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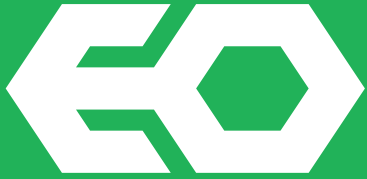
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EXPLOITATIONAL CHARACTERISTICS OF ELECTRIC VEHICLES

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Abstract: Various electric vehicles are exploited in Latvia. The paper analyses experimental data for three different electric vehicles: a Fiat Fiorino Electrico, a converted automobile Renault Clio and a Think City. The paper focuses on the following parameters of the electric vehicles: charging parameters, range per charge and cost per charge. Lower cost per 100 km distance covered – EUR 2.91 for converted Renault Clio.

Keywords: ELECTRIC VEHICLES, EXPERIMENTAL ROUTE, BATTERY CHARGE, ELECTRIC MEASUREMENT, ELECTRICITY CONSUMPTION.

1. Introduction

The world's non-renewable energy resources are limited. The consumption of the resources increases from year to year. According to various scenarios, the energy resources are sufficient for the next 40-50 years if their use is not reduced. A great deal of the world's energy resources is consumed by road transport. Consuming non-renewable oil products, road transport produces exhaust gases that contain a number of hazardous components. Exhaust gases are hazardous for humans and the surrounding environment. To reduce the effects on the environment and the consumption of oil resources, new technologies are developed, for example, biofuels for internal combustion engines and vehicles powered by electricity [1].

The idea of electric vehicles is not new. Electric vehicles appeared together with internal combustion automobiles more than a century ago. However, internal combustion vehicles developed faster and out competed electric vehicles having a number of advantages, such as silent, zero emission operation and easy start. Initially, the key advantage of internal combustion vehicles was their greater range per gasoline tank relative to the range of electric vehicles per charge.

During the entire evolution of automobiles for more than 120 years, electric automobiles were manufactured in small experimental series for the purposes of certain companies. However, a wider use of electric automobiles did not take place. Electric automobiles became more popular by the turn of the century. Sales of hybrid automobiles Toyota Prius began. Hybrid technologies for other serial automobiles developed, yet, the serial production of electric automobiles charged from the mains supply began later. The Mitsubishi IMi may be regarded as one of the first ones. This electric automobile was not equipped with an internal combustion engine but only with an electric motor. The key disadvantages of serial electric automobiles, compared with internal combustion automobiles, were the high cost and the small range per charge. For these reasons, enthusiasts suggested using electric automobiles particularly in cities. The main advantages and disadvantages of electric and internal combustion automobiles are summarised in Table 1.

Table 1: Main advantages and disadvantages of electric and internal combustion automobiles

Electric automobiles		Internal combustion automobiles	
Advantages	Disadvantages	Advantages	Disadvantages
1. Silent operation of the motor 2. No exhausts are produced where exploited	1. Low range per charge 2. Insufficiently developed infrastructures in a number of countries	1. Relative low cost 2. High range per fuel tank 3. Developed infrastructures in the entire	1. Noisy operation of the engine 2. Exhaust gases (CO, CO ₂ , NO _x , C _n H _m , PM)

