuracy of the determined speed, the camera is placed at an angle of about 60° in relation to the road surface. After that, a polygon was formed on the road using four tiles marked with markers, and the distances between them, as well as the diagonals, were measured.



Fig. 6 Layout of the training ground where the research was conducted

Vehicle movement speeds when passing through the training ground, determined using the AnalyzerPro program, were compared with the tentative target speeds defined by the research, as well as with the speeds determined using GPS technology. The analysis showed that the differences between the speeds determined by rectification and those measured by measuring devices installed in the vehicle are minimal. The comparative view between the targeted, measured and calculated vehicle speeds when passing through the virtual polygon is illustrated in the following diagrams.

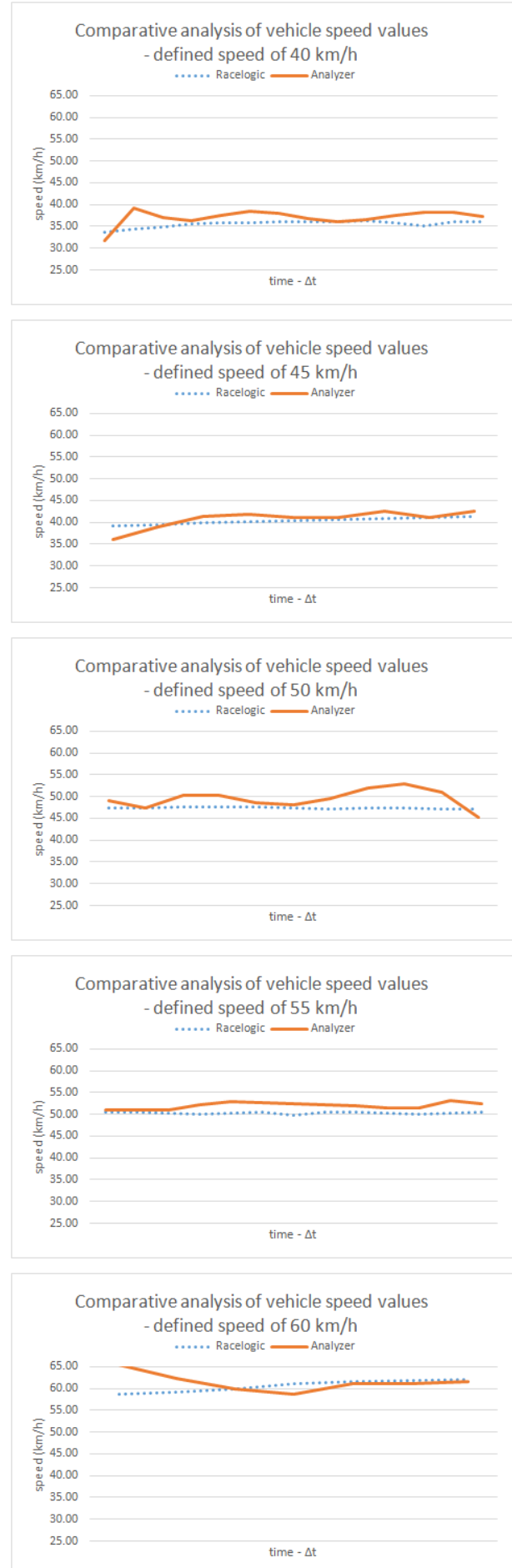
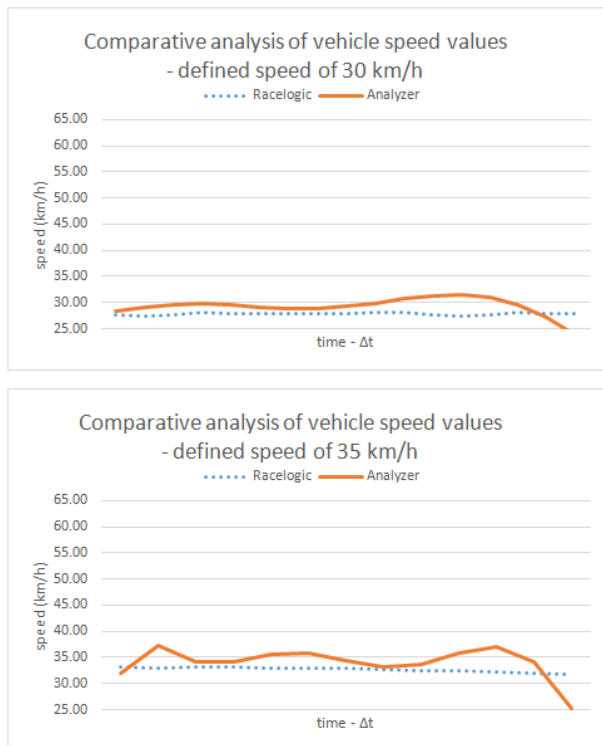


Fig. 7-13. Comparison between the targeted, measured and calculated vehicle speeds when passing through the virtual training ground at speeds of 30-60 km/h

4. Conclusion

The application of information technologies in the human environment has become an integral part of modern life. Video technology is mainly used in traffic for the purpose of traffic management, i.e. establishing the mode of movement of vehicles with light signaling in accordance with the traffic load. In addition, video recordings are also used for the purpose of detecting traffic violations and their perpetrators, and increasingly in the process of traffic accident reconstruction. Circumstances included in the video recording related to the occurrence of traffic accidents often represent one of the most important sources of information for their analysis. One of the basic factors in the analysis of traffic accidents is the speed of movement of the accident participants.

Within the AnalyzerPro software package, a module has been developed that provides the possibility to determine the speed of movement of participants in an accident under certain circumstances. Those circumstances imply knowing the distance between at least two characteristic points visible on the surface, if the object is captured by recording a square or rectangular shape, or knowing the distance between all points of the quadrangle, as well as the length of the diagonals.

After the research carried out, which included a comparative analysis between the speeds of the vehicles that participated in the experiment and those determined by rectification, the following can be concluded using the AnalyzerPro program:

- If the video recording includes an orthogonal surface, with known distances between characteristic points, the speed determined based on the analysis of the video can be considered quite reliable for the analysis of the event or traffic accident, which are the subject of the research.
- The error in the calculated speed, i.e. greater dispersion in relation to the "fit" speed curve, due to the constant value of the frequency of the video, increases with the increase in the speed of the vehicle that is the subject of the research.
- The smaller the angle between the position of the camera and the surface covered by the video, the greater the dispersion of the video and the error in the calculation of the speed of the object whose speed is the subject of research.
- Depending on the frequency of the video recording, a smaller dispersion of the actual speeds compared to the speeds determined by the video analysis can be expected at higher speeds of the objects (vehicles) that are the subject of the analysis.

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Experience of applying the acoustic emission method for monitoring systems

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Abstract: An important aspect in organizing acoustic emission monitoring is the analysis of recorded data and selecting useful information. Despite noise suppression using frequency methods, its quantity in the recorded information can reach 99% because the process of degradation during operation typically progresses slowly, whereas the presence of acoustic noise is an inherent attribute of the technological process.

Noise suppression after data recording is carried out within the framework of the monitoring system's software, although filtering algorithms may be specific to each application.

KEYWORDS: ACOUSTIC EMISSION, SYSTEM, MONITORING, INTEGRITY, LOCATION

1. Introduction

In order to make a decision on the feasibility and effectiveness of applying acoustic emission (further in the text AE) monitoring in a particular case, preliminary work is necessary to determine the technical and operational characteristics of the installation that affect the parameters of the designed monitoring system. Therefore, before deciding on the installation of an AE monitoring system, it is very important to assess the main parameters of the system, including estimating the required number of channels.

The number of channels required for monitoring is one of the key parameters of the system. The sensitivity of the system and the reliability of defect detection depend on the number of channels. The more AE transducers installed on the structure, the higher the probability of detecting defects. On the other hand, increasing the number of channels leads to a higher cost of the system. [1]

In other words, to choose the main parameters of the system, it is necessary to know the following:

- a) what the amplitudes of stress waves generated during the occurrence and development of defects in the material of the structure are;
- b) how this amplitude decreases as it propagates from the location of the defect to the location of the receiver;
- c) if it is possible to register stress waves with such amplitude by a system that has a certain amplitude threshold determined by the level of acoustic noise.

2. Characteristic features of the acoustic emission method

The main advantage of the AE method is that it enables the detection and recording of evolving, potentially most hazardous defects. Thus, the method allows for the classification of defects not by their size but by their level of danger.

The primary advantages of the AE method over traditional non-destructive testing methods include the following:

The integral nature of the method lies in the fact that using one or several sensors fixedly installed on the surface of an object enables monitoring the entire object as a whole (100% coverage). This feature of the method is particularly useful when examining hard-to-reach or inaccessible surfaces of the monitored object (such as inspecting the root part of a wing beneath the aeroshell). [2]

Unlike scanning methods of non-destructive testing, the AE method *does not require meticulous preparation of the surface of the test object*. Consequently, the execution of the inspection and its results are not dependent on the condition of the surface or the quality of its preparation. Insulation coating (if present) is only removed at the locations where sensors are installed.

Detection and registration of evolving defects allow for the classification of defects not by their size (or other indirect characteristics such as shape, position, or orientation of defects),

but by level of their danger (impact on durability) for the monitored object. [3].

High performance, surpassing by many times the performance of traditional non-destructive testing methods such as ultrasonic, radiographic, eddy current, magnetic, and others.

The ability to monitor various technological processes and assess the technical condition of the object *in real-time mode*, which allows preventing the catastrophic failure of the monitored object.

Type I and type II errors are excluded.

Before planning the installation of a monitoring system on a certain object, it is necessary, at the very least, to determine the level of noise. To do this, appropriate measurements need to be conducted.

Our experience shows that during load testing in factory conditions, the optimal frequency range is between 100 kHz and 300 kHz when using receivers with a resonance frequency of 150 kHz. The maximum distance between sensors is usually up to 5 meters. Load tests are typically conducted during scheduled maintenance periods when the system is taken out of operation and noise levels are minimal. During regular operation, the noise level can be significantly higher, requiring a shift to a higher frequency range, which will lead to a reduction in the distance between receivers and, consequently, an increase in the number of channels. Furthermore, during pressure testing to determine the location of AE sources, it is possible to use a method called zonal location, where the registration of the source by at least one sensor is sufficient to estimate its location, and the location of the source is confined to the sensor's control zone. Such accuracy is satisfactory for many specialists because after loading and AE monitoring, additional inspections of these areas are conducted using other non-destructive testing methods, such as ultrasonic testing, to precise the location of defects and determine their quantitative characteristics. When searching for defects, the defect inspector primarily focuses on areas of their most probable location within the specified zone, such as weld seams, pipe entries, etc.

For monitoring purposes, such an approach is unlikely to be acceptable because, in addition to defects, there may be numerous external sources over such a large area. Moreover, it is not always feasible to conduct additional measurements using alternative control methods during the operational period of the installation. The American ASTM E 1139-02 document [4], which regulates the use of AE in monitoring, requires the use of an accurate method for calculating coordinates, whereby the source should be registered not by one, but by at least three receivers. In this case, the maximum distance between receivers will be further reduced. Additionally, as mentioned earlier, additional sensors may be required to monitor shadow zones.

Therefore, the question of measuring the level and nature of noise on a working installation may be decisive in the design of an AE monitoring system.

Currently, there are devices available that allow for the real-time registration of the waveform of AE signals. This provides the opportunity to obtain a vast number of additional characteristics, which can be useful both during the filtering stage and in the

process of decision-making regarding the classification of sources and assessment of the overall technical condition of the installation. Specialized software products have been developed that allow for data analysis in a multi-parameter space using pattern recognition algorithms.

Modern aviation, in particular, requires the application of precise non-destructive testing technology, which is aging in large quantities but continues to be intensively utilized. [5].

In particular, the acoustic emission method has recently been applied very effectively to a large fleet of American C-130 Hercules transport aircraft (Lockheed Martin), replacing the previously used eddy current method for inspecting the attachment nodes of outer wing sections to the central section. Defects (cracks) were detected that could not be identified using the eddy current inspection method. This demonstrates the advantages of the AE method in the early stages of defect formation in structures, which cannot be detected by other methods, and, due to the integrity of the AE method, significantly reduces the time required for defect detection and location. Additionally, the AE method was successfully used in fatigue testing of the Airbus A-340-600 aircraft in Dresden, where all defects were confirmed, and moreover, defects that are not detected by conventional inspection methods, such as fretting, were also identified.

3. Physical principles of acoustic emission

The technology of AE control is based on the phenomenon of acoustic emission. AE is the process of material emitting mechanical waves caused by local dynamic restructuring of the material's internal structure under external impact.

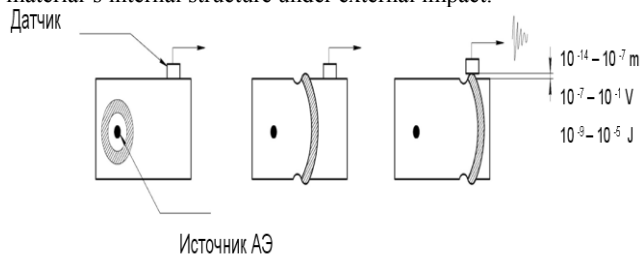


Fig.1 Scheme of AE signal propagation

Waves, upon reaching the material surface, propagate further as surface waves, causing mechanical oscillations of the surface, with amplitudes ranging from 10^{-14} - 10^{-7} m. The registration of such small oscillations is performed using piezoelectric sensors.[6]

4. Study of the application of acoustic emission method

An important aspect of organizing AE monitoring is the analysis of recorded data and the selection of useful information. Despite noise suppression using frequency methods, their quantity in the recorded data can reach up to 99%. This is because the process of structural degradation during operation typically progresses slowly, whereas the presence of acoustic noise is an inherent attribute of the technological process.

Noise suppression following data registration is managed within the monitoring system's software. While filtering algorithms may vary depending on the application, several common approaches exist.

Firstly, correlation analysis is applied, linking the measured parameters of AE signals with each other. There are known relationships between the parameters of real AE signals that differ from similar relationships for noise signals. It is very effective to apply correlation between AE parameters and parameters describing the technological process, such as pressure and temperature.[7]

Secondly, precise location using registration time is also a highly effective factor in combating noise signals. Often, only a few percent of AE signals registered by the system are actually involved in the formation of AE events reflecting real sources caused by defects. Below are examples of developed control techniques based on the AE monitoring method.

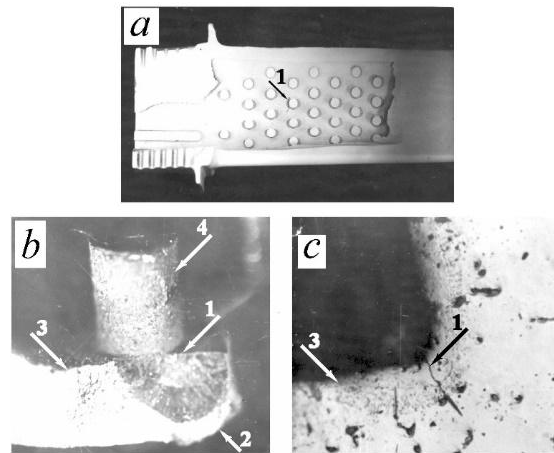


Fig. 2 AE detected internal crack in a cooled blade



Fig.3 AE monitoring of the shock absorber strut of the main landing gear of the aircraft

A fatigue crack has been localized in the load-bearing structure.



Fig.4 AE monitoring during static tests of the aileron

Previous work on the D16T sheet material has demonstrated high effectiveness in detecting the onset and kinetics of crack growth.

Real-time monitoring of wing structure elements, linked to flight parameters, aircraft GPS coordinates, and flight modes, which differently influence structural fatigue defects, enables safer aircraft operation by providing early warning of defect development and allowing avoidance of modes that accelerate their progression. Cracks generate AE that propagates as mechanical vibrations into surrounding structures, while sensors positioned around the structure detect these AE "events". The ASIS program analyzes the time differences in arrival of acoustic events at each sensor and determines the crack's location.

An example of effective AE usage is evident in results indicating that AE monitoring of aircraft glider can be achieved even during flight under the most stringent conditions, provided that AE is recorded in frequency ranges exceeding 700 kHz (recommended range of 1 MHz and above), where the signal-to-noise ratio reaches 2:1.

Additionally, various practical and experimental efforts have been undertaken to implement AE in monitoring.

5. Conclusions

In the implemented projects, our field of activity addressed the following main problem areas:

1. Experimental establishment of “signal-defect” correlation relationships on samples made of steels, aluminium alloys, and certain composites (positive results are already available).
2. Development of appropriate methods of signal analysis and selection of the most informative AE parameters for assessing the presence and location of defects.
3. The inherent reliability of the AE monitoring system under conditions approximating operational ones. This primarily concerns piezoceramic transducers and their protection from degradation under extreme static and dynamic loads, as well as aggressive environmental impacts.
4. Development of methodologies for carrying out non-destructive testing for various objects.

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[http://ftp.rta.nato.int/public/FullText/RTO/MP/RTO-MP-007/\\$MP-007-19.PDF](http://ftp.rta.nato.int/public/FullText/RTO/MP/RTO-MP-007/$MP-007-19.PDF)

Geometric design and efficiency of ship ventilation flow: analysis of sudden expansion in laminar flow by numerical simulation with ansys

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Abstract: This scientific report focuses on investigating the influence of geometric design on ship ventilation flow efficiency through numerical simulation with ANSYS. Many sources on the subject state that in a ship's ventilation system, the flowing fluid encounters various devices and fixtures such as valves, fans, and bends that can cause sudden expansions or contractions of the flow. These geometric factors cause energy loss, which can be of importance to the efficiency of the ship's ventilation system, especially in the complex conditions of power generation. Such energy losses are considered significant in these industries and are the subject of serious design and optimization of flow systems. Using engineering simulations, this report investigates steady laminar flow through a pipe with sudden expansion in order to understand and predict the energy losses resulting from the expansion. The practical example of application can be the analysis of the ventilation system of a ship, where such geometric designs can affect the efficiency of the ventilation and therefore the performance and safety of the crew and passengers. Such research is essential to improve the manufacturing and operational processes of ships and to ensure their optimal working conditions.

KEY WORDS: SHIP VENTILATION SYSTEM, PIPELINE, SUDDEN EXPANSION OF FLOW, NUMERICAL SIMULATION, ANSYS, DESIGN, NUMERICAL SIMULATION, CFD ANALYSIS

Introduction:

This scientific report focuses on investigating the influence of geometric design on ship ventilation flow efficiency through numerical simulation with ANSYS [4]. Many sources on the subject state that in a ship's ventilation system, the flowing fluid encounters various devices and fixtures such as valves, fans, and bends that can cause sudden expansions or contractions of the flow. These geometric factors cause energy loss, which can be of importance to the efficiency of the ship's ventilation system, especially in the complex conditions of power generation. Such energy losses are considered significant in these industries and are the subject of serious design and optimization of flow systems. Using engineering simulations, this report investigates steady laminar flow through a pipe with sudden expansion in order to understand and predict the energy losses resulting from the expansion. The practical example of application can be the analysis of the ventilation system of a ship, where such geometric designs can affect the efficiency of the ventilation and therefore the performance and safety of the crew and passengers. Such research is essential to improve the manufacturing and operational processes of ships and to ensure their optimal working conditions.

1 Geometry

The problem statement involves the movement of fluid through a pipe extension (Fig. 1). The flow is laminar and axisymmetric. Fig. 1 shows a section of the tube along the axis line (BD) and thus the computational domain is established over half of the tube. Pipeline dimensions: $V3 = 1\text{m}$, $V4 = 2\text{m}$, $H1 = 20\text{m}$, $H2 = 100\text{m}$

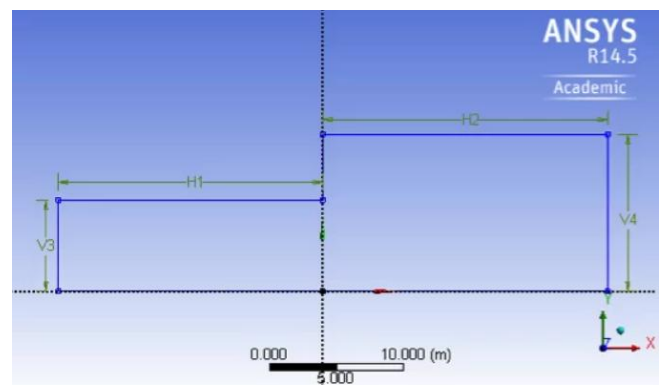


Figure 1 Geometry of pipe [4]

The inlet velocity is uniform, $U1 = 0.277\text{ m/s}$. The liquid flows into the surrounding atmosphere, which is at a pressure of 1atm . The density $\rho = 1\text{ kg/m}^3$ and the dynamic viscosity is: $\mu = 0.01\text{ kg/(ms)}$. Inlet Reynolds number $Re = 55.4$.

In the tube with the smaller diameter, the viscous boundary layer increases along the tube wall (fig.2). This process is monitored from the inlet, and with sufficient pipe length a fully developed velocity profile is formed. Passing from the smaller diameter pipe to the larger diameter pipe at the entry point, a recirculation zone is formed [1]. The secondary flow will develop fully after the recirculation zone with sufficient length of the second pipe.

Setting boundary conditions in Fluent requires the edges of the geometry to be named [4]. The pipe with the smaller diameter is defined as "Inlet" and the one with the larger diameter is "Outlet". The axis line is defined as "CenterLine" and the walls of the tube are defined as "Wall" as shown in Fig.4.

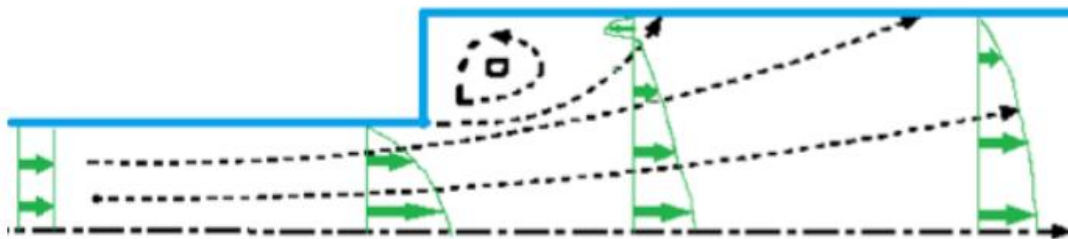


Figure 2 View of the viscous boundary layer through an expanding tube [3]

2 Mesh

For simulation purposes, it is necessary to form a mesh model of the pipe geometry with a certain number of divisions in the radial and axial directions. Grid points and dimensions are shown in Fig.3.

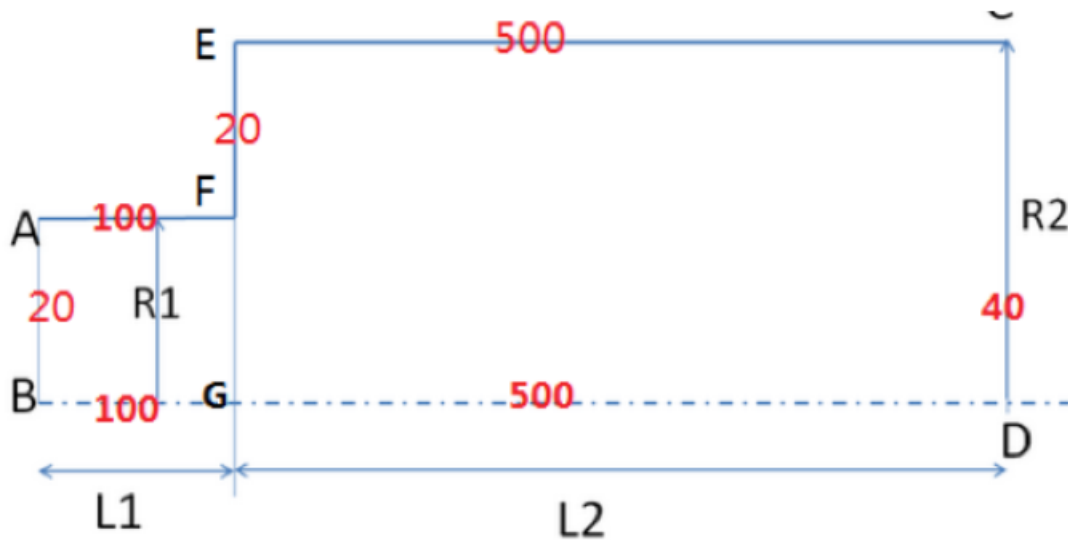


Figure 3 Pipe's dimensions [4]



Figure 4 Pipe's boundary conditions [4]

3.1 Pressure Contours

In the movement of a real fluid, there is a resistance to movement caused by the friction between the walls of the pipe and the fluid (external friction) and friction between the individual layers of the fluid (internal friction) [1]. Since frictional processes consume energy, this leads to a decrease in the total energy of the system. Therefore, when a real fluid moves along a horizontal pipe of constant cross-section, the static pressure decreases uniformly along the wavelength. The magnitude of the reduction depends on the length and section of the pipe and on the viscosity of the liquid. The longer and narrower the tube along which the fluid moves, the greater the friction and the lower the velocity of the flowing fluid.

At the places where the cross-section changes, in some cases vortices occur, in which additional energy is lost. These vortices are more likely and larger in the transition from larger to smaller cross section than in the transition from smaller to larger cross section (fig.6).

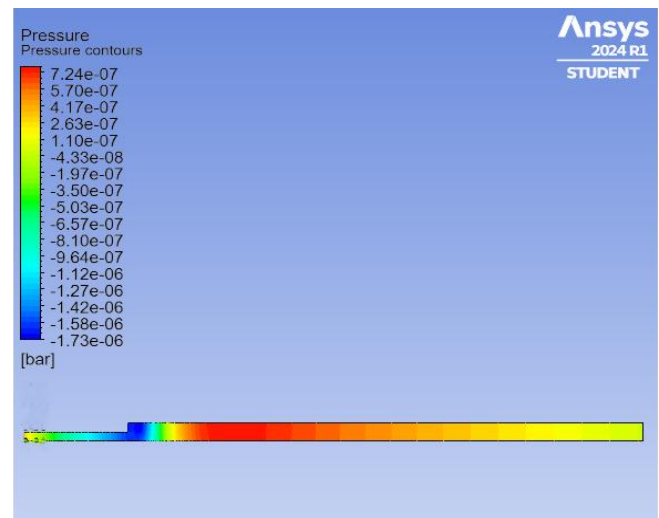


Figure 5 Illustration of pressure contours through the pipe [4]

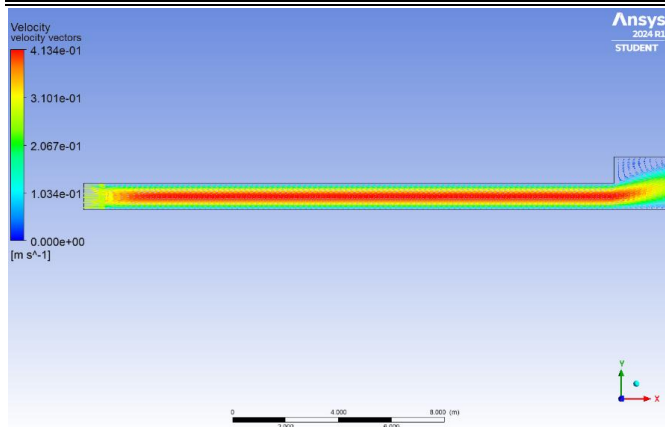


Figure 6 Velocity vectors of laminar flow through the pipe [4]

3.2 Velocity mag Contours

When moving a liquid along a pipe with a variable cross-section, the flow rate, and hence the static and dynamic pressure, depends on the cross-section. In places with a smaller cross-section, the velocity is greater, and from there the dynamic pressure will be greater and the static pressure less according to Bernoulli's law [2]. Since the fluid is real, due to internal and external friction, an additional pressure gradient is also created, inversely proportional to the cross-section of the pipe.

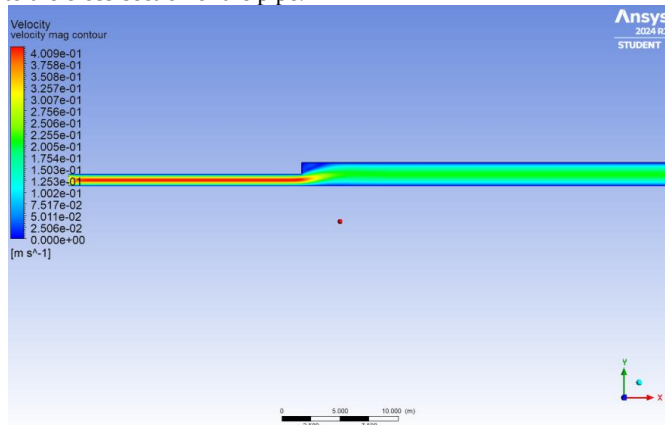


Figure 7 Velocity magnitude contour [4]

Particles in contact with the tube wall adhere to it and are immobile. If we mentally divide the fluid into thin cylindrical layers, they will slide relative to each other, moving at different speeds. The further from the pipe walls a layer is, the greater its velocity. The speed of the particles moving along the axis of the pipe is maximum (Fig. 8)

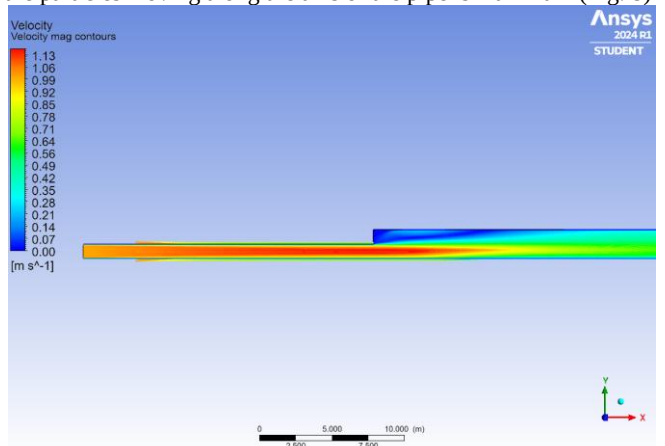


Figure 8 Velocity magnitude [4]

Laminar motion is stationary: it is stable and the pattern of streamlines does not change over time [2]. An important characteristic of the current is its average speed. This is such a constant speed, the same for all particles of the fluid, when moving

with which the same volume of the fluid would pass through the cross section of the pipe in a unit of time, as in the real flow, where the individual layers move at different speeds (Fig. 9).

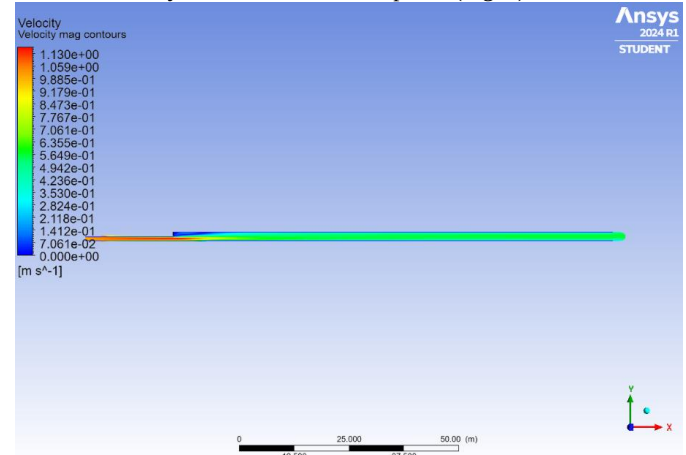


Figure 9 Velocity contours [4]

3.3 Velocity vectors

An important characteristic of the current is its average velocity v . This is such a constant speed, the same for all particles of the fluid, when moving with which the same volume of fluid would pass through the cross-section of the pipe in a unit of time, as in real flow, where individual layers move at different speeds.)

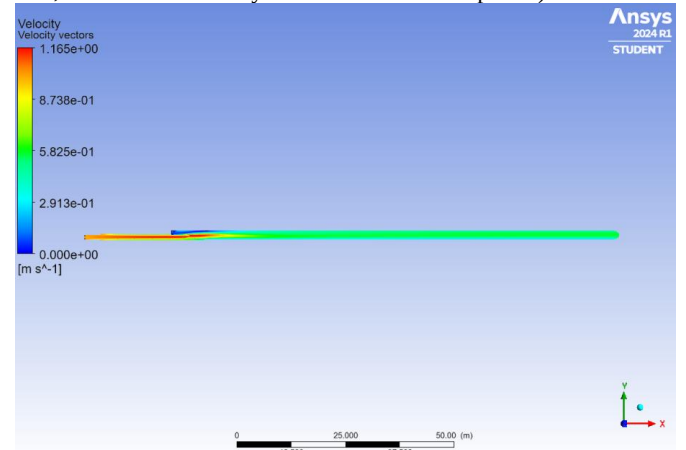


Figure 10 Velocity vectors [4]

A characteristic feature of laminar flow is that each particle of the liquid moves along a smooth trajectory and the trajectories of the particles do not cross (Fig. 10)

In established laminar fluid flow, the trajectory along which a given particle moves is called a streamline. The fluid velocity at any point is directed tangential to the streamline.

Figure 11 shows the velocity profile in the pipe at two different ratios.

The graph shows a comparison of the velocity profile of laminar flow through a pipe with a sudden expansion.

Laminar flow:

- The velocity profile is parabolic.
- The highest velocity is in the center of the pipe.
- The velocity decreases towards the walls of the pipe.

Sudden expansion of the pipe:

- The velocity profile is flatter than laminar flow.
- The highest velocity is near the walls of the pipe.
- The velocity decreases towards the center of the pipe.

Differences:

- Laminar flow has a higher velocity in the center of the pipe, while sudden pipe expansion has a higher velocity near the walls of the pipe.

- The velocity profile of laminar flow is more peaked, while the velocity profile of sudden pipe expansion is flatter.

Cause of the differences:

- The sudden expansion of the pipe leads to swirling of the flow, which flattens the velocity profile.

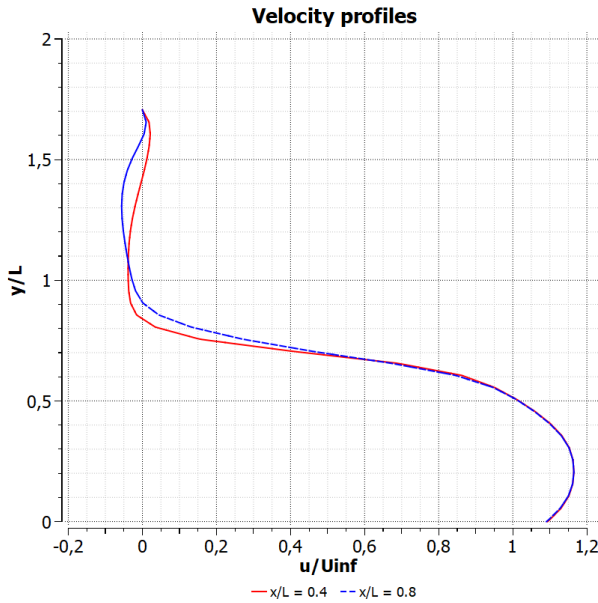


Figure 11 Velocity profile [4]

Consequent:

The graph shows that sudden pipe expansion leads to a change in the velocity profile of laminar flow. The highest velocity shifts from the center of the pipe to the walls of the pipe, and the velocity profile becomes flatter.

Additional notes:

- The graph shows two velocity profiles: for $0.4X/L$ and $0.8X/L$. X/L is a dimensionless quantity that represents the distance from the beginning of the pipe expansion divided by the diameter of the pipe.

- The graph shows that the velocity profile changes with distance from the beginning of the pipe expansion.

Results, Conclusions

The conducted simulations confirmed the theoretical propositions for energy loss in the transition part of a pipeline with a variable section. In fig. 12 shows a comparison between velocity and pressure in the pipeline in the two sections. In the transition zone from a smaller diameter to a larger one, low pressure and low velocity are observed. Along the length of the pipe, velocity and pressure remain relatively constant.