3. Exhausts are localised in electricity generation sites 4. High energy efficiency and a high efficiency factor 5. Simple structure, a few motor-related assemblies 6. Low exploitation costs 7. Maintenance does not require changing motor oil and a filter 8. Starting up the motor is not necessary 9. Motor power and torque curves are adequate for the operation of an automobile 10. Electricity generated from renewable sources may be used	3. High cost 4. Users are accustomed to classical and traditional technologies 5. Lifetime of the battery can be shorter than the period of use of the electric automobile 6. Limited choices when purchasing an electric automobile 7. Batteries have to be disposed of and recycled 8. Special cab heat-up system is necessary, which consumes electricity or fuel 9. New and not always fully tested technologies 10. Long battery charging time	world 4. Heat generated by the engine can be used for heating up the cab 5. Technologies and designs have developed over the century 6. High energy density of liquid fuel, the weight and volume of fuel are small 7. It takes a short time to fuel up an automobile at a gasoline station 8. Usually there is no need to change costly assemblies during the lifetime of the automobile 9. Maximum cost of damaged assemblies is less than 30% of the cost of the automobile	3. Complicated structure of the engine, a lot of rotating and moving assemblies that have to be oiled and lubricated 4. Low efficiency factor, below 40% 5. Special start up system is necessary 6. Optimal use of power and torque curve characteristics is possible only within a small range of engine rotation frequency 7. High exploitation and fuel costs 8. Engine oil has to be periodically changed and the used oil has to be disposed of 9. Use without a gearbox is not possible 10. Use in a city harms its residents
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Enthusiasts of electric mobility tried to make electric automobiles by applying their own efforts. The cost of conversion is high, an electric motor, its control unit and batteries are the main items of expenditure. Yet, if converting an automobile into an electric one, it may be tailored to the requirements of any particular user. If the user needs an electric automobile for travelling only 30 km per day, the automobile can be equipped with batteries whose capacity is 3-5 times lower than for industrially manufactured electric automobiles. This is the way how to reduce the conversion cost.

At present, the spectrum of electric automobiles offered in the market and being in use is wide, therefore, to make the right choice of electric automobiles that meet the consumer requirements, a comparative experimental research study on electric automobiles was performed, which was the key objective.

2. Researched exploitation parameters of electric vehicles and the research methodology

To compare and assess electric vehicles, a special experimental programme was developed, which involved a number of series of experiments and various kinds of experiments.

2.1. Methodology for determining the time to fully charge batteries and the amount of electricity consumed

The experiments were performed with an electric automobile under stationary conditions, doing slow charges from the 16 A mains supply. Before any experiment, it was made sure that the mains were grounded, as electric vehicles of some models cannot be charged if the mains are not connected to the ground wire. Slow-charge experiments are easier for comparison, as such a kind of charging may be usually used for any electric automobile. Fast charging options are various, and some models of electric automobile might not have them. The experiments were performed based on the following methodology:

- before performing a charging experiment, the odometer reading, km, was recorded. The charge indicator reading (the remaining battery charging rate, %) was also recorded. The experiment used as much discharged batteries as possible – when the discharge indicator was in the alarm zone;
- measurements were done in a closed room. The air temperature was $+15 - +20^{\circ}\text{C}$. The charging time was at least 8-10 h, from the one-phase 16 A mains;
- during the charging operation, the amount of electricity consumed was determined by means of an electric power meter;
- additionally, a data logger was connected during the charging operation to measure voltage and current;
- the experiment was repeated at least 5 times, and average charging parameters were used for the result.

2.2. Range per full charge for electric automobiles in the regimes of urban and non-urban driving

The experiments were conducted in Jelgava city on a certain circular route that was chosen and approbated before (Figure 1). The route included both central city streets with heavy traffic and detour streets, thus varying the intensity of traffic. The experiments were also conducted outside the city at a speed of 90 km/h, entering the flow of traffic. The experimental methodology was as follows:

- the electric automobile was fully charged. The experiments were done on asphalt roads with an average rolling resistance coefficient of 0.013 – 0.015. The experiments were performed when the road surface was dry; the air temperature was $+10 - +20^{\circ}\text{C}$. The wind speed was less than 3 m/s;
- the electric automobile was driven on the route, strictly observing the traffic rules, not exceeding the speed limit of 50 km/h in the city and of 90 km/h in the non-urban driving regime and smoothly entering the flow of traffic. The experiments were not interrupted and the automobile was not stopped, except in cases where the traffic conditions required it;
- the experiments in the non-urban regime were done on the road section between Jelgava city and Dobeles town (Figure 2). The experiments were conducted back and

forth on the mentioned road section, not entering the urban area of Jelgava and Dobeles;

- the driving regime of the automobile (driving speed, time, distance) was registered by the data logger and, after the experiment, the distance covered was compared with the reading of the odometer. The experiment was repeated 3 times.

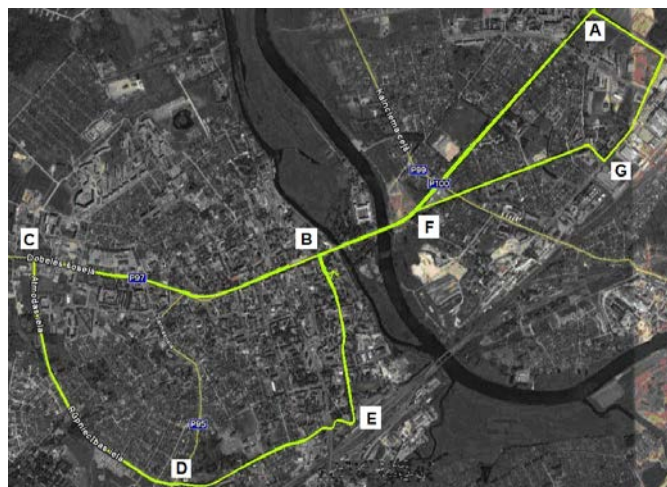


Fig.1. Experimental route in Jelgava city: ABC- route down the main street of the city; CD- detour route, $v=70$ km/h; DE- detour route, $v=50$ km/h; EBF- city route with medium traffic; FGA- city route with light traffic



Fig. 2. Experimental route for the non-urban regime on the road section between Jelgava and Dobeles: AB- start and finish for the automobiles in the city driving regime in Jelgava; BC- experimental back-and-forth route.

3. Equipment used in the experiments and the experimental objects

Three various electric automobiles were used in the experiments: a Fiat Fiorino Elettrico HC-S, a Think City and a converted automobile Renault Clio.

3.1. Experimental electric automobiles

A Fiat Fiorino Elettrico owned by the JSC Latvenergo was used in the experiments.

The Fiat Fiorino is conceived for build-up urban environments and small cities. It combines performance, agility and comfort with the load capacity. The car's main technical parameters:

- category – M1;
- motor – asynchronous, nominal power 30 kW, maximal power (peak) 60 kW;
- brakes – energy recovery;
- recharging socket – 230 VAC – 16 A – 3 kW;
- battery – lithium up to 22 kWh;
- transmission – direct drive;
- maximum speed – up to 100 km·h⁻¹
- distance of run with a single full charge (range ECE 101 cycle) 100 km;
- heating system with a fossil fuel [2, 3].

An electric automobile Think City belonging to the enterprise Rīgas Satiksme was used in the experiments. The electric automobile Think City is a two-seated car. Its key parameters:

- weight –1065 kg;
- maximum speed –120 km/h;
- maximum distance with a single charge – up to 180 km;

- climate control – electric heating of the cab, conditioner;
- brakes – energy recovery with ABS;
- transmission – fixed reduction permanently connected to drive wheels. Ratio 1: 10,15;
- 3-phase electric induction motor, Max power 34 kW 89.5 Nm [4].

The industrially manufactured electric automobiles used in the experiments are shown in Figure 3.



Fig. 3. Experimental industrially manufactured electric automobiles
a) Fiat Fiorino Elettrico HC-S b) THINK City

A converted automobile Renault Clio was also used in the experiments. The automobile was converted at Latvia University of Agriculture, Faculty of Engineering. The automobile's key parameters:

- category – M1;
- maximum motor power – 20 kW;
- battery voltage – 96 V, 100 Ah battery elements;
- weight – 1125 kg;
- transmission – standard 5-gear;
- maximum speed – 80 km/h;
- cab heating system – during the charging operation– 220 V cab heater; when driving – internal combustion heater running on E85, 2.5 kW 96 V electric heater.

The Renault Clio used in the experiments is shown in Figure 4.