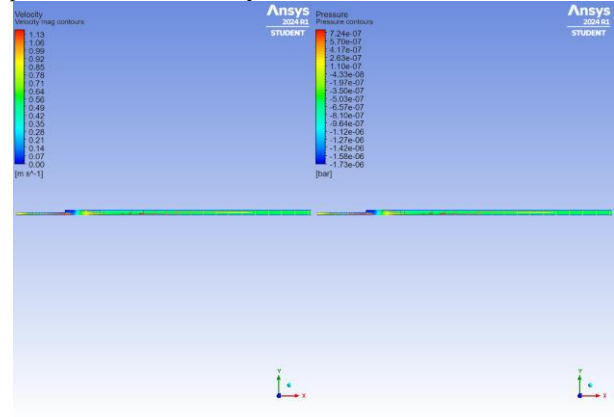


Figure 12 Comparison of velocity mag contour and pressure contour [4]

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Statistical estimates of the probability of fail-safe functioning of freight wagons in the interval between repairs

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Summary. During exploitation wagons must fully implement the transportation process safely. Wagons spend their own technical resources in the process of exploitation, and therefore they need to be restored. During the process of moving, accumulated defects in the moving part, axle boxes, brake equipment and in other knots of wagons, and the number of failures in wagons depend on the reliability of the construction and on the quantity of kilometers that the wagons have run.

Key words: REPAIR, WAGON, PROBABLY, INDIFFERENCE, RELIABILITY SERVICE LIFE, PRODUCTION, TECHNICAL CONDITION, STATISTICAL, QUALITY, MAINTENANCE.

Introduction.

According to GOST 27.002.89 reliability is defined as the ability to maintain all the parameters (TS, maintenance, storage, transportation and movement) that characterize the functions of the

object (wagon) during technical exploitation within a specified period of time. The reliability of the object is characterized by complex indicators such as fail-safe functioning, durability, repairability, and maintenance [1.4].

Table 1,

Production year	Covered wagon	Platform	Gondola	Isothermic	PR	Cistern	Total
Until 1985	1006	436	850	511	909	712	4424
1986	125	114	-	-	-	141	380
1987	172	113	-	-	-	100	385
1988	95	127	-	16	116	72	426
1989	96	111	-	17	135	110	469
1990	69	104	-	15	80	96	364
1991	72	64	-	5	33	43	217
1992	21	3	-	-	-	4	28
1993	16	2	-	-	1	20	39
1994	2	-	-	-	-	-	2
1995	-	-	-	-	-	14	14
1998	-	-	-	-	-	4	4
1999	-	-	-	-	-	9	9
2000	-	-	-	-	-	4	4
2001	-	-	-	-	-	46	46
2002	-	-	-	-	-	51	51
2003	-	-	-	-	-	61	61
2015	401	400	1000	-	700	530	2031
2016	-	-	-	-	-	70	70
2021	40	30	50	-	60	76	256
Total	2115	1504	1900	564	1974	2087	10280
Exploitation period	32	32	22	30	30	32	-

Main part. According to GOST27.002.89, the object losing its self-sufficiency is called refusal. When it comes to the refusal of freight wagon (cistern), it is understood that wagon would lose its operational capability and go repair beyond the plan. In this section, key issues of the fail-safe functioning which are the key component for reliability will be analyzed. Fail-safe functioning is a feature of continuous maintenance of the working condition of the object (wagon) for a certain period or period of operation. The existing distribution features of the key parameters of reliability require more accurate approach to the fail-safe functioning in the possible aspect. The possible aspect is reflected in various indicators of reliability.

The database of the experimental research works in the article is based on the data of the “Automated Data Bank” of the Freight Wagons Fleet of the “Commonwealth of Independent States” information system. The Automated Databank of the Freight Wagons Fleet contains all information on wagon owner, its registration, technical characteristics, passage of planned and non-planned maintenance types, technical condition, modernization of wagons, etc. Table 1 shows age-structure of Freight Wagons Fleet of Azerbaijan Railways Closed Joint Stock Company (CJSC) [5,7]. The implementation of a new information resource at the Wagon Repair Enterprises of the CIS countries since 2009, on “Planned repair of freight wagons and a half-system of production quality

within the framework of expanding the functional capabilities of the integrated information system of wagon management” highlighted the fulfillment of the following issues:

Table 2

№	Parameters names	Units	Indicators
1	Model of wagon		15-1443
2	Assigned service life (ASL)	Year	32
3	The number of capital repairs during ASL	Year	2
4	Periodicity of conducting capital repairs	Year	13
5	1 st Planned repair after operation	Year	3
6	Periodicity of conducting warehouse repairs	Year	2
7	The number of warehouse repairs during ASL		12

- improving the accuracy of the assessment of production and repair quality assurance at the wagon manufacturing and repairing enterprises, based on the analysis of inter-service operation of repaired and produced wagons;

-improvement in quality of planned repair types (warehouse and capital) of freight wagons and performance of production at wagon repairing and manufacturing enterprises;
 - increasing the number of work parks of the railway network;
 - reducing operating expenses of freight wagons by reducing the number of wagons involved in current repair;

- organization of a single information database in the field of repair quality of freight wagons at the expense of the organization of an automated system for the control of wagon repair and exploitation quality [3,6].

Table 3

Operation, day	Warehouse Repair (WR)		Capital Repair (CR)		Increasing the service life of the Capital Repair		New wagon (NW)	
	Probability of fail-safe functioning	Probability of failure	Probability of fail-safe functioning	Probability of failure	Probability of fail-safe functioning	Probability of failure	Probability of fail-safe functioning	Probability of failure
30	0,9908	0,0092	0,9922	0,0078	0,9897	0,0103	0,9978	0,0022
90	0,9622	0,0378	0,9736	0,0264	0,9672	0,0328	0,9876	0,0124
150	0,9304	0,0696	0,9537	0,0463	0,9412	0,0588	0,9761	0,0239
210	0,8936	0,1064	0,9324	0,0676	0,9113	0,0887	0,9653	0,0347
270	0,8531	0,1469	0,9095	0,0905	0,8824	0,1176	0,9525	0,0475
330	0,8122	0,1878	0,8858	0,1142	0,8478	0,1522	0,9357	0,0643
390	0,7755	0,2245	0,8586	0,1416	0,8002	0,1998	0,9123	0,0877
450	0,7426	0,2574	0,8314	0,1686	0,7554	0,2446	0,8868	0,1132
510	0,7154	0,2846	0,8067	0,1933	0,7088	0,2912	0,8602	0,1398
570	0,6978	0,3022	0,7871	0,2129	0,6603	0,3397	0,8538	0,1662
630	0,6856	0,3144	0,7697	0,2303	0,6194	0,3806	0,8082	0,1918
690	0,6765	0,3235	0,7551	0,2449	0,5831	0,4169	0,7829	0,2171
750	0,6714	0,3286	0,7484	0,2516	0,5625	0,4375	0,7591	0,2409
810	-	-	-	-	0,5544	0,4456	0,7371	0,2629
870	-	-	-	-	0,5512	0,4488	0,7142	0,2856
930	-	-	-	-	0,5484	0,4515	0,6918	0,3082
990	-	-	-	-	0,5472	0,4528	0,6566	0,3434
1050	-	-	-	-	0,5464	0,4536	0,6465	0,3535
1080	-	-	-	-	0,5456	0,4544	0,6380	0,362

Taking into account the above mentioned requirements, the following indicators are used in the dissertation work to estimate the proposed and required quality of Azerbaijan Railways CJSC in the wagon economy:

- Indicator of fail-safe functioning- K is a numerical value indicating fail-safe functioning during exploitation or a specified period of exploitation within the movement and expressed in %;

- flow parameter of failure – λ_a is a ratio of the number of failures in wagons occurring during the period under review to the number of wagons in exploitation.

-average operating time to failure – T_a is expressed in km, and characterized by the ratio of the total number of the wagon operation.

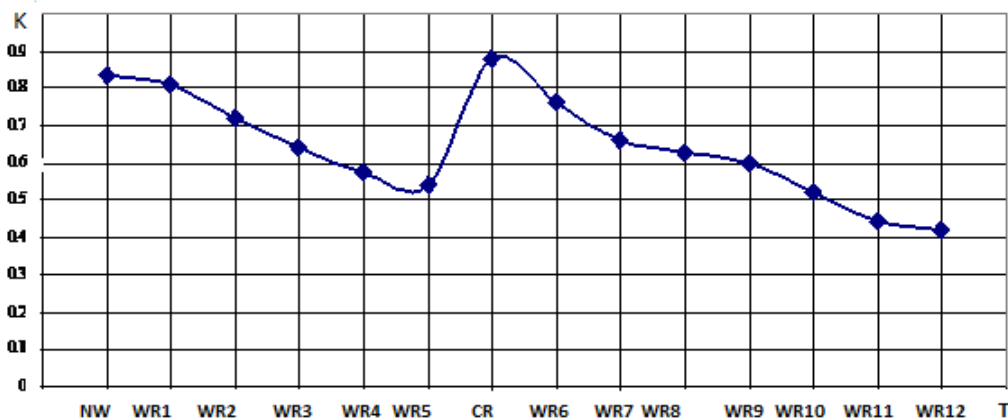


Figure 1. The schedule of change in the average limit probability of the fail-safe functioning of the cistern wagon in the interval between repairs.

The characteristics of the repair system of cistern wagon are given in Table.2 [2]. Estimate of the planned repair of freight wagons and quality of preparation (production) is carried out using the existing information technology in automated mode.

The survey estimates that are expressed in a day for the reliability indicators of the cistern wagon on performed work: production, warehouse repair, capital repair, capital repairs that lead to lengthening of useful life period, and the exploitation of wagons are determined according to the indicators of 2016. These reliability

indicators of the cistern wagons are shown in Table 1.3 in accordance with the data from “the Central Directorate for repair of freight wagons” of CIS countries [2]. Taking into account the degradation (aging) of the wagon construction, estimates of the probability of fail-safe functioning in the life cycle of the cistern wagon 15-1443 model are given in Table 4. Figure 1 shows the graphs of the probability of fail-safe functioning of the cistern wagon during the interval between repairs.

Table 4

Exploitation time, day	Estimate of the probability of the fail-safe functioning in the interval between repairs.													
	New wagon	WR1	WR2	WR3	WR4	WR5	CR	WR6	WR7	WR8	WR9	WR10	WR11	WR12
30	0,998	0,992	0,883	0,786	0,699	0,643	0,992	0,888	0,781	0,715	0,706	0,624	0,555	0,527
90	0,989	0,962	0,856	0,764	0,678	0,636	0,975	0,862	0,760	0,705	0,694	0,612	0,531	0,506
150	0,977	0,931	0,829	0,737	0,658	0,612	0,956	0,839	0,738	0,691	0,672	0,598	0,512	0,496
210	0,966	0,895	0,795	0,708	0,632	0,596	0,933	0,812	0,719	0,678	0,650	0,573	0,498	0,472
270	0,954	0,853	0,761	0,675	0,603	0,574	0,909	0,791	0,695	0,653	0,631	0,551	0,473	0,450
330	0,935	0,812	0,722	0,645	0,576	0,552	0,887	0,774	0,671	0,631	0,612	0,530	0,455	0,432
390	0,914	0,777	0,692	0,618	0,548	0,524	0,859	0,751	0,653	0,614	0,598	0,514	0,434	0,408
450	0,888	0,743	0,662	0,587	0,524	0,503	0,833	0,733	0,631	0,603	0,572	0,495	0,414	0,392
510	0,861	0,717	0,638	0,567	0,509	0,488	0,807	0,711	0,614	0,595	0,551	0,471	0,395	0,374
570	0,835	0,698	0,622	0,554	0,494	0,463	0,787	0,690	0,596	0,571	0,524	0,452	0,378	0,352
630	0,809	0,684	0,611	0,541	0,482	0,441	0,771	0,669	0,572	0,554	0,501	0,430	0,364	0,335
690	0,784	0,677	0,603	0,537	0,479	0,438	0,758	0,638	0,512	0,501	0,470	0,401	0,352	0,301
750	0,759	0,672	0,599	0,533	0,474	0,434	0,742	0,633	0,503	0,494	0,465	0,394	0,341	0,296
810	0,738	-	-	-	-	-	-	-	-	-	-	-	-	-
870	0,716	-	-	-	-	-	-	-	-	-	-	-	-	-
930	0,693	-	-	-	-	-	-	-	-	-	-	-	-	-
990	0,669	-	-	-	-	-	-	-	-	-	-	-	-	-
1050	0,648	-	-	-	-	-	-	-	-	-	-	-	-	-
1080	0,639	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	0,836	0,811	0,722	0,643	0,573	0,539	0,877	0,763	0,661	0,626	0,598	0,520	0,446	0,420

Table 5

№	Interval between repairs	The average probability of fail-safe functioning	Interval between repairs, monthly	Duration of fail-safe functioning, monthly
1	New wagon-warehouse repair (WR) №1	0,836	36	30,096
2	WR №1 -WR №2	0,836	24	19,464
3	WR №2 -WR №3	0,836	24	17,328
4	WR №3 -WR №4	0,836	24	15,432
5	WR №4 -WR №5	0,836	24	13,752
6	WR №5 – CR	0,836	24	12,936
7	CR - WR №6	0,836	24	21,048
8	WR №6 -WR №7	0,836	24	18,312
9	WR №7 -WR №8	0,836	24	15,864
10	WR №8 -WR №9	0,836	24	15,024
11	WR №9 -WR №10	0,836	24	14,352
12	WR №10 -WR №11	0,836	24	12,480
13	WR №11 -WR №12	0,836	24	10,704
14	WR №12- wagon removal from the inventory park	0,836	24	10,088
15	Average estimate	0,836	-	16,205

The schedule change in the average limit of the probability of fail-safe functioning of the cistern wagon. The average estimates of the probability of fail-safe functioning of the cistern wagon in the interval between repairs are shown in table 1.5.

Abstract. The probability of the fail-safe functioning of the cistern wagon in the designated service period has been determined using the information resources of “the quality subsystem of the production and scheduled repair of freight wagons”. The schedule change of the average limit of the probability of fail-safe functioning of the cistern wagon in the interval between repairs has been compiled.

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Development of a theoretical calculation algorithm for forecasting the number of tourists for the regional tourism business

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Abstract: Forecasting the number of tourists by month can help the region's tourism business prepare for the next season, in particular, in the future, in the correct selection of capacity of hotels, appropriate inventory, number of workers serving the facilities, capital investments, investments, volume and other economic indicators of tourist infrastructure facilities, as well as their implementation dates and raising financial rewards from them. The simplest method of forecasting is the method of direct extrapolation, which is based on the study of the dynamics of change in economic events during a particular time span and the transfer of patterns revealed to the future.

Keywords: TOURISM; SEASONALITY; NUMBER OF TOURISTS; FORECASTING.

1. Introduction

Tourism is an integral part of life in modern society. The role of tourism in the global economy is constantly growing. The development of tourism in Georgia can bring a major boost to the country's economy, have a positive impact on the development of regions, lead to an improvement in the socio-economic situation of the population, and promote the wider use of the country's rich material resources. Forecasting the number of tourists by month can help the region's tourism business prepare for the next season, in particular, in the future, in the correct selection of capacity of hotels, appropriate inventory, number of workers serving the facilities, capital investments, investments, volume and other economic indicators of tourist infrastructure facilities, as well as their implementation dates and raising financial rewards from them. The simplest method of forecasting is the method of direct extrapolation, which is based on the study of the dynamics of change in economic events during a particular time span and the transfer of patterns revealed to the future.

2. Main part

As we noted above, the simplest method of forecasting is the method of direct extrapolation, which is based on the study of the dynamics of change in economic events during a particular period and the transfer of patterns revealed to the future [3, 4, 5].

The advantage of the method lies in its universality, although it requires observation of many numbers – a time series. **A time series** is a sequence of time-varying retrospective values of the prediction object. The method of extrapolation allows to identify the general trends of change of a time series over the years - to build a smooth line (trend) of the development of a given series. **A trend** is an analytical or graphical representation of a change in a time-varying function, which is obtained as a result of separating a regular (non-random) component of a time series. Analytical alignment (smoothing, interpolation) of a time (statistical) series is used to build a trend, the essence of which is to find a mathematical representation $y_t = f(t)$ that reflects a major pattern of alteration in a given event, such as a function of time. Tourist flows are of a clearly seasonal nature, which is determined by many factors (time of year, climate, holiday periods, vacations, etc.). Only using the curves that are widely used to adjust the data (line, parabola, hyperbola,...), it is not possible to take into account seasonal changes, since they are not periodic functions of time.

Seasonal events can be represented by a Fourier series whose harmonic coefficients will also be a function of time to reflect long-term change as well. The use of a Fourier series is convenient when the character of the alteration in the event during the year is close to sinusoidal. In other cases, the number of required harmonics increases, and the process of smoothing a time series is complicated. From this perspective, in the case when the alteration in the event (tourist flow intensity) according to the months of the year is described by a curve of a rather complex shape, we must first find out the regularity (tendency) of change of its slowly variable, relatively constant component by finding the trend over a relatively long time (several years), and then taking

into account the influence of seasonal factors. The procedure of smoothing a time series is aimed at minimizing the random deviations of the empirical points representing the process from a certain theoretical smooth curve (trend). The most common is the method of averaging the levels of the surrounding points from a certain set, while this operation moves along the row of points, which is why it is called a **moving (sliding) average**. An important task is to select the shape of the trend that best reflects the essence of the process under study, as well as to find the best values of the unknown ($a_0, a_1, a_2 \dots$) parameters of the trend equation [3]. Different trend shapes can be used to determine the regular multiplier for smoothing analysis:

- First-degree polynomial or linear function;
- Second-degree polynomial or parabola;
- Value dependence;
- Logarithmic dependence;
- Hyperbolic dependence.