Fig. 4. Electric vehicle Renault Clio

3.2. Equipment used in the experiments

Using the universal data collection and processing logger HOLUX GPSport 245, the electric car's running distance, speed and time were measured. The logger technical parameters [5]:

- weight – 72 g with battery;
- memory – RAM: 64KB;
- IO interface – Mini-USB charging;
- adaptor – input 100 – 240 VAC, 0.5 A max, DC output 5 V/1 A
- thought Mini-USB;
- function – save log data and 200,000 waypoints, show speed, time;
- environment temperature – operating temp. -10 °C to 60 °C.

For the registration of the consumed electric energy during charging, the digital energy measuring tool ES-T9162 was used (P1 in Figure 5). The energy meter's technical parameters:

- voltage range- 190-276V;
- electric energy consumed during charging, 0- 9999.99 kWh;

- charging capacity, 5-4416 W;
- current range 0.02-16 A [6].

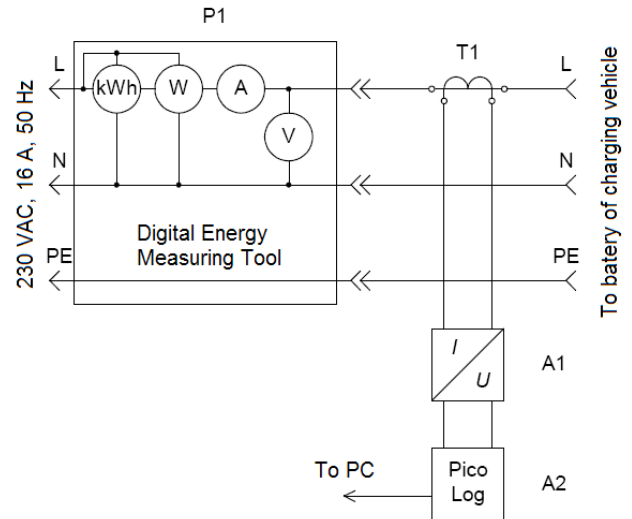


Fig. 5. Electric measurement diagram

The electricity characteristics were measured with 10 second intervals during the charging. A PicoLog ADC-24 data logger was used for gathering the experiment results. The data logger was equipped with a current converter A1 and a current transformer T1 (Figure 5). The actual power, current and voltage values were controlled by the digital energy measuring tool P1, which also was registering the total consumed electric energy [6].

3. Research results

When charging the batteries of the electric automobiles, changes in the current during charging were registered. All the electric automobiles were charged from the 230 VAC 16A mains. One of the examples of registered curves for the electric automobile Fiat Fiorino Elettrico is presented in Figure 6. The average charging time for discharged batteries ranged from 7 to 8 h. An automatic balancing operation for the batteries was done during the final hour. A charging algorithm for all the electric automobiles was similar, as the battery management system (BMS) was employed in all the cases to charge the batteries. The converted electric automobile had a programmable BMS system that allowed choosing the charging regime, reducing the charging current to 5 A. In such a way, it was possible to charge an electric automobile from a small power socket. However, in this case, it took a longer time to charge a battery.

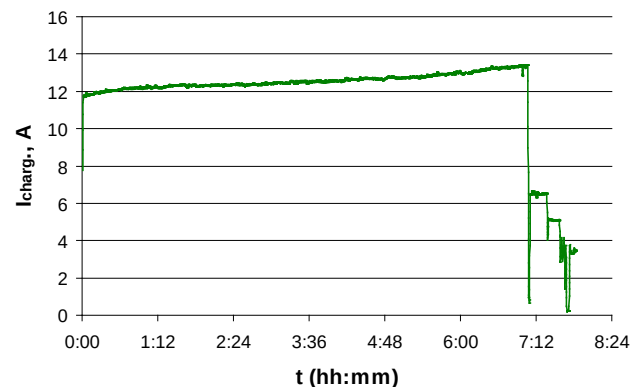


Fig. 6. Changes in the current during charging the lithium ion batteries of the electric automobile Fiat Fiorino

Users prefer electric automobiles not only owing to their environmental characteristics but also because of their low exploitation costs. According to the experimental data, the cost to drive 100 km for the researched electric automobiles ranged from EUR 2.91 to 3.77 (Figure 7), which was, on average, up to 2 times less than for internal combustion automobiles of a similar category.

The low cost per 100 km for the converted automobile may be explained by its small capacity batteries and the relatively small weight of its batteries, which were at least 2-2.5 times lighter than those of the other researched electric automobiles.

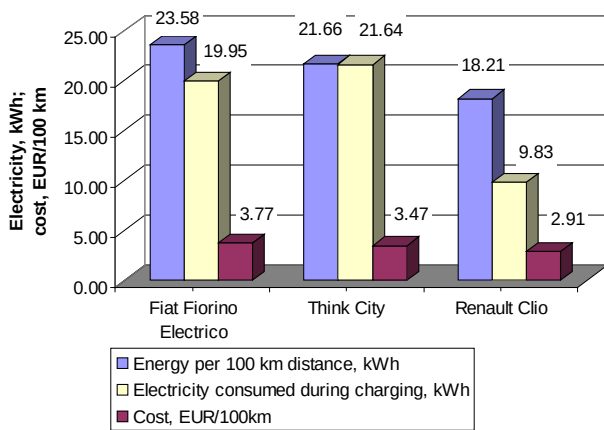


Fig. 7. Electricity consumed to charge the electric automobiles, energy per 100 km distance covered and energy cost per 100 km

The charging current exceeded 14 A in neither case. Such current is close to the nominal current intended for two-contact sockets. For this reason, an electric automobile has to be charged from the mains consisting of wires of adequate diameter. An obligatory requirement is the ground wire, as a few electric automobiles may not be charged if no ground wire is installed. The maximum charging power in all the cases ranged within 2.91- 3.15 kW.

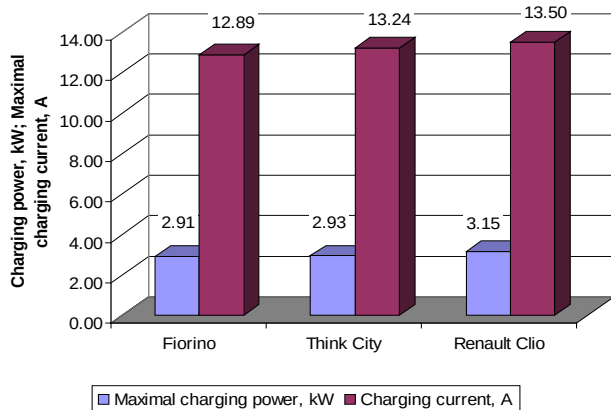


Fig. 8. Maximum charging characteristics for the electric automobiles

The range experiments were performed in Jelgava city and in non-urban traffic in accordance with the methodology described in Chapter 2. Route data from the data logger are presented in Figures 9 and 10. Driving on the city route involved a number of instances of braking, stopping and acceleration.

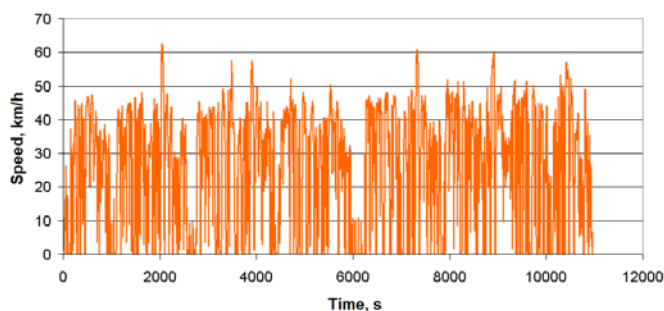


Fig. 9. Example of the driving speed graph for an electric automobile in the urban driving regime

Using the graphs obtained, it is possible to make an analysis of a micro-route; yet, more precise data were obtained at the next research stages by means of a scientific radar STALKER.