For linear dependence:

$$\hat{y} = a_0 + a_1 t; \begin{cases} \sum y = na_0 + a_1 \sum t \\ \sum yt = a_0 \sum t + a_1 \sum t^2 \end{cases} \quad (1)$$

For parabolic dependence:

$$\hat{y} = a_0 + a_1 t + a_2 t^2; \begin{cases} \sum y = na_0 + a_1 \sum t + a_2 \sum t^2 \\ \sum yt = a_0 \sum t + a_1 \sum t^2 + a_2 \sum t^3 \\ \sum yt^2 = a_0 \sum t^2 + a_1 \sum t^3 + a_2 \sum t^4 \end{cases} \quad (2)$$

For logarithmic dependence:

$$\hat{y} = a_0 + a_1 \log t; \begin{cases} \sum y = na_0 + a_1 \sum \log t \\ \sum y \log t = a_0 \sum \log t + a_1 \sum (\log t)^2 \end{cases} \quad (3)$$

For hyperbolic dependence:

$$\hat{y} = a_0 + \frac{a_1}{t}; \begin{cases} \sum y = na_0 + \frac{a_1}{\sum t} \\ \sum \frac{y}{t} = \frac{a_0}{\sum t} + \frac{a_1}{\sum t^2} \end{cases} \quad (4)$$

For value dependence:

$$\hat{y} = a_0 * a_1^t \Rightarrow \log \hat{y} = \log a_0 + t \log a_1; \begin{cases} \sum \log y = n \log a_0 + \log a_1 \sum t \\ \sum \log(yt) = \log a_0 \sum t + \log a_1 * \sum t^2 \end{cases} \quad (5)$$

In the case of linear interpolation of the initial data with linear dependence, the coefficients a and b of the linear regression equation $y = bx + a$ are found using the expressions [2]:

$$a = \frac{n \sum (t \cdot y) - \sum y \cdot \sum t}{n \sum t^2 - (\sum t)^2}; \quad b = \frac{\sum y \cdot \sum t^2 - \sum (t \cdot y) \cdot \sum t}{n \sum t^2 - (\sum t)^2}. \quad (6)$$

After calculating the parameters of the equation, we obtain the mathematical model of the descriptive function $\hat{y} = f(t)$, however, the evaluation of the parameters in the equation itself is not a proof that the data calculated according to this model will necessarily approach the actual ones and this model correctly expresses the trend of the event development.

Methods for choosing the best shape of the trend are as follows:

1. **Visual** – based on graphic representation of a time series.
2. **Method of sequential differences**, that is, finding the first, second, third differences of the levels.
3. **Growth characteristics method**: absolute and relative growths of the studied index are calculated.

Seasonality is taken into account through seasonality indices (coefficients). When it comes to a one-year period, then the seasonality index is defined as the ratio of the initial (empirical) y_i - level of the i -th month of a time series during the year to its average y level

$$k_{s,i} = \frac{y_i}{\bar{y}}. \quad (7)$$

It is evident from this that if we know the average level $\bar{y}$ and the seasonality index for any year, then we can determine the value y_i by the formula

$$y_i = \bar{y} \cdot k_{s,i}. \quad (8)$$

When it comes to a period of several (m) years, in order to avoid random deviations, resort to calculating the values of seasonality indices averaged by these years

$$\bar{k}_{s,i} = \frac{\sum_{j=1}^m y_{i,j}}{\bar{y}_0}, \quad (9)$$

where $y_{i,j}$ is the initial (empirical) level of the i -th month of a time series for the j -th year ($i=1,2,\dots,12$);

$\bar{y}_0$ - average level for the entire reporting period.

The average seasonality indices calculated in this way are free from the influence of the main development trends and random deviations. In the practice of economic analysis, various methods of calculating seasonality indices are used, including simple averages, analytical alignments, relative numbers, moving averages, etc. [1,2,3]. the ratio of the initial (empirical) y_i -level of the i -th month of a time series during the year to its average y level. The seasonality index is generally determined by the ratio of the initial (empirical) y_i , level of the i -th month for the j -th year of a time series to the theoretical (calculating) $y_{t,i,j}$ level which serves as a comparable base. If the trend level at point t (month) is taken as a comparable base for the average level during the corresponding year, or the average level during the entire reporting period, then we will have the following expressions:

$$k_s = \frac{y_t}{\bar{y}_{tr}(t)}, \quad k_s = \frac{y_t}{\bar{y}_{year}(t)} \quad \text{or} \quad k_s = \frac{y_t}{\bar{y}_0}. \quad (10)$$

Figure 1 illustrates a diagram built in the Microsoft Excel environment based on the aforementioned methodology for forecasting monthly tourist flows. Along with the data of the previous 3 years (36 months), the data of the next forecast year are included here. Figure 2 shows a bar graph for the forecast of monthly tourist flows for the next forecast year.

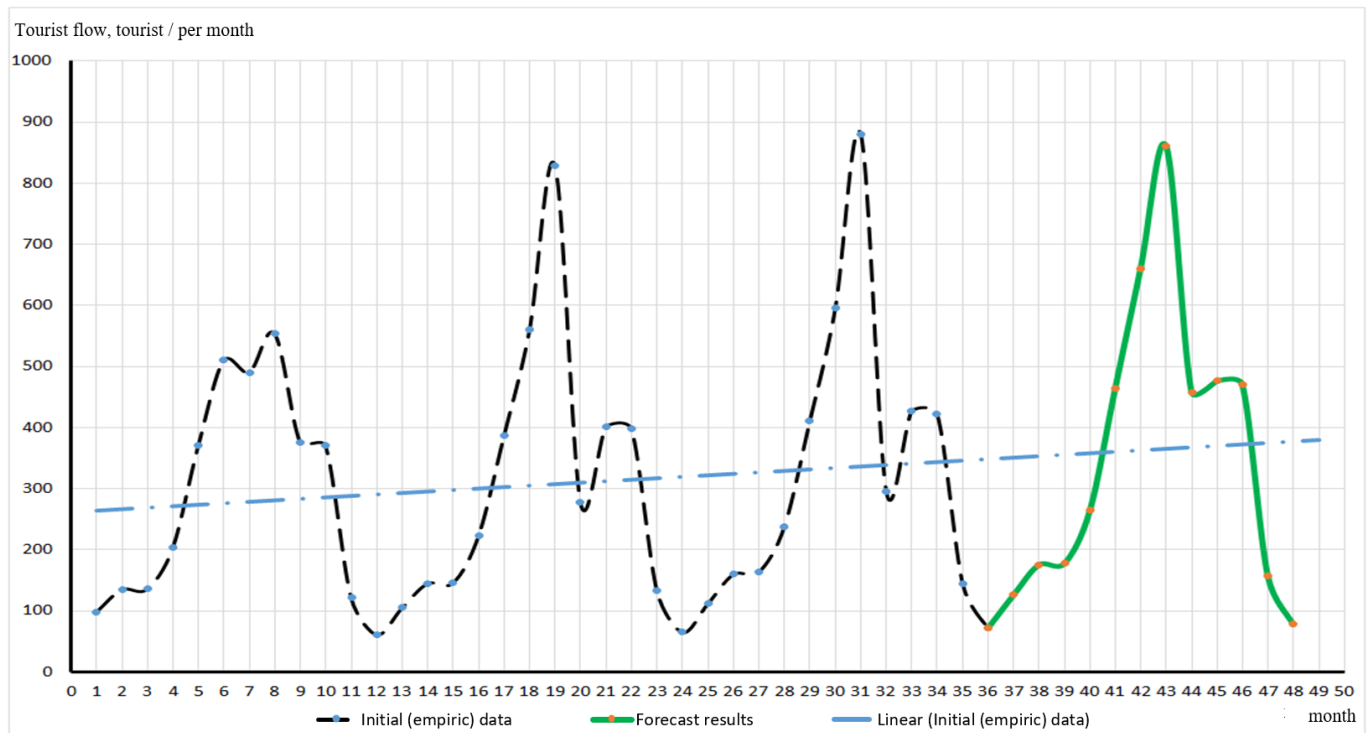


Fig. 1. Forecast of the tourist flow for the next 12 months based on the data of the previous 36 months

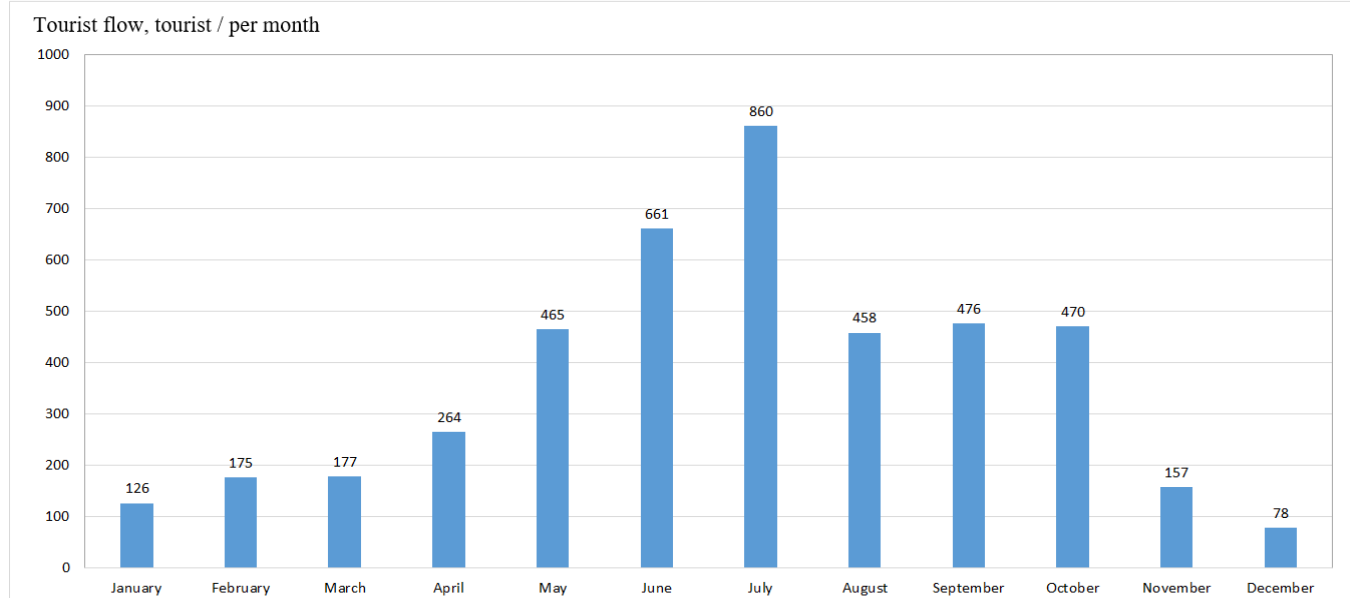


Fig. 2. Histogram of forecast monthly tourist flows for the next forecast year

It is not enough to take into account only the increase in the number of tourists for more accurate forecasting of tourist flows. It is also necessary to take into account additional factors, which significantly affect the volume of the tourist flows. In general, studies conducted throughout the region have shown that the current approaches to tourism in the region do not contribute to its rapid development. It is necessary to implement quick measures that can have a positive impact on the tourism development in the region and simultaneously increase the attractiveness of the tourism sector [4]. Among them, it is important to expand competitiveness in the tourism direction in the region, to allow tourism and transport enterprises to increase their contribution to the development of the country's economy. It should be noted that proposals and recommendations from both theorists and practitioners in the field of tourism should be used [4,5,6]. The conducted studies allow us to conclude that the existing scientific, methodological, and practical approaches in the field of tourism and transport, the structural reforms implemented in Georgia in the direction of transport and tourism, are not sufficient and effective in order to promote tourism development. The joint efforts of all participants of the regional tourism market are definitely needed to ensure the development of the region's tourism potential by implementing specific measures in a short period, which in itself will have a beneficial effect on the economic and social spheres in general. However, that requires not just the new methods of research and analysis of tourism, but also a more effective mechanism for their implementation[4,5].

3. Conclusion

1. An algorithm for theoretical calculation of seasonal tourist flows on tourist routes was developed, which allows forecasting the number of tourists by month based on the data of the previous three years, which can help the tourist business to prepare for the next season.

2. It is not enough to take into account the increase in the number of tourists for a more accurate forecast of tourist flows. It is also necessary to take into account additional factors, which significantly affect the volume of the tourist flows. Important among these are:

- Absence of an integrative approach in tourism development plans, which is a significant obstacle in tourism development and deprives the sector of one of the growth

points of development in terms of attracting additional investments;

- Insufficient statistical registration of passengers, tourists and traffic flows, without which it is impossible to forecast and plan the tourism potential of the region;
- The existing opportunities that the region has are currently insufficiently used for the development of tourism business.

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Road Safety – a New Look at the Factors That Influence Road Traumatism

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Abstract: *The creation of a safe system is crucial to a more stable urban environment and the improvement of society's well-being. The primary components for successfully reducing the number of traffic accidents and road traumatism in general are the capacity of state institutions and the management of processes that involve road safety. Despite the massive amount of funds invested in designing safe roads, as well as restrictive elements along the road infrastructure and especially control, the share of drivers who view speeding as natural is growing. The purpose of the paper is to identify the invisible factors that push drivers to drive with excessive speed within urbanized environments. Emphasis is put on the significance of the personality characteristics, competence and behavior of drivers. The inferences from this study can help determine the direction of development for road safety in Bulgaria.*

Key words: road safety, road traumatism, accidents, human factor, excessive speed

1. Introduction

While the number of traffic casualties in Bulgaria has dropped by 5% over the last 3 years (2021-2023), there has been an 11% increase in the number of injured people, and a 12% increase in the number of serious accidents [1]. In Sofia, the number of casualties and injured vulnerable traffic participants such as pedestrians and cyclists has grown in recent years. While the reasons for these alarming numbers are often found in human mistakes, traffic organization and road infrastructure are equally as important. The latter is designed to give cars the right of way, despite the growing number of violations and reckless drivers and the increasingly inadequate implementation of traffic laws. Quite often vulnerable participants are accused of jaywalking, looking at their phones while on the cross-walk, cycling in pedestrian zones, but in the majority of cases it is the fault of drivers who either drive with excessive speed or deny pedestrians the right of way.

In practice, most traffic accidents (TA) are directly or indirectly involved with the human factor, i.e. the way drivers behave while driving. The implementation of a multitude of preventive measures for limiting road traumatism does not always help improve road safety. In order to achieve maximum effect, the restrictive measures need to be in synergy with rules and effective sanctions for traffic law violations. Effective traffic safety training and regular communication campaigns are required as well. Depending on the reasons for traffic accidents, there are risk factors which are always subject to scrutiny such as speeding, neglecting the use of seatbelts and helmets in the case of cyclists and motorists, and driving under the influence of alcohol and narcotic substances. Emphasizing the human factor as a generator for change and a primary element for preventing emotional actions while driving is fundamental to the creation of a safe transport system. Accidents result from a multitude of factors which interact under the influence of a specific reason that is the cause of conflict situations – denying right of way, failure to observe roadway markers, ignorance of the meaning of road signs, and ultimately misjudging the road environment. Most systems that classify the reasons for traffic accidents focus on the mistakes and actions of traffic participants [2]. The purpose of this article is to show how people's behavior or emotional state can result in misjudgment of the transport situation, which in turn leads to the occurrence of traffic accidents.

2. Methods and Data Processing

The study utilizes data from a questionnaire survey conducted by the author on location during the occurrence of TA within the city of Sofia, more specifically in the Druzhba and Mladost residential districts. Accidents where there were no casualties, only injuries and material damage, have been studied. In most cases bilateral protocols have been drawn up without the participation of MTC "Traffic Police" representatives. Individual interviews have

been conducted with drivers and other traffic participants (passengers, pedestrians, cyclists and, in some cases, people who had witnessed the accidents). The main questions are focused on information regarding the reasons for the accidents, namely:

- The actual traffic situation before, during and after the accidents;
- What is the physical and psychological state of the people involved in the accidents (sometimes it is a personal judgment of the author of the research);
- Background of the journey; purpose of the journey; is it routine or is it incidental;
- Driving habits and practice; driver occupation and age; years of driving experience;

During the interviews there were difficulties in regards to determining the level of education of the participants, whereas gender was not taken into account for subjective reasons. The volume of the information depended primarily on the actual psychological state of the people involved in the accidents. In order to determine all the factors that led to the occurrence of the accidents, quantitative and qualitative analyses have been implemented, especially with the cooperation of MTC "Traffic Police" personnel. The method that was utilized to process the data is analysis of the collected content.

3. General Formulation of the Issue of Road Safety in Bulgaria

The issue of road traumatism is exacerbated by the rapid motorization in Bulgaria, the low quality of the safety of road traffic systems, and the lack of institutional capacity (even for management of results). From a socio-economic perspective, Bulgaria is paying a heavy price for automotive mobility, which is the reason for economic losses that amount to approximately 2% of the GDP [3]. In that regard, measures for improving road safety and reducing the number of casualties and people injured in traffic accidents are being undertaken in Bulgaria. Practical measures which have proven to be effective in specific aspects of safety in terms of drivers' behavior, creating a safe infrastructure, renewing the vehicle fleet and imposing speed limits are being implemented systematically. The national strategy for improving traffic safety along Bulgarian roads for the 2021-2030 period [4] is primarily focused on the way drivers behave while driving. There are multiple factors that influence drivers' behavior, namely experience, age, emotions, occupation, driving conditions, fatigue, attitude towards traffic rules and traffic situations. The behavior itself can be characterized as ranging from normal through risky to aggressive, which changes alters the ability of drivers to assess risks correctly and make the right decisions when driving in different situations. Making a decision about aggressive or normal (calm) driving is

crucial to improving road safety and reducing road traumatism [5]. The way drivers behave gives us information about the connection between risk perception and improving the ways we use personal vehicles on a daily basis.

The analysis of the road safety data based on the number of deaths per 100 000 or 1 million shows a drop in these indicators (deaths resulting from TA) in both Europe and Bulgaria. This data is visualized in Table 1 [6].

Table 1: Number of casualties, injured people and serious traffic accidents for the 2021-2023 period

Years	Deaths per 1 million	Casualties	Injured	Serious TA
2021	81	561	7609	6080
2022	78	531	8422	6609
2023	82	525	9101	6993

Source: Ministry of Interior

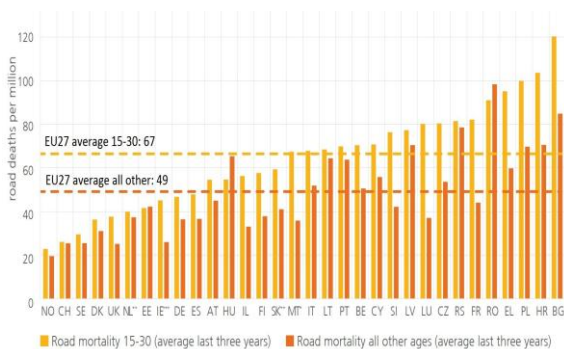


Fig. 1 Number of casualties and injured people in the EU for the 2019 – 2023 period.