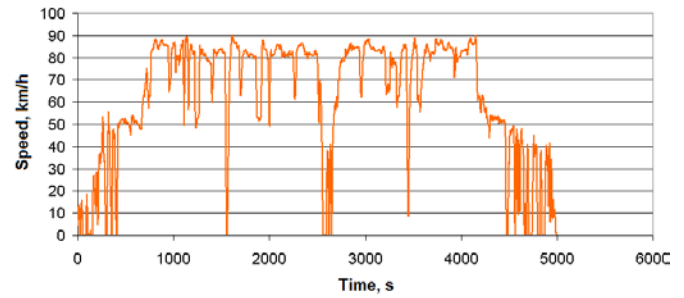


Fig. 10. Driving speed graph for an electric automobile in the non-urban driving regime

Figure 11 presents data on the movement of the electric automobiles in the urban driving regime. In all the experiments, the average speed was approximately 30 km/h. The longest distance covered was achieved by the electric automobile Think City, 101.5 km. According to the charge data, the electric automobile Fiat Fiorino had batteries of slightly smaller capacity. The longest distance covered by the Think City may be also explained by its smaller weight. The converted automobile covered the shortest distance, 56.8 km, as its batteries' capacity was only 100 Ah, while the nominal voltage was 96 V.

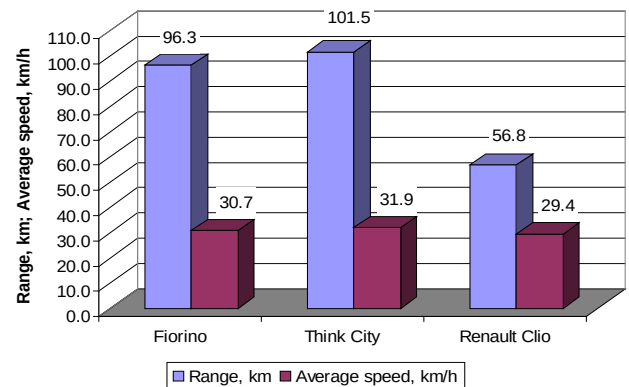


Fig. 11. Distances covered by the electric automobiles in the urban driving regime

In the non-urban driving regime, the electric automobile Think City achieved a 16.9% shorter distance than the Fiat Fiorino. Besides, unlike the other electric automobiles, this vehicle covered a longer distance in non-urban traffic than in the city. It might indicate the poor performance of the regeneration system of this electric automobile when driving in a city or the too small power limit when accelerating.

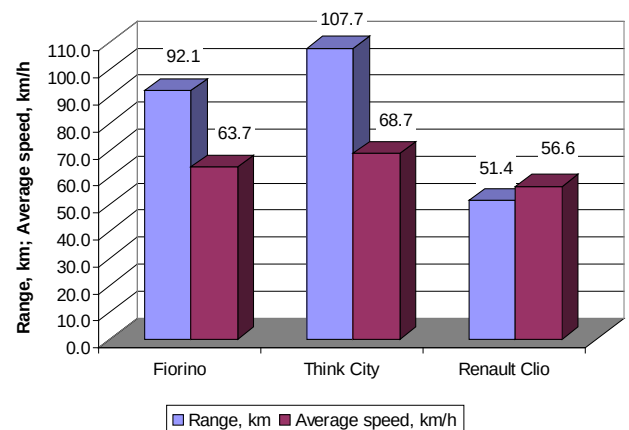


Fig. 12. Distances covered by the electric automobiles in the non-urban driving regime

In the result of effective performance of the regenerative braking system, in city traffic, the distance covered is usually slightly longer than in non-urban traffic, as the air resistance force is smaller at lower speeds and, when standing at an intersection, the motor is not running, unlike it is with traditional automobiles without a start-stop system.