Source: Eurostat, ETSC [7-8]

Generally, the population in Europe has increased by a little under 1% (from 736 million to 742 million) over the last 10 years, whereas the vehicle fleet in Europe has grown by 20% (from 200 million to 250 million). In other words, more people + more cars = more accidents [9]. For Bulgaria, the statistics for the last 10 years are stranger, namely less people – a 13% drop (by 800 000) in the population, and a 13,3% increase in the number of cars (400 000 more, from 2,6 million to 3 million) [10].

A common misconception is that, in order to solve the issue of road mortality, low-income countries need to become high-income economies first and focus their efforts on building and developing higher-class roads (respectively higher speed), which will help improve the economic efficiency of transport. In actuality, speeding leads to increased traffic jams and as a whole the benefits are insignificant, especially over short distances, like in an urban environment. The rule is to invest in road safety, which, in addition to being cost-effective, can also help low-income and medium-income countries become high-income countries. The risks of death and injuries from TA in countries with low level of economic development are systematically higher compared to countries with high level of development.

4. Analysis of the Factors That Influence Traffic Accidents

Excessive speed is a fundamental factor when it comes to securing road safety, and as such, it is the leading cause for approximately 40% of all risks that driving involves. The role of

excessive speed is examined in terms of the way it influences drivers' behavior when they react to various critical situations. Speed influences safety even when we are driving within the speed limit but in a way that is still too fast for specific road conditions, i.e. if the roads are poorly lit during nighttime, if weather conditions change drastically, or if the traffic is temporarily reorganized due to repair work. In addition to being a violation of the Road Traffic Act, speeding has a number of consequences, namely:

- Even the slightest distraction or road obstacle increases the probability of losing control over the car;
- Considerably increased braking distance, including longer reaction time;
- Heavier economic and social consequences due to the increased degree of severity of the collision and respectively the heavier injuries;
- And, of course, increased fuel consumption.

Ultimately, speeding endangers the lives of the drivers, their companions and all the people present in the environment where the cars are being driven.

The main factors analyzed during the post-accident polling of the participants within two residential districts in Sofia (Druzhba and Mladost) include: personality traits of drivers, social pressure, use of alcohol and narcotic substances, the road infrastructure and its accompanying environment, the vehicles themselves and listening to music. It has been determined that one of the main reasons that influence the occurrence of TA is driver negligence, which is caused by busy everyday life, talking on the phone, listening to music, and the transport environment itself. The first factor, which can be defined as a "personality" factor, is associated with our way of life, value systems and the attitudes we have before we get in our cars. All of them influence decision-making and govern our emotional control when we are in a risk situation. Analysis of the answers in the questionnaire interview has outlined the role of instructors which can study drivers' self-reflection and determine the risk tendencies and personality traits that affect their driving. The personality factor is also associated with the driver's profession. A CNN Money survey [11] shows the influence that people's professions have when they find themselves involved in risky situations and incidents. The study identifies 40 professions which have the most predisposition to involvement in traffic accidents. Something interesting about this study is the professions occupying the Top 5 spots and the ones occupying the Bottom 5 spots. The top spots in the list of the most dangerous drivers are occupied by students, doctors, lawyers, architects and real estate brokers. What people who work fields have in common is overstrain, which is associated with their everyday commitments, as well as using mobile phones as a means of distraction, considering the nature of their jobs. For Bulgaria specifically, in addition to the aforementioned signs, there is another one, namely the profitability of these professions, which makes the people working in these fields indulge in speeding when driving. Although students are an exception to that rule, the reason why they are at the top of the list is due to inexperience and self-validation in front of their colleagues. The main reasons why young drivers are the ones most frequently involved in traffic accidents include:

- Inexperience;
- Driving with other teenagers;
- Negligent or sleepy driving;
- Excessive speed;
- Driving in an intoxicated state;
- Driving at night;
- Incorrect use of seatbelts and helmets.

Another thing that drivers who work in these fields have in common in terms of their frequent involvement in accidents is their

ambition and excessive confidence in their ability to control things around them, which makes them take bigger risks.

Pilots, firefighters, farmers and housekeepers are classified as drivers who pose the least amount of risk. A common trait of people who work in the first two fields is that they are well-trained in terms of the dangers of driving. Furthermore, firefighters take part in cleanup and provide first aid at sites where serious accidents occur, not to mention they are very much aware of the consequences of speeding. People's personality traits and the way they behave when driving are crucial in regards to the other two professions. In Bulgaria, the same can be said for people who work in the first two fields and housekeepers to a certain extent. The rule of profitability and ambition applies more to farmers. Slight corrections are made to the top and bottom spots of the list in regards to the two categories – involvement in traffic accidents and speeding, but without resulting in accidents, only penalties in accordance with the Road Traffic Act (slips and acts).

Compliance with general traffic movement (social pressure) is another factor that influences road traumatism. When we are out on the road, especially at the large boulevards with dividing stripes between individual traffic lanes, we tend to comply with the movement of the other participants. When we are overtaken with sound signals, glares and/or vulgar gestures during certain moments of our journey, some drivers accelerate as a result of this "social pressure". The interviews with the drivers have determined that this pressure can also work in reverse, towards steadying the traffic. This can be achieved when the other traffic participants create conditions where aggressive drivers can overtake at places where it is convenient and safe to do so, thus helping steady the traffic and decrease road tension.

The growing number of problems in a society, such as the pandemic from 4 years ago, the inflation processes in Europe and Bulgaria, war conflicts, and general injustice in society, has caused many people to develop various psychological and chronic disorders, which in turn has forced them to resort to medication, and in some cases, particularly with young people, to the use of alcohol and narcotic substances. As a result, vehicles and by extension driving have become a type of outlet for this disappointment and the anxiety that comes with it, thus triggering road rage, which leads to speeding and overreacting to even the smallest provocations. The increased use of these medications impedes drivers' judgment, influences their mood and causes them to make the wrong decisions when they are driving. The fact of the matter is that most of us have disregarded traffic limits at one point, simply because we have never been in an accident caused by the speed at which we drive. In actuality, most drivers do not have an adequate judgment about the danger they can cause when speeding. The majority of them disregard speed limits due to the fact that they have never found themselves in a critical situation as a result of that. This sense of safety is based on the fact that luck, time and the tolerance of other traffic participants have kept aggressive drivers from finding themselves in a critical situation despite speeding. Judgment about the way of driving is determined in accordance with drivers' perceptions of what is safe, not what is actually on the road and the things that can happen. Bad habits, lack of experience, excessive confidence, negligence and to a certain extent complacency impede correct and adequate assessments of road risks. When it comes to speeding, the main misconception is that the faster we drive, the more difficult it is to cognitively process the rapidly changing road situation. The majority of the interviewed drivers have turned out to be people who have never used public transport and rely solely on their personal vehicles to travel within the urban transport system, which is the primary reason why they are more inclined to go over the speed limit to "make up for lost time", greatly overestimating the benefits of saving time in the process.

The design of the roads in the studied regions is of vital (key) importance for speeding, respectively traffic accidents. The streets in Sofia are designed on the basis of increasing transmissivity, i.e. a city oriented towards cars, not the safety of vulnerable traffic

participants – pedestrians and cyclists. For instance, the expansion of "Alexander Malinov" Blvd. in Mladost, "Ivan Geshov" Blvd. in Sofia's center, "Jawaharlal Nehru" and "Tsaritsa Giovanna" Blvd. in Lyulin and "Buxton Brothers" Blvd. with more lanes and better visibility gives confidence that we can travel at higher speed. In actuality, however, the possibility of driving more safely at higher speed based on improved visibility, is an illusion. In an urban environment, the design of more narrow streets, combined with trees and vegetation, increases uncertainty, which is a prerequisite for reducing speed. In fact, as Charles Marohn shows in his study on "85% of speed", roads between populated areas are different compared to streets in an urban environment [12]. Roadways in cities are far more complex and, in a way, they are a platform for building wealth within a community. This concept suggests that most drivers do not determine their speed on the basis of a specific number, but rather on the basis of how safe the environment seems to them. As such, the implementation of "85% of speed" is inappropriate when streets in an urban environment are designed and the approach of letting violations go unpunished (condonation) is frequently used. This in turn causes drivers to misjudge and misperceive the complexity of the environment in which they drive. The engineering expansion of the streets in Sofia creates comfort zones, makes turns smoother, and additional elements, which in principle are interurban roads and highways, are designed. This creates a deceptive feeling that the environment is simple, that you can relax as a driver, that you can dull your attention and not be vigilant. In actuality, speed increases and accidents become more frequent, i.e. the wrong signal is given that safe driving with excessive speed is possible through designing streets. As a result of this wrong idea, drivers make the wrong decision due to incorrect assessment of the situation, which leads to frequent crashes. The latest technological solutions, such as electric cars, further exacerbate this problem, as their design includes powerful engines and perfectly insulated coupes, which is a prerequisite for smooth and unnoticeable speeding. With these cars, power is supplied instantaneously, quietly and mainly in an exciting manner. This once again provides us with a false sense of safety and is a serious prerequisite for ending up in critical situations.

In conclusion, streets in an urban environment need to be designed in a way that will make drivers feel uncomfortable if they decide to endanger their safety, as well as the safety of the other traffic participants, by increasing speed.

Road traumatism is strongly influenced by listening to music in cars. Strong and fast musical rhythms elevate the pulse, which in turn affects the manner of driving. A study conducted by the South China University of Technology has determined that drivers who listen to loud music in their cars drive faster, have an elevated pulse, are more easily distracted and diverge more frequently from the traffic lane [13]. In regards to the surveyed drivers in Sofia (post-TA), results have shown that almost all of them (89%) had their radio or music device on, but all of them answered that this did not influence their behavior prior to the occurrence of the accident. The questionnaire survey shows that drivers who listen to music with a higher tempo in their cars and do not use public transport to traverse the urban environment are more frequently involved in accidents.

5. Conclusion

Deaths and heavy injuries caused by traffic accidents can be prevented if they are controlled effectively, so they do not exceed the permissible levels of injury for people. Of course, the easiest thing to do is to point out and accuse the obvious traffic violators, namely the young people who most frequently race on the streets and aggressively violate the rules. Identifying risk patterns of behavior during driving through clear policies in the training of young drivers is a prerequisite for reducing future road accidents.

The questionnaire survey has shown that the implementation of a system approach to road safety needs to take into account drivers' behavior in the context of traffic conditions, the changing environment and all factors that contribute to the prevention of

crashes. Road safety in urban conditions can be achieved with certain specific measures such as dynamic determination of speed limits, various forms of "intelligent" law enforcement, limiting speed through street design (3D cross-walks), automatic emergency braking of vehicles as a key component for preventing collisions.

The safety of vulnerable participants can be improved through positive approaches that take into account the limitations of human capabilities while simultaneously helping drivers react adequately, correctly and in a timely fashion when unforeseen road dangers suddenly arise. Examples in that regard are purposeful, accessible real-time information regarding traffic in Sofia, warnings about changes in the traffic situations due to repairs, new traffic organization, conflict intersections, even the dangers of bad meteorological situations. Road infrastructure safety can be achieved by turning it into an intelligent one, based on intelligent speed management systems and the avoidance of factors that cause distraction. The achievement of these recommendations requires effective actions oriented towards results and resource collateral in road safety management. This involves shared responsibility of all traffic participants, as well as the creation of a system for designing, planning, commissioning, managing and using intelligent transport systems that provide safety despite human fallibility.

The mission for “zero mortality” on Bulgarian roads (in particular in Sofia) can be an achievable goal if safety policies, which are adapted to new challenges such as urban traffic jams, the increasingly aggressive behavior of drivers and the dwindling resources for infrastructure maintenance, are implemented [14]. As Nikolova writes, “society desires the implementation of transport policies that guarantee the security of human life, by implementing actions for increasing road safety” [15].

Decisions involve better and more intelligent speed management, improving the parameters of the infrastructure regarding the safety of vulnerable traffic participants and providing innovative systems for fast travel via public transport in an urban environment. A step in the right direction when it comes to reducing road traumatism is studying the possibility for implementing “coaching” as a training method in the development of driving skills and a basis for preventing negative behavior during driving. In conclusion, we all know that there is a difference between existing possibilities and realized (utilized) possibilities in terms of road safety management.

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Port infrastructure as an element of the logistics supply chain

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Abstract: Ports are what initiate the social and economic growth of a region, not only enabling trade but also serving as a center for social activities. Nowadays, most ports (especially seaports) are well equipped with specialized machinery such as forklifts and gantry cranes to facilitate regular cargo transactions. Ports are also a major source of employment as a large number of workers are employed there.

Keywords: ECONOMIC GROWTH, PORT INFRASTRUCTURE, SOURCE OF EMPLOYMENT, TRANSACTIONS, CARGO

1. Introduction

A port is a facility on the shore of a sea, river, lake or bay designed to receive vessels and load and unload cargo and passengers from them. The term is also used for a city with such a facility. It is also called a port, and an obsolete word with the same meaning is a harbor. A port can be defined as one with its adjacent waters or water area that can provide shelter for many boats and ships (to transfer of people or cargo), and it can also allow for constant or periodic delivery of shipments. In layman's terms, a port is a place to facilitate the loading and unloading of vessels.

Increasing the efficiency of the maritime business is important not only for the business itself but also for those employed in it. The need for efficient, human-oriented and "green" shipping is also important because of the importance of shipping itself in today's world. In the European Union alone, 90% of the foreign trade and over 40% of the domestic trade is carried out by sea. Annually, 3.5 billion tons of cargo and 350 million passengers pass through European seaports, which generates an added value of about 20 billion euros. The outlook for shipping and related activities is also positive. According to research by the Irish Maritime Institute, the sectors with the greatest potential for growth are shipping, ports, aquaculture, renewable energy, underwater telecommunications and marine biotechnology. In addition, maritime transport is a locomotive for many other sectors: shipbuilding, marine equipment manufacturing, insurance, banking, brokerage, etc.

2. Ports as an element of the logistics supply chain

In Bulgaria, seaports of national importance are the Port of Burgas and the Port of Varna, and on the Danube - the ports of Ruse, Svishtov, Lom and Vidin. The Rhine-Main-Danube waterway is a major transport corridor in Europe. Through our Danube ports, there is a profitable and direct connection along the entire corridor from and to Bulgaria to Western and Central Europe, Ukraine, Moldova, Russia and Belarus. Bulgaria is also home to the southernmost port (Svishtov International Port) on the Danube River – fig. 1.

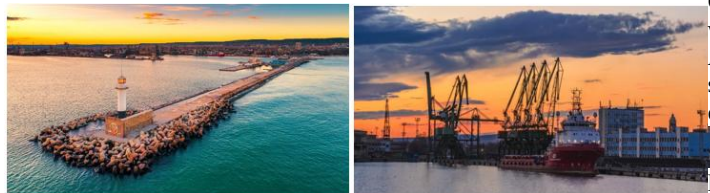


Fig. 1 Port of Varna

The main types of ports are:

1. Inland Ports – Inland ports are ports built for relatively smaller bodies of water such as rivers or lakes. They can be either for cargo or passengers or both. Traditionally, inland ports are man-made or naturally maintained harbors on the shores of small waterways such as lakes, rivers or estuaries and are rarely seen on seashores. Some of the inland harbors may also be specifically built for recreational purposes, allowing only small vessels or may only be used for ferries carrying people or for fishing activities. The St. Lawrence Seaway is an important inland port, and Montreal's inland port is the largest of its kind.

2. Fishing ports - fishing ports are related to the commercial sphere, since fishing is the main activity associated with them. Fishing activities can also be treated as a way of recreation. The existence of a fishing port is entirely dependent on the availability of fish in that region of the ocean. A fishing port can be an inland port or a sea port.

3. Warm water ports - these are the ports where the water remains yearly at a higher temperature. The biggest advantage when it comes to warm water harbor is that the water does not freeze during the frosty winters. Therefore, it is free to work all year round, without temporary interruption due to freezing. Such ports largely help to boost the nation's economy and the growth of the region where they are located. Two such major revenue-generating ports are Valdez Port in Alaska and Vostochn Port in Russia.

4. Dry Ports - Dry ports are defined as inland terminals that can be interconnected with a sea port through road or rail transport facilities and usually act as multimodal logistics hubs. A dry port is useful in the import and export trade of cargo and can help reduce the inevitable congestion at a nearby seaport. It is used specifically for transshipment of cargo to domestic destinations. This type of ports are used to connect importers and exporters from remote areas who do not have access to seaports for commercial or other purposes. There are close to 300 to 330 dry ports in India alone and surely more are being developed.

6. Seaports - Seaports are the most common type of ports in the world that are used for commercial shipping activities. These harbors are built close to the sea and accommodate both small and large ships. A seaport can be further categorized as a cargo port or a cruise port. Seaports form some of the largest and busiest ports in the world. They are the most common type of port and constitute a major element of water transport.

Ports are an indispensable and integral part of the logistics supply chain, and, in order to develop as logistics centers, they must operate in such a way as to meet the requirements of shippers and receivers of goods, the shipping companies and freight forwarders, as well as to coordinate of activities with port operators. Collaboration between supply chain partners must be ensured, which is crucial for the proper functioning of port operations. Adequate connectivity of ports with different modes of transport such as road and rail is necessary for transshipment activities to be carried out efficiently.

Ports are complex facilities that represent the link in the logistics chain between the supply of raw materials, the manufactured products, the storage of goods and their distribution to customers.

A port can be a natural facility or a man-made structure that provides a place for cargo to be loaded and unloaded. Ports can be for large oceangoing vessels, and, on the other hand, for inland waterways such as rivers and lakes as their depth plays a vital role and allows various types of ships to enter and berth in the port. To be efficient and normally functioning, seaports must meet various requirements, namely:

- Sea access – which refers to the physical characteristics of the port in terms of its access from the sea (naturally or through canals) and the necessary depths in the water area of the port;

•Port infrastructure - mainly represents the equipment of the port including the relevant equipment and facilities necessary for the loading and unloading activities and the storage of goods;

•Land access – in addition to sea access, land access is also needed to be able to reach the port.

Adherence to these basic principles, namely the availability of deep waterways and anchorages, protection from wind and swell and access to land transport, makes a given port attractive and well-functioning. All these requirements make the link between ports and logistics efficient and well functioning. When all these requirements are met, the actual execution of a delivery becomes quickly and easily achievable. When there is a connection between the ports and all modes of transport so as to optimize the delivery process, the whole process in question ensures no overdue delivery time (when there are no force major circumstances), and the faster everything is accomplished, the more deals will be made and thus the more income will be obtained. Once a port is strategically located, it is attractive to merchants whose main goal is making profit [4,6,7].

3. Stowage and securing of the cargo in the containers

There are a number of basic principles that apply to the stowage of cargo in containers. Cargoes that will be transported in containers must be well secured to prevent possible shifting of the cargo, as far as general cargo is concerned, and leakage, as far as bulk cargo is concerned. The safe transport of containers mainly depends on proper and stable stowage and even weight distribution. Containers must be stowed tightly so that the lateral and longitudinal shifting of the cargo in it is impossible - the cargo must be effectively secured. One of the main things that needs to be done is arranging the containers on board tightly. This can be achieved by converting the shape and dimensions of the package into an optimal container module or by loading the container on the basis of a module unit [2,3]. Methods of securing the cargo in the container are:

- Shoring - gratings, struts and beams located in the intercargo space to keep the cargo pressed against the walls or other cargo. Lashing - ropes, wire, chains, tapes or nets attached to the correct anchorage points and stretched against the load.

- Wedging: wooden pieces spaced, synthetic material pads, inflatable reinforcement to fill voids in the cargo and keep it stationary against the container walls. Lock - the load is built to give a three-dimensional effect of a brick wall.

There is no simple formula to follow when securing cargo. Each storage location must be treated individually - the type of cargo, the way it is stored, the equipment available or the permanent fittings in the container. The heaviest items should be wedged, nailed and tied down to prevent falling, damage or injury. It is also important to ensure that when the container doors are opened, the cargo will not fall out – fig 2.

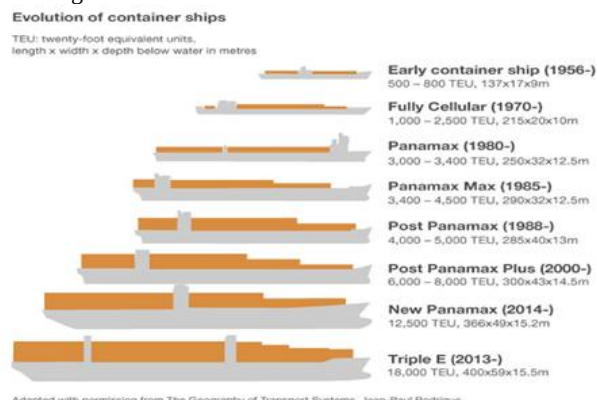


Fig. 2 Evolution of container ships

Organization of container transports. Liner shipping by sea arose in order to meet the increasing demands of shippers. During the past 50 years, the rise of container shipping has been evident,

developing the idea of general cargo transportation under linear conditions. It is believed to be the most efficient and environmentally friendly method of transporting goods. A medium-sized container ship emits 40 times less carbon emissions than a large aircraft. A line can be defined as ships that run on a schedule and on a specific route. This is a higher step in the development of shipping as a whole, as it provides an opportunity for merchants to plan their deliveries. For a line to exist, there must be a constant and sufficient volume of cargo flow of containers in the given direction. The largest share of global container shipping falls to the top 25 companies in this business. First in the ranking are MAERSK LINE, followed by MSC, and in third place is CMA CGM. As of 2020, the largest container ship is the HMM Algeciras with a capacity of 24,000 containers.

There are two types of container lines - feeder and ocean ones. Ocean lines transport containers over long distances, unloading them at transshipment ports - from there they are loaded onto feeder lines that deliver the containers to the final receiving ports. The organizational structure of a given line consists of several departments - logistics, marketing and operational, as well as an accounting department and line agents that support the overall and efficient execution of the process.

It should be taken into account that in sea transport, when the shipment is a container (FCL - Full container load), the handover takes place simultaneously with the acceptance of the loaded container by the sea carrier. When the goods are not placed in an entire container (LCL - Less than container load), the seller is obliged to transport it to the container terminal and hand it over to the carrier. In the partial load of goods (LCL - Less than container load), goods of more than one company are placed in a given container. Therefore, these services are more expensive.

Tariff charges are set in Swiss francs for the transport of a container between the main Danube ports. Depending on the load capacity of the container, the tariff is differentiated. Freight rates for 40-foot containers are determined by a factor of 2.0 compared to those for 20-foot containers. Freight charges for empty containers are set with a factor of 0.5, compared to those for full ones.

An interesting fact is that the International Code for the Carriage of Dangerous Goods by Sea contains requirements regarding the carriage of dangerous goods in containers.

The following rules apply: - the container must be sealed, dry and protected from damage and contamination;

- all parcels must be affixed with labels with a code;

- the product packaging must comply with the regulations and must not be damaged;

- only goods of the same danger class may be loaded;

- the goods in the container must be secured and compacted.

Leaders in Europe in terms of handling containers in port terminals for 2011 are: in first place Rotterdam (Netherlands), with a total of 14.7 million TEU containers handled, in second place Hamburg (Germany) with 9.0 million, in third place Antwerp (Belgium) with 8.3 million, in fourth place Bremerhaven (Germany) with 5.9 million, and in fifth place is Valencia (Spain) with 4.3 million handled TEU containers, i.e. the top five container terminals in Europe handled a total of 42.2 million TEU containers, representing approximately 28% of global container trade in 2011.

Documents for the handover of containers.

The main documents that are used for container shipping, as well as for international sea shipping itself, are:

1. The most important document is the Bill of Lading - it is a document certifying the acceptance of cargo for transportation, which is signed by the master or a person authorized by the shipowner for this purpose and plays the role of both transport and commercial document. It is a negotiable document.

The functions of the bill of lading are:

- receipt for cargo accepted for carriage and/or loaded on the ship - the bill of lading is issued for each individual consignment by one consignor to one consignee. As a receipt for accepted cargo, the bill of lading has two varieties: advance bill of lading and bill of lading issued upon loading.

- document of title - this function of the bill of lading turns it into a document proving ownership of the cargo, i.e. the designated consignee is entitled to receive the cargo.

- proof of concluded contract of carriage – these are issued by the line operator upon completion of loading, since in practice there is no other document that fulfills the function of a contract of carriage between the consignor and the carrier.

2. Sea Waybill – it is a receipt for cargo accepted for carriage and proving the existence of a carriage contract. The bill of lading is drawn up by the consignor in accordance with the cargo order in at least two original copies. The sea waybill is not a document of title certifying ownership of the cargo and is therefore a non-negotiable document.

3. Mate's Receipt - it is a document that certifies the acceptance of the cargo on board the ship. It contains data on the quantity and visible condition of the cargo and serves as a basis for issuing a bill of lading.

4. Cargo manifest - the manifest is an inventory of all the bills of lading on which the individual cargo lots are loaded on board the ship. The consignments are described separately by port of discharge.

5. Outturn report - a document containing information on the results of the delivery of the cargo for each bill of lading batch.

6. Certificate of quality - it is a declaration of quality, as it is a commercial document and its absence does not prevent the unloading of the cargo.

7. Other documents - for export, import or transit processing of shipments on transoceanic routes; certified certificates of origin; commercial invoices; insurance certificates; packing lists; blacklist certificates; certificate of commodity control before shipment; certificates of radioactivity; certificates for sanitary and veterinary control and others [8].

4. Pandemic of covid-19 affect shipping and ports

Since the early days of the COVID-19 crisis, the resilience and ability of ports to continue moving cargo has been determined by their ability to provide both safe and expeditious cargo handling and maritime services (e.g. loading and unloading, cargo storage and handling, patrol and emergency vessels, towing services, pilots, lashers, etc.). Keeping ports operational amid the COVID-19 outbreak, widespread lockdowns and growing restrictions on movement and travel required ports around the world to act quickly. Actions are focused on containing the outbreak, protecting the health and safety of the port community, and maintaining port operations and business continuity [1].

The drop in processed containers in the Black Sea terminals for the first half of the year and during the crisis that developed as an effect of the coronavirus COVID-19 pandemic is minimal and within the statistical error. The data showed that Black Sea container terminals reported just 0.33% fewer units handled, or 1,172,737 TEU. Nevertheless, Bulgaria ranks last in terms of the number of processed containers. While the rest of the countries reported a minimal decline, Ukraine recorded a substantial growth of 5.85%. An interesting fact is that of the total number of processed containers in the Black Sea, 4.28% passed through Varna, and 3.55% passed through Burgas. There is no change in the leadership position, which belongs to DP World's container terminal in Constanta, through which 17% of all containers handled in the Black Sea pass.

5. Conclusion

We live in a fast-paced, modern and technological world of daily innovations and sensational discoveries. This prompts us more and more to look for ways to optimize work not only in our everyday life, but also in water transport, shipping and ports in particular. As they affect various industries, technologies are giving impetus to their development - for example, artificial intelligence and blockchain, mainly embedded in smart ports, which also use the Internet to ensure more efficient processing of goods passing through them. All this facilitates the work of both the ports themselves and the internal work of the ships. Container shipping is the step towards the growth of maritime transport. The ability of containers to store and transport large quantities of goods (and also of different shippers) at competitive prices makes them affordable and desirable to shippers. Efficient storage and arrangement of containers on board the ship is another prerequisite for the growth of interest in this type of transport - it guarantees speed of delivery, safe packaging and correct marking. The advantages of this type of transport make it a leader in the maritime industry [5,9].

Ports are the link between the vast sea and the land. They are the basis for the development of trade, for the facilitation of delivery processes and the livelihood of millions. All the innovations gradually implemented or introduced nowadays in the maritime industry make ports the beating hearts of maritime trade. What will the future hold for us - we have yet to find out!

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Issues and concerns in the maritime education regarding cyber risk management

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Abstract: In accordance with Resolution MSC.428(98) "Maritime Cyber Risk Management in Safety Management Systems" the companies must implement the issues to their Safety Management Systems no later than the first annual verification of the company's Document of Compliance after 01 January 2021. Some of the biggest companies and associations from the industry have published their own Guidelines on Cyber Security Onboard Ships. However, the question on ship's cyber security is still not implemented in the syllabuses. As per International Ship and Port Facility Security Code (ISPS Code), part B, 8.3.5 the ship's security assessment should include radio and telecommunication systems, including computer systems and networks. This necessitates finding answers to the following questions: whether the Ship's Security Plan has to be revised to include the appropriate measures to protect both equipment and communication links or Cyber security plan itself will be enough to cover the issues; whether the Cyber Security Officer (CSO) will be the person who will tackle the problem or the companies have to hire a well-qualified additional person; whether such a person has to be a mariner or IT specialist. The aim of this article is research regarding implementation of Maritime Cyber Risk Management requirements to the vessel's Ship Security Plan (SSP) and qualification of the person responsible for companies' fleet cyber security.

KEYWORDS: SECURITY PLAN; CYBER, ISPS CODE, SSP

1. Introduction

Maritime cybersecurity is a problem which despite getting more and more attention, is still a major reason for concerns. Many organizations are involved in the issue: IMO, INTERCARGO, INTERTANKO, IUMI...

In general, the cyber security policy of each Ship's management Company provides guidelines to ensure the following:

- Confidentiality: Any important information that should be kept confidential and to protect access to confidential data and safety critical systems by placing a robust password control policy.
- Integrity: Maintain the integrity of information assets to keep everything complete, intact, and uncorrupted.
- Availability: Maintain the availability of systems, services, and information as and when required.

Cyber security requires an interdisciplinary approach and a comprehensive governance commitment to ensure that all aspects of the business are aligned to support effective cyber security practices.

2. Principality's cyber security system's characteristics

A cyber security framework is a set of cyber security activities, desired outcomes and applicable references that are common across critical infrastructure sectors. These frameworks can present industry standards guidelines and practices in a manner that allows for communication of cyber security activities and outcomes across the group both onshore and onboard vessels. Any shipping company identifies the need to establish and maintain an appropriate governance and risk management framework to identify and address risks for communications, networks and services. The cyber security framework functions include the following:

- Identify which assets need securing, as well as the threats and risks to them.
- Protect assets with the appropriate safeguards.
- Detect intrusions, breaches and unauthorized access.
- Respond to a potential cyber security event.
- Recover from a cyber security event by restoring normal operations and services.

According to the professor and former director of Information Security Group Keith Martin [1] in the sea at the moment is around 50,000 ships which are highly vulnerable for cyber attacks. In 2015 cybersecurity experts presented how easy it is to hack vessels [2]. They found security holes in Global Positioning System (GPS), Automatic Identification System (AIS), Electronic Chart Display and Information System (ECDIS) used for viewing digital nautical charts. Taking control over these devices might easily send the ship of the course while faking correct course on display. The International Maritime Organization (IMO), the United Nations (UN) body responsible for creating maritime regulations was really

late in case of cybersecurity recommendation because just in 2014 consulted what maritime cybersecurity guidelines should contain. Two years after that, they published first guidelines on cybersecurity risk management, but it was too general therefore not helpful with fighting against the hacker.

There is various equipment on board that can be classified into two categories:

- Information Technology (IT) equipment
- Operational Technology (OT) equipment

The IT and OT equipment on board are further broadly categorized as:

- Access Control systems
- Bridge systems
- Cargo management systems
- Communication, PA systems
- Propulsion and power management systems
- Administrative and crew welfare systems

The critical OT equipment is defined as a system, failure of which can immediately impact the safe operation of the ship or can directly result in a commercial loss/exposure. For the purpose of cyber security, below mentioned equipment of the vessel is identified as the OT critical equipment:

- RADAR (both X-band and S-band)
- AIS
- ECDIS
- GPS
- VSAT
- FBB
- Digital publication computer (CHARTCO / ADP & eNP publication PC Main & BackUp)
- Loading program / Stress monitoring system / ODM (Oil Discharge Monitor)
- Main Engine Control and Safety System

IT systems manage data while OT systems control the physical world and differ from traditional IT systems. OT is hardware and software that directly monitors/controls physical devices and processes, whereas IT covers the spectrum of technologies for information processing, including software, hardware and communication technologies. Traditionally OT and IT have been separated, but with the prevalence of the internet, OT and IT are coming closer as historically stand-alone systems are becoming integrated. Consequently, disruption of the operation of OT systems may impose significant risk to the safety of onboard personnel, cargo, damage to the marine environment and ship's operation. Typical differences between IT and OT systems can be seen in the table below:

Table 1: Differences between IT and OT systems

Category	IT System	OT System
System operation	*systems are designed for use with commonly	*differing and possibly proprietary operating

	known operating systems *upgrades are straightforward with the availability of automated deployment tools	systems often without built-in security capabilities *software changes must be carefully made according to maker's instructions because of the specialised control algorithms and possible involvement of modified hardware and software
Resource constraints	*systems are specified with enough resources to support the addition of third-party applications such as security solutions	*systems are designed to support the intended operational process and may not have enough memory and computing resources to support the addition of security capabilities
Performance requirements	*non real time *response must be consistent *less critical emergency interaction *tightly restricted access control can be implemented to the degree necessary for security	*real time *response is time critical *response to human and any other emergency interaction is critical *access to OT should be strictly controlled but should not hamper or interfere with human machine interaction
Availability (reliability) requirements	*responses such as rebooting are acceptable *availability deficiencies may be tolerated depending on the system's operational requirements	*responses such as rebooting may not be acceptable because of operational requirements *availability requirements may necessitate backup systems
risk management requirements	*manage data *data confidentiality and integrity is paramount *fault tolerance may be less important *risk impacts may cause delay of: ships clearance, commencement of loading/discharging, commercial and business operations	*control physical world *safety is paramount, followed by protection of the process *fault tolerance is essential even momentary downtime may not be acceptable *risk impacts our regulatory non-compliance, as well as harm to the personnel on board, the environment, equipment and/or cargo

3. Cyber security threat identification

In general, cyber-attacks can be categorized as “untargeted” and “targeted”.

“Untargeted” are attacks where a company or a ship’s systems and data are one of many potential targets and include the following tools and techniques:

- **Malware** – Malicious software designed to access or damage a computer without the knowledge of the owner. Such types include trojans, ransomware (i.e., data encryption on systems until a ransom is paid), spyware, viruses and worms. Malware software may also exploit known deficiencies and problems in outdated / unpatched business software. The term “exploit” usually refers to the use of a software or code, which is designed to take advantage of and manipulate a problem in another computer, software, or hardware. This problem can, for example, be a code bug, system vulnerability, improper design, hardware malfunction and/or error in protocol implementation and can be triggered remotely, or locally, often executed by the user, sometimes distributed via links in email attachments or through malicious websites.

- **Phishing** – Sending emails to a large number of potential targets asking for particular pieces of sensitive or confidential information. Such an email may also request that a person visits a fake website using a hyperlink included in the email.

- **Water holing** – Establishing a fake website or compromising a genuine website to exploit visitors.

- **Scanning** – Attacking large portions of the internet at random.

“Targeted” are attacks where a company or a ship’s systems and data are the intended target and include the following tools and techniques:

- **Social engineering** – A non-technical technique used by potential cyber attackers to manipulate insider individuals into breaking security procedures normally, but not exclusively, through interaction via social media.

- **Brute force** – An attack trying many passwords with the hope of eventually guessing correctly. The attacker systematically checks all possible passwords until the correct one is found.

- **Denial of Service (DoS)** – Prevents legitimate and authorized users from accessing information, usually by flooding a network with data. A distributed denial of service (DDoS) attack takes control of multiple computers and/or servers to implement a DoS attack.

- **Spear-phishing** – Like phishing but the individuals are targeted with personal emails, often containing malicious software or links that automatically download malicious software.

- **Subverting the supply chain** – Attacking a company or ship by compromising equipment, software or supporting services being delivered to the company or ship. Above examples are not exhaustive as other methods are evolving such as impersonating a legitimate shore-based employee in a shipping company to obtain valuable information, which can be used for a further attack. The potential number and sophistication of tools and techniques used in cyberattacks continue to evolve and are limited only by the ingenuity of those organizations and individuals developing them.

Cyber threats can be classified into 2 categories – “External” and “Internal”.

“External” threats include but are not limited to the following:

Table 2: “External” threats classification

Group	Motivation	Objective
Activists	*reputational damage *disruption of operations	*destruction of data *publication of sensitive data media attention
Criminals	*financial gain *commercial espionage industrial espionage	*selling stolen data *ransoming stolen data *ransoming system operability *arranging fraudulent transportation of cargo
Opportunists	*the challenge	*getting through financial cyber security defences *financial gain
states, state sponsored organisations, terrorists	*political gain *espionage	*gaining knowledge *disruption to economies and critical national infrastructure

“Internal” threats include but are not limited to the following:

Table 3: “Internal” threats classification

Group	Motivation
insecure systems	*unlocked equipment cabinets, offices or facilities *unattended user equipment
theft or equipment or data	*equipment or systems left unattended *inadequate security practises
impersonation of account	*weak passwords *loss of ID credentials *default admin account passwords
malicious software	*malware *outdated antivirus software
malfunctioning software	*unpatched software *inadequate change management process
restriction control violation	*inadequate access controls *inadequate security configuration
social engineering	*phishing attacks *ransomware

4. Qualification of the person responsible for companies' fleet cyber security

Effective cyber risk management relies on a clear allocation of responsibilities and tasks within the company. Cyber risk management is an integral part of ship management and ship operation, and different employees have different roles, responsibilities, and tasks. Furthermore, in some companies, some roles, responsibilities, and tasks are outsourced to third parties. The various responsibilities and tasks should be mapped to the job descriptions and/or role descriptions found in the SMS. As cyber risk management planning and execution involves the whole company it may be useful during the mapping process to clarify who is the responsible person, and who is required to support that person. For example, a ship IT manager may well be the responsible party for cyber risk management in ships, but he relies on support from other managers and staff from across the whole company, security staff, safety staff, training staff, procurement staff, marine HR staff, crew etc. Often, the allocation of responsibilities and tasks will work best if it is aligned with the normal chain of command. For example, when allocating the responsibility for compliance with cyber risk management procedures on board a ship, it will often make sense to appoint the Master or the Chief Engineer [3].

Cyber risk management should involve the senior management level of a company on an ongoing basis, instead of for example, only the ship security officer or the IT manager [4]. There are several reasons for this:

- Some cyber risks have wide-ranging destructive potential to the safety of personnel and the environment as well as the performance and reputation of the company. Cyber risks are therefore not simply security challenges, but business challenges that require leadership's involvement;

- Initiatives to heighten cyber security and safety may affect standard business procedures and operations by rendering them more time consuming and/or costly. It is, therefore, a senior management decision to evaluate and allocate the necessary resources to establish risk mitigation to an acceptable level of residual risk;

- Initiatives, which heighten cyber awareness, may change how the company interacts with unions, customers, suppliers, and authorities, and impose new requirements on the cooperation between parties. It is a senior management decision whether to drive these changes in relationships and how best to do so.

The answers to the following questions may be used as a basis for informing and involving senior management about the importance of addressing cyber risks onboard ships:

- What assets are at risk?
- What is the potential impact of a cyber incident to the business, customers, partners, and stakeholders?
- Who has the final responsibility for cyber risk management?
- Are the OT systems and their working environment protected from unauthorized access and changes?
- Is there remote access to the OT systems and, if so, how is it monitored and protected?
- Are the IT systems protected and is access being monitored and managed?
- What cyber risk management best practices are being used?

Based on the answers, the company should describe and delegate authority as appropriate, and allocate the resources needed to develop and maintain suitable solutions based on the risk assessment results.

Security Officer is the first line of defense against malicious actors in the IT industry. They screen their company's critical IT infrastructure for weaknesses and create robust countermeasures to prevent future incidents. Security Officer also train ship's crew on security best practices and advice management on investments to safeguard the company's and or ship's computer and network systems [5]. Here are examples of Security Officer responsibilities:

- Develop, execute and track the performance of security measures to protect information and network infrastructure and computer systems.

- Design computer security strategy and engineer comprehensive cybersecurity architecture.
- Identify, define and document system security requirements and recommend solutions to management.
- Configure, troubleshoot and maintain security infrastructure software and hardware.
- Install software that monitors systems and networks for security breaches and intrusions.
- Monitor systems for irregular behavior and set up preventive measures.
- Plan, develop, implement and update company's information security strategy.
- Educate and train staff on information system security best practices.

5. Conclusion

Is there any minimum requirements recommendation for the company to appoint person responsible for Companies' fleet cyber security and on board Cyber Security Officer? There is no requirement decided by the IMO. Competency requirements are found in the ISM Code and in the Maritime Labour Convention (Regulation 1.3). In my opinion there must be people with cyber security responsibility in the company and on board the vessels and communication between those persons to ensure ongoing compliance and continuous improvement. Despite that from the ISM Code it must be inferred that there has to be a person or persons on board responsible for handling the safety management systems measures on cyber security, from the ISM/statutory perspective no regulation for a ship cyber security officer (SCSO), his qualifications and trainings. That said, there are requirements from ISM and the MLC that staff shall be qualified for their tasks. This allows the shipping Company to develop and implement solutions (including through external providers) to handle their obligations.

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Simulation-based Investigations of Different Combustion Concepts for Hydrogen-fuelled Large Gas Engines

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Abstract: The development of a combustion concept for hydrogen-fuelled high-speed large engines requires a suitable development methodology, including the interaction between 1D and 3D simulation as well as experimental investigations on research engines. The main subject of this paper is the development of one-dimensional single cylinder and multi cylinder engine models used for turbo matching and to gain a better understanding of combustion anomalies. The latter are especially affected by the mixture formation process which is investigated by means of 3D CFD simulations for port fuel injection and direct injection engine operation. Boundary conditions are generated based on experimental investigations on a single cylinder research engine with displacement of about 6 liters. The paper concludes with an assessment of the benefits and limitations of different engine configurations.

Keywords: HYDROGEN FUELLED ENGINES, 1D SIMULATION

1. Introduction

Hydrogen belongs to the zero carbon fuels and will play an important role in the decarbonization of many industry sectors where large engines are used for power production or transportation purposes. The hydrogen combustion in the engine does not create emissions of carbon dioxide and unburned hydrocarbons and, the only relevant emissions are nitrogen oxides [1]. Compared to natural gas, hydrogen has a lower minimum ignition energy, approximately six times higher laminar flame speed and wide ignition range. These fuel properties can pose some important challenges in engine operation. Pre-ignition is a self-ignition of fresh mixture in the cylinder during the intake stroke. For port fuel injection (PFI) engines, the following backfire into the intake pipes can cause harm. The risk of backfire can be reduced by using direct injection (DI) mixture formation. This variant requires specific injectors and a sophisticated approach for the mixture homogeneity. Further challenges are cycles with knocking combustion or cycles with self-ignition after the intake valve closing and as a result very high maximum cylinder pressure [2], [3], [4], [5]. To avoid abnormal combustion the engine often operates with lean hydrogen-air mixtures, which can lead to challenges for selecting proper turbochargers [6].

2. LEC Development Methodology

LDM (LEC Development Methodology) [7] is based on the intensive interaction between simulation and experimental investigations on single cylinder research engines (SCE) and multicylinder engines (MCE), see Figure 1. This methodology makes use of 3D CFD simulation and 0D/1D engine cycle simulation. The 1D simulation as part of LDM is an efficient tool that meets the demands for flexibility, predictability and computational time. While 3D CFD simulation is mainly employed to optimize the details of relevant processes (e.g., mixture formation and combustion in the prechamber (PC) and main combustion chamber, determination of the location of knock), 0D/1D engine cycle simulation is applied to pre-optimize significant engine parameters (e.g., compression ratio, valve timing). When applying the LDM methodology, it must be guaranteed that the results from single cylinder tests can be transferred to the multicylinder engine. For this it is necessary to acquire boundary conditions at the SCE to get conditions comparable to the ones of the multicylinder engine. Not only the thermal boundary conditions but also the conditions at the beginning of the intake stroke (temperature, pressure, and in-cylinder gas composition) are required. These conditions are determined in an iterative process based on 1D engine cycle simulation of the multicylinder engine and the single cylinder setup.

The design of the single cylinder test bed has some specific features. While the piping system of the single cylinder engine test bed is being designed, it is important to adapt the gas dynamics in the intake and exhaust piping system. The objective is to achieve similar conditions in the cylinder of the SCE and the corresponding multicylinder engine.

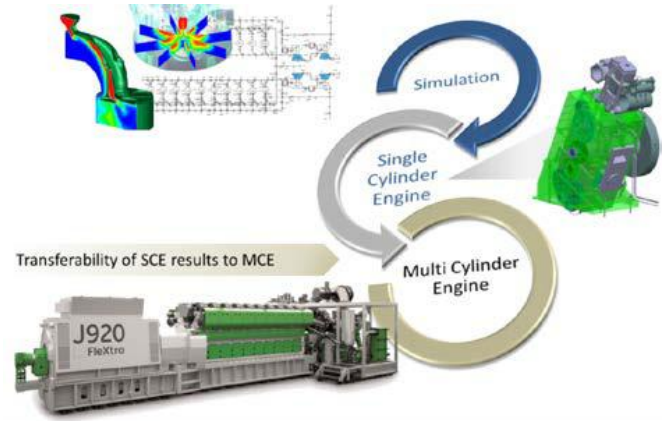


Fig. 1 LDM: LEC Development Methodology.

3. Single cylinder research engine

All experimental investigations presented in this paper were carried out on a high-speed four-stroke SCE with a displacement of about 6 liters. Series-production cylinder heads were modified for the installation of the PFI valve or the accommodation of the DI injectors. Like in the series engine, a prechamber spark ignition concept and a camshaft with early intake valve closing (IVC) timing, also known as Miller valve timing, were used. The compression ratio was chosen to be in the range of typical natural gas fueled gas engine applications. Table 1 summarizes the engine specification.

A mock-up of the SCE is shown in Figure 2. Charge air is supplied to the engine by an electrically driven compressor. The air humidity is controlled by means of a steam generator that admixes water steam to the cooled (dehydration) and re-heated air. Cooling water and lubricating oil are conditioned before being supplied to the engine.

Table 1: SCE specification

Parameter	Value/type
Working principle	4-stroke
Displacement	ca. 6 L
Engine speed	1500 rpm
Valve timing	Miller intake valve timing
Ignition concept	prechamber spark ignition

Hydrogen (H₂) is provided by tube trailers with filling pressures of up to 300 bar. The H₂ feed stream is split: a part is supplied to either the PFI valve or the DI injectors (depending on engine configuration) via a gas control train or a pressure regulator, respectively, that reduces the pressure to PFI and DI pressure level of below 10 bar and 30 bar, respectively. The other part of the H₂ feed stream is supplied to the H₂-scavenged prechamber via a gas control train. A back pressure flap in the exhaust piping is used to set the back pressure generated by the turbine of a turbocharger on a

multi-cylinder engine. The exhaust gas analysis is done with an AMA i60 exhaust gas measurement system from AVL List GmbH. In addition, unburned H₂ in the exhaust gas is detected with an HSense measurement device from V&F Analyse- und Messtechnik GmbH. Time-based measurement data is recorded and processed by the software Tornado from Kristl, Seibt & Co GmbH; crank angle-resolved data is recorded and processed using the indicating system IndiSet Advanced Gigabit and the software package IndiCom from AVL List GmbH.

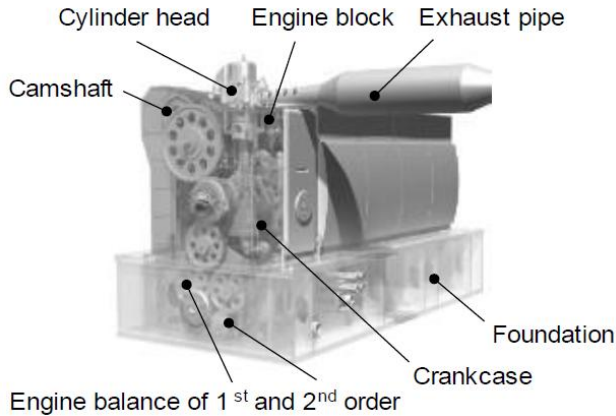


Fig. 2 Computer aided design mock-up of the SCE.

4. Database and data analysis

For following the LDM, in a first step a reference case has to be created using measurement data from a physical engine with the purpose of further development and calibration of the simulation models. The available database includes measurements of different parameter variations: indicated mean effective pressure (IMEP), excess air ratio (EAR), ignition timing, manifold air temperature, start of injection of hydrogen etc. The hardware variants include different compression ratios, valve lift curves, prechambers and sparkplugs.

Measurement data is required for the development and calibration of models as well as for the calculation of the rates of heat release for direct specification in the 1D simulation. Developed at the LEC, the engine cycle calculation program LEC CORA is used to analyze the operating points measured on the test bed. The software package CORA (Combustion Optimization, Research and Analysis) was designed to analyze and simulate the high-pressure cycle of the working process of combustion engines. It enables the analysis of measured pressure traces as well as simulation of in-cylinder conditions during the high-pressure cycle upon specification of the rate of heat release histories or the rate of heat release models. The software is used in combustion analysis mainly for pressure offset correction, compression ratio and top dead center adjustment as well as pressure history analysis (high-pressure cycle) and loss analysis.

The high demand on the quality of the measurements used as a basis for analysis, leads to the necessity to check this quality, whenever possible directly and automatically at the test bed, to allow early detection of errors [8]. In this context, a methodology for automated error diagnosis on engine test beds was developed at the LEC. The algorithms this system is relying on, are provided in the "LEC MCheck" (LEC Measurement Check System) software solution and are used directly on the test bed. A consistent use of these tools guarantees a high quality of measurement data and the resulting rate of heat release histories, which in turn is advantageous, when calibrating simulation models and interpreting the results.

5. 1D Simulation

For a detailed analysis of the mixture formation and to generate the boundary conditions required for the 3D CFD simulation, a 1D single cylinder model has been used. This model corresponds to the

engine integrated on the test bed. Figure 3 shows the topology of the model in the commercial software package GT Power including the prechamber, prechamber gas valve (PCGV) and PFI valve. The objective in developing the model is to determine the conditions not only in the main chamber, but also in the prechamber as precisely as possible, therefore also the prechamber is depicted in the 1D model. Air and hydrogen fuel from the PI valve is mixed in the intake system. The prechamber mixture flows through the gas rail and the prechamber gas valve. The model uses measured pressure traces from the measured operating points for the intake as well as the exhaust manifold and in front of the PCGV. Different measured operating points from the database were simulated using the 1D SCE model.

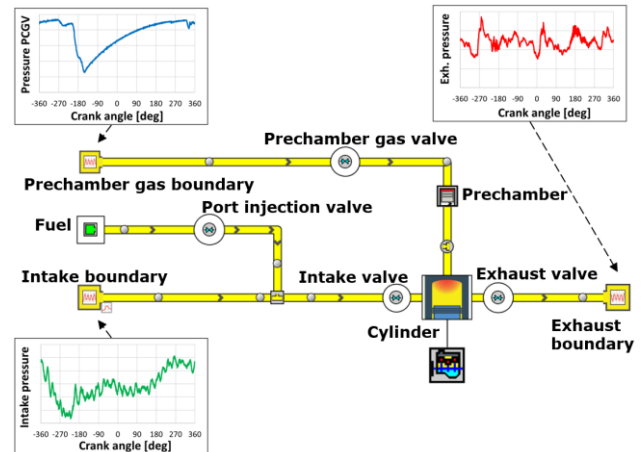


Fig. 3 Topology of the 1D model of a single cylinder engine with a prechamber and PFI.

The 1D simulation also plays an essential role when explaining combustion anomalies. Figure 4 shows a measured cylinder pressure curve and the mass flow through the valves.

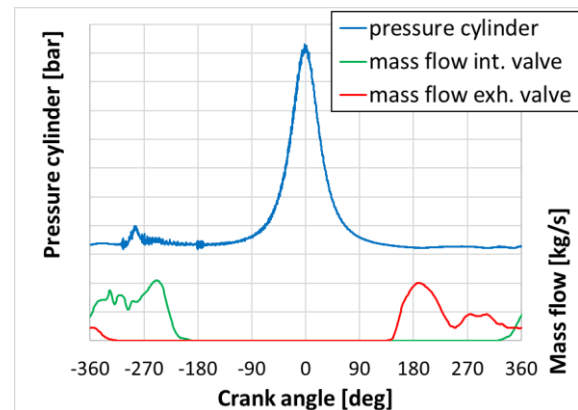


Fig. 4 Hydrogen operation: measured cylinder pressure of a cycle with pre-ignition and mass flows from 1D simulation.

The self-ignition occurs at ca. -300 deg CA for the shown cycle. The reason for this anomaly is often a hot spot in the main combustion chamber or zones with hot residual gas [2], [3]. The simulation of this measured operating point with the 1D SCE model reveals that at this time hot residual gas flows from the prechamber through the prechamber ducts into the main chamber, red curve in Figure 5. Positive values indicate flow from the prechamber into the cylinder. The hot gas jets coming from the prechamber contain particles from the combustion in the PC. They reach the fresh hydrogen-air mixture in the cylinder which can cause the self-ignition of the fresh charge.

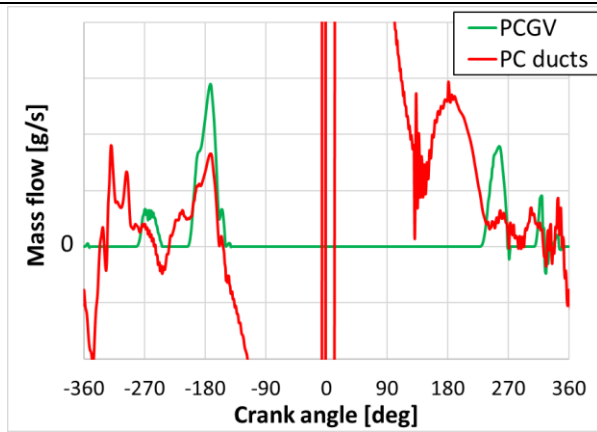


Fig. 5 1D simulation: mass flow rates.

One possible improvement measure to reduce the risk of preignition is an intensive flushing of the prechamber with fresh gas from the prechamber gas valve during the exhaust phase, green curve in Figure 5, from ca. 220 to ca. 360 deg CA. Positive values again indicate flow from the prechamber gas valve into the prechamber. The fresh gas displaces hot residual gas from the PC and also cools it. The gas flow from the prechamber to the main chamber that occurs around -300 deg CA therefore contains mostly cold fresh gas that is less likely to initiate preignitions.

Another way to avoid combustion anomalies such as backfire and knocking is water injection [3]. Figure 6 shows a screenshot of another 1D SCE model. Two water injectors are integrated: one in the intake pipe (PFI injector) and the second one for water injection directly in the cylinder (DI injector). The following variants were simulated:

- DI water injection, 17 kg/h, injection duration from 334 to 470°CA
- PFI water injection, 17 kg/h, injection duration from 334 to 470°CA
- PFI water injection, 17 kg/h, permanent injection.

All variants show a reduction of the cylinder temperature, which means a lower risk for backfire and knocking combustion compared to the variants without water injection.

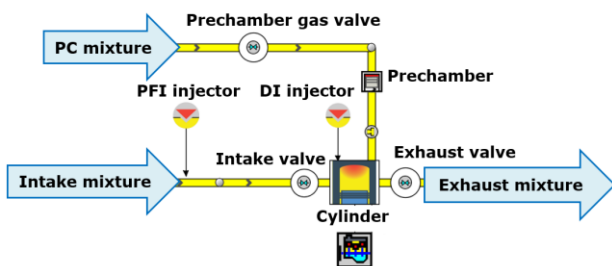


Fig. 6 1D simulation model with water injection.

Figure 7 shows the temperature reduction in the main combustion chamber for H₂ operation and DI water injection. The simulations with permanent water injection in the intake pipe have shown a risk of water condensation in the intake pipe, if the intake valve is closed. This could lead to lube oil dilution. All variants with water injection have been tested on the test bench. The measurements have shown that the water atomization depends heavily on the injector design and the risk of abnormal combustion is generally reduced.

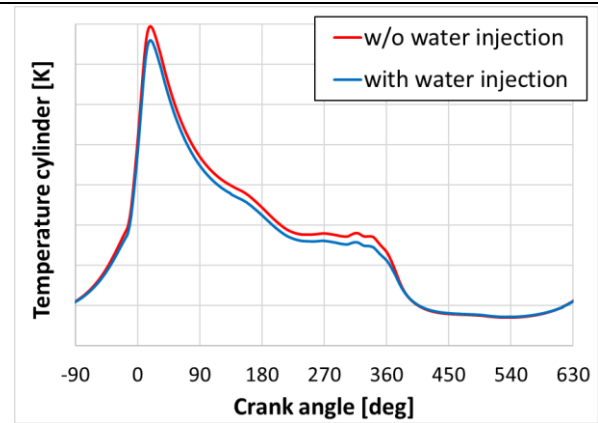


Fig. 7 Influence of water injection: results from 1D simulation.

A multi cylinder engine model with single stage turbocharging and PFI was developed and calibrated based on measurements on the 12-cylinder engine at LEC. Using this model and boundary conditions from SCE measurements in H₂ operation, simulations with the target turbocharger selection were made. The H₂ engine operation requires a higher excess air ratio compared to the natural gas operation for the same indicated mean effective pressure. That means higher required boost pressure, but on the other hand the higher EAR causes lower turbine inlet temperature. Two different engine configurations were investigated with boundary conditions of the SCE measurement: port fuel injection and direct injection. According to the simulation results, the DI variant needs a bit lower boost pressure at the same EAR, but the EAR value is defined by knock-free combustion and is also depending on the mixture homogeneity.

6. Investigation of mixture formation using 3D CFD simulation

In addition to experimental investigations, 3D CFD simulations were performed to investigate the effect of the fuel injection concept on mixture homogeneity. Simulations were performed using the software AVL FIRE™ from AVL List GmbH. Computational meshes were created using the integrated meshing tool FAME Engine+. Figure 8 shows surface models of the engine in both PFI and DI configuration. As can be seen, the injection sleeve and its nozzle used in the PFI configuration is located at the upper part of the intake port relatively close to the intake valves, whereas the DI injectors are mounted between intake and exhaust valves in the combustion chamber. Two different H₂ jet-forming caps, referred to as v1 and v2, were used in the DI simulations and also later on in the experimental investigations. The simulations were performed at IMEP ≈ 21.5 bar and excess air ratio $\lambda \approx 2.40$. In the PFI simulation, the start of injection was around intake valve opening, while in the DI simulations it was shortly after IVC. Boundary conditions were generated using 1D engine simulations.

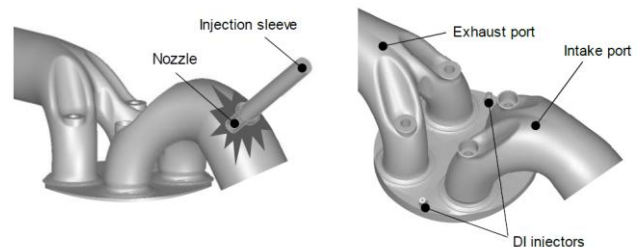


Fig. 8 Surface models of the SCE in PFI (left) and DI configuration (right).

The homogeneity of the in-cylinder H₂-air mixture was assessed based on the uniformity index γ . It is a function of λ in each cell, the mean λ of the entire computational domain and the volume of each cell. The closer γ is to one, the more uniform, i.e. homogeneous, a mixture is.

In Figure 9, γ -traces of in-cylinder charge for PFI and DI configurations are plotted against crank angle. The time difference in the start of injections between PFI and DI, denoted as SOI_{PFI} and SOI_{DI} , respectively, is clearly visible. In the PFI simulation, a time delay of approximately 15 degree between SOI_{PFI} and the first rise in γ can be observed, resulting from the travelling time of H₂ from the injection location to the cylinder. The gradient in γ is significantly higher compared to the DI cases. This can be attributed to two reasons: first, as the piston is relatively close to top dead center when H₂ reaches the cylinder, the relatively small volume is quickly occupied by H₂, leading to high γ values and gradients. Second, the turbulence generated around the intake valves during the intake stroke contributes to the mixing. The latter effect is not made use of in the DI simulations and the cylinder volume at SOI_{DI} is also larger compared to the cylinder volume at SOI_{PFI} . This results in a slower increase in γ , i.e., slower mixing, and eventually lower mixture homogeneity at time T₁ near ignition timing. Moreover, the time period available for mixing from SOI_{DI} to T₁ is shorter compared to the interval from SOI_{PFI} to T₁. Final γ values of simulation cases DI v1 and DI v2 are lower by approximately 16 % and 13 %, respectively, compared to the PFI case. The zones with richer mixtures might contribute to higher NO_x emissions and a higher risk of abnormal combustion phenomena in DI engine operation.

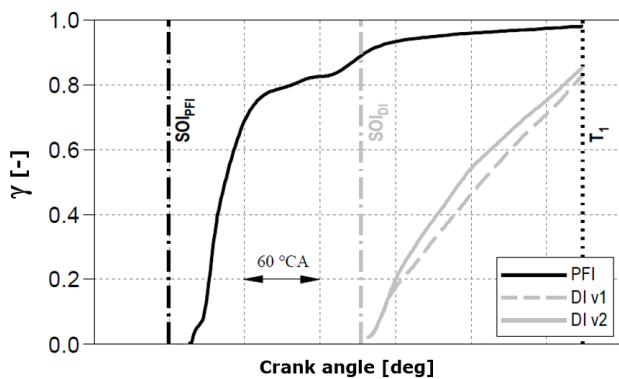


Fig. 9 Uniformity indices of in-cylinder charge for PFI and DI configurations.

7. Summary and outlook

This paper presents the development of 1D simulation models for investigation of possible causes of abnormal combustion in hydrogen operation. Using 1D simulation, boundary conditions for 3D CFD simulation were generated. Hydrogen PFI and DI combustion concepts were investigated by means of 3D CFD simulation with regard to mixture homogeneity, engine operation as well as emission formation. Simulation results show that mixture homogeneity in DI operation is lower compared to PFI operation, however, it can be increased by using an optimized design.

Further investigations are planned with enhanced hardware and relevant adaption of the operating parameters.

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Extracted Handal seed oil (Citrullus Seeds) used as biodiesel fuel in internal combustion engines

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Abstract: Most important of fuel economy research and vehicle industry today is to find a unique fuel with high calorific value and low tail pipe emissions . in this research a good effort was spent to find a solution for automotive industry by presenting a new fuel which was extracted from Citrullus and presented as handle seeds oil to be used as bio fuel in internal combustion engine, which is very important issue for automotive industry . The importance of extracting Handel oil has led to investigate the characteristics of chemical and physical properties of new fuel, such as density, specific gravity, kinematic viscosity, flash point, pour point, cloud point, which will help of controlling the composition of biofuel and improve the fuel quality which can be used in internal combustion engines . The two important processes were used for biodiesel production are Esterification and Transesterification.

KEYWORDS: , HANDAL SEED OIL , BIOFUEL

1. Introduction

Biodiesel as promising fuel in the future and replacing diesel fuel as diesel is described as fatty acid methyl or ethyl esters (FAME) from vegetable oils or animal fats. One of the most important properties to characterize fuel is its energy content (1) . Biodiesel is fuel made of plant or animal oils. There are several non-edible oils, animal fat and vegetable oil sources for biodiesel production. Jatropha plant/oil seed containing 27-40% oil while the residue (press cake) can also be processed and used as biomass feedstock to power electricity plants or used as fertilizer as it contains nitrogen, phosphorus, and potassium (2) .

Biofuel can be blend with diesel and be used in compression engines leading to lower exhaust emissions with similar power (3) ; biodiesel has a technical advantage such as less exhaust emission and toxicity, biodegradability, a derivation from a renewable and domestic feedstock, negligible sulfur content, superior flash point, higher combustion efficiency and they would not require a significant modification of existing engine hardware (4) .

Therefore, nonedible plant oils become very promising alternative feedstocks for biodiesel production because of the large demand for edible oils as food, the higher prices of edible oils than that of fossil fuels, and the lower cost of non-edible oil plant cultivation . Biodiesel production has derived from forestry, agriculture, and agro-industrial wastes that exhibit good properties as feedstocks (5)

The transesterification process depends upon a number of process parameters that are required to be optimized in order to maximize the biodiesel yield, such as molar ratio, catalyst concentration, reaction time, and reaction temperature (6) . But before converted the oil to biodiesel the main problem faced vegetables crude oil is particles, impurities, moisture, and high content of free fatty acids, so they must be removed from the crude Hndal oil before converted to biodiesel. Gums should be separated from the oils to make the oils suitable for use as fuel. The use of crude oil without pretreatment can cause problems such as emulsification in the transesterification process (7) , it becomes imperative to analyzed the sunflower methyl ester (SFME) and its blends as an alternate source of fuel for diesel engines. Biodiesel was prepared from sunflower oil by base transesterification. Four- cylinder Deutz F4L912 diesel engine was used to perform the tests on various blends of sunflower biodiesel. The emissions of CO, HC were lower than diesel fuel for all blendstested. The NOx emissions were higher due to the high volatility and high viscosity of biodiesel.

Others blended biodiesel from Citrullus lanatus with petro-diesel, thereby forming blends of different percentages, 5%, 10%, 15%, 20%, and 25%. The calorific values of the biodiesel and blends were all within the ASTM standard with B20 value slightly below that of pure diesel; similarly, the flash point of the pure biodiesel and its blends were above the pure diesel value but falls within the ASTM range. The fuel was safe to handle during storage because it cannot easily spark when exposed to flame and hence they were

recommended for use in the CI engines. The pour points of all the fuel samples conform to the ASTM standards. The cetane numbers are all greater than that of pure diesel and conform to ASTM standards. The biodiesel will be having the shortest possible ignition delay when they burn in the CI engines. (8).

2. Work process

2.1. Collection

The samples were collected from different area in Jordan such as Wadi Ram, Al Baydah and Al Deseh of Maan city south of Jordan as well as Azraq east of Jordan .

2.2. Preparation

Plenty of handal were collected and reserve 20 kg to be used, Hndal Samples were smashed with taking the seeds out and cleaned. Then seeds were dried for three days at room temperature, and then were ground using an electric blender .

2.3. Extraction of oil

First sample was 2 kg of grind seed to be used for extraction purposes. Hundred gram each of grinned seed was packed into the thimble of the soxhlet extractor that incorporates a condensation system . Hexane (extraction agent) is heated to reflux in the distillation flask, the vapors are condensed in the reflux condenser and drop into the chamber containing the thimble with the material to be extracted. The chamber slowly fills with the warm solvent and some of the material is dissolved in the solvent. When the Soxhlet chamber is almost full it is automatically emptied by a siphon sidearm, with the solvent running back down to the distillation flask. This cycle is repeated several times to enrich the solvent in the distillation flask with the extracted material. The mantle heater was set at 60oC close to the evaporation temperature of hexane (64oC).

2.4. Samples Production

The amount of NaOH required for the transesterification of the oil. ca 1 ml oil was dissolved in 10 ml isopropanol and titrated with 0.1M NaOH solution (standardized against KHP). A suitable mass of the catalyst-based on above titration is dissolved in methanol (NaOH: Methanol: Oil; 0.0016 g:0.2ml:1ml) with 20 min vigorous stirring until dissolve all NaOH to prepare methoxide (CH₃O⁻). Then, this mixture is transferred to the reactor (R-flask) containing treated moisture-free oil.

2.5. Esterification Process

In this work, the procedure of known researcher for the esterification process was followed (9) . Titration solution was prepared by adding 1 gram of potassium hydroxide to 1 liter of distilled water. In a small beaker, 1 ml of oil was added to 10 ml of ethanol and was stirred well to get a mixture. 2 drops of phenolphthalein were added as an indicator to the mixture. KOH solution was poured drop by drop by a burette to the mixture until it turns into a pink solution.

It is the most commonly used and important method to reduce the viscosity of vegetable oils. In this process, triglyceride react with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester, and glycerol. The process of

removal of all the glycerol and the fatty acid from vegetable oil in the presence of a catalyst is called esterification (10). glycerol from the bottom of the funnel and pour the top layer (crude biodiesel) back into the beaker.

2.7. Washing process

In this process, water is used for purification, thus, warm distilled water was added to the separator funnel that contains crude biodiesel. Then the separator funnel was shaken gently to mix water with crude biodiesel. Allow the water to settle down of the biodiesel for one day. The water was drained out and the washing process was repeated for 3 to 4 more times until the water has completely become transparent. To remove undesired components such as the excess methanol or existing water, the washed biodiesel samples were dried at 110 °C for 2 hrs

3. Results and Discussion

The results for the comparison of the properties of the biodiesel produced from used vegetable oils and those from diesel fuel are discussed as follows:

3.1. Density

The density of Handal oil is 899 kg/m³, whereas in biodiesel was measured is 888kg/m³. It is higher than that of standard diesel (820-870 kg/m³).

The limit value proposed in pre-standard Fuels for vegetable oil compatible combustion engines - Fuel from rapeseed oil ranged between 900 to 960 kg/m³, so as not to exclude vegetable oils such as castor, jatropha, mahua, neem, or babassu oil, it was mentioned that, indicating density of Handal agrees with pre-standard Fuels for vegetable oil compatible combustion engines- Fuel. (11)

3.2. Specific gravity

The specific gravity of Handal oil is 0.898 at 20°C, while in biodiesel was observed is 0.886. The Specific gravity of Thumba oil slightly variable between 0.880 and 0.905.

3.3. Kinematic viscosity

The significant physical properties of Handal oils indicate that the kinematic viscosity of Handal oils is 16.49 cSt at 40° C, which is an order of magnitude almost 4 times higher than that of diesel.

Viscosity is a rapid indicator of fuel quality before use, especially if the nature of the feedstock is not well known, or if the oil could have been deteriorated or polymerized during storage. The kinematic viscosity of Handal oil is higher than that of conventional diesel fuel but lower than that of heavy fuel oil. (12)

3.4 Flash point

The flash point of Handal oil is very high (above 180 °C) and the heating values are in the range of 39.603 MJ/kg, while biodiesel was measured is 39.5, as compared to diesel fuels which is about 66 MJ/kg. The used Handal biodiesel oil had a flash point (OC) of 49.5 and was lower than that, Petroleum diesel, Diesel fuel, and fossil diesel, which had values of, 68.3, 68, and 47 °C, respectively.

3.5. Pour point

The pour point of Handal oil value is -9 °C, whereas biodiesel value is +3. The results observed that the vegetable oil shows the least values of pour point ranging from -9 °C to 40°C, while the Pour point of the used Thumba oil was -8, and lower than that of Thumba biodiesel which is -12. The corn oil had the pour points is -40°C while the Jatropha oil and Karanja oil have to pour point values 8°C and 6 °C, respectively (Table 3). Vegetable oils can be mixed with conventional diesel in any proportion and blends can be used successfully in engines (13). It can be concluded that all the chemically modified oil products have the pour points below 0°C which is a desirable property for lubricating oil. The pour point obtained (12°C) is still much higher than that is required for any lubricant application (-6°C for two- stroke engine lubricant as per IS14234) (14).

4. Conclusion

4.1.A lower viscosity and density was observed by dilution of handal oils with diesel oil., flash points of handal oils blends were higher than that of diesel oil.

4.2. The Handal oils exhibit relatively different flash point, cloud point, pour point, and sulfur content.

4.3. Handal oil showed have high energy content and obviously good fuel properties,

4.4. The treated handal oils, could be converted into biodiesel, which has properties suitable for application in diesel engines

4.5. The transesterification process has been the most suitable and acceptable method for biodiesel production

4.6. The density of Handl seed oil agrees with pre-standard Fuels for vegetable oil compatible combustion engines- Fuel.

4.7. The kinematic viscosity of Handal oil is higher than that of conventional diesel fuel but lower than that of heavy fuel oil

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