Conclusions

1. A methodology for determining battery charging parameters and distances covered for electric vehicles at various driving regimes was developed and approbated.
2. An experimental route for determining distances covered by electric vehicles in Jelgava city and in non-urban traffic was developed and approbated.
3. Charging current curves for all the researched automobiles were similar. It took 7-8 hours to charge the batteries of the researched electric automobiles in slow charging from the 230 VAC 16A mains supply.
4. At the end of charging, automatic battery balancing was observed, which lasted for 0.7- 1 h.
5. The charging current exceeded 14 A in neither case; yet, such current is close to the nominal current intended for particular sockets. For this reason, an electric automobile has to be charged from the mains consisting of wires of adequate cross sectional area. An obligatory requirement is the ground wire, as a few electric automobiles may not be charged if the ground wire is damaged.
6. Industrially manufactured electric automobiles are equipped with 18-22 kWh capacity batteries and an electric motor for a voltage of 300 V. Such electric automobiles are designed for the average range of 100 km.
7. Electric motors for a voltage of less than 200 V are usually used for converted electric automobiles. At such a voltage, the electrical current rises up to 600 A. Batteries are chosen according to the specifics of their use.
8. In all the cases, the maximum charging power ranged within 2.91- 3.15 kW, which was observed during the beginning of charging.
9. The average speeds of the electric automobiles in the urban driving regime did not significantly differ and were within a range of 29.4-31.9 km/h. The longest distance in the city was covered by the electric automobile Think City, 101.5 km. The shortest distance, 56.8 km, was covered by the electric automobile Renault Clio, the batteries of which had the smallest weight and capacity.
10. Reducing the weight and capacity of batteries results in lower conversion costs and lower cost per 100 km distance covered – EUR 2.91.
11. In non-urban traffic too, the electric automobile Think City achieved the longest distance, 107.7 km. The average speed of the electric automobile Renault Clio was lower than that of the other experimental electric automobiles, as its maximum driving speed was only 80 km/h.

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DETERMINATION OF THE FRICTION COEFFICIENT OF THE HEAVY-DUTY DISC BRAKES OF AGRICULTURAL VEHICLES

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Abstract:

This article discusses the braking system of a heavy-duty engine for the determination of the friction coefficient. The agricultural vehicle progresses at 40 km / h speed; its weight is 30,000 kg. While braking such a heavy vehicle, a significant amount of heat is released as a result of the disc brake's friction. A significant part of the resulting heat is removed from the system using oil cooling. The cooling oil lubricates the various components and affects the frictional conditions significantly. This article describes the construction of the braking system. It contains a description of the measurements on the test bench and the evaluation of the results. This study determines the frictional performance and describes the method for determining the friction coefficient of a given construction. The author shows the changes in the friction coefficient depending on the pressure and the temperature, and draws conclusions from the results.

Keywords: AGRICULTURAL VEHICLE, DISC BRAKE, BRAKE FLUID, BRAKING, FRICTION, STRIBECK CURVE

1. Presentation of the braking system

The brake-system with disc forming the subject of the study can be found in the hub. During the operation of the vehicle the brake system can have two statuses. When there is no braking, the brake-discs are in open position and they are rotating. The brake-house is filled up with fluid up to 19 mm above the mid-axis. The cooling oil is flowing freely between the discs and withdraws heat from the system through the heat-exchanging processes. During the experiment the braking took place in 2 seconds. During the braking the hydraulic system is compressing the rotating brake-discs, they are closing, and there is significant friction between the discs. The cooling oil participating in the heat-withdrawal is leaving from between the discs. When the vehicle is stopped through emergency braking there is a temperature of 298 C° between the discs due to the friction. Due to the friction the friction work is transforming almost in full into heat. The friction work always appears as loss in the energy balance. The brake-fluid flowing in between the brake discs (reopening after the braking) is removing the friction heat from the system. If there is no heat withdrawal then it would lead to the fast fatigue of the equipment since due to the big heat burden the surface level of the discs would dilate to a great extent and contract compared to the layers under the surface. The process would lead to the breaking of the surface layers of the parts.

Besides removing the heat the brake fluid flowing in between the brake discs has also the role of lubricating the machine elements participating in the friction. In this way the surface deterioration occurring due to the friction force can be prevented.

When the braking is over, the brake-discs are opening again, brake-oil (fluid) is flowing between them. The brake-oil is taking over a significant part of the occurred heat from the equipment, then due to the centrifugal force it hits the wall of the brake-house. In this way a portion of the received heat is given away to the environment. The heat that remains in the system is being lead away from the system by a water-cooling oil-cooler.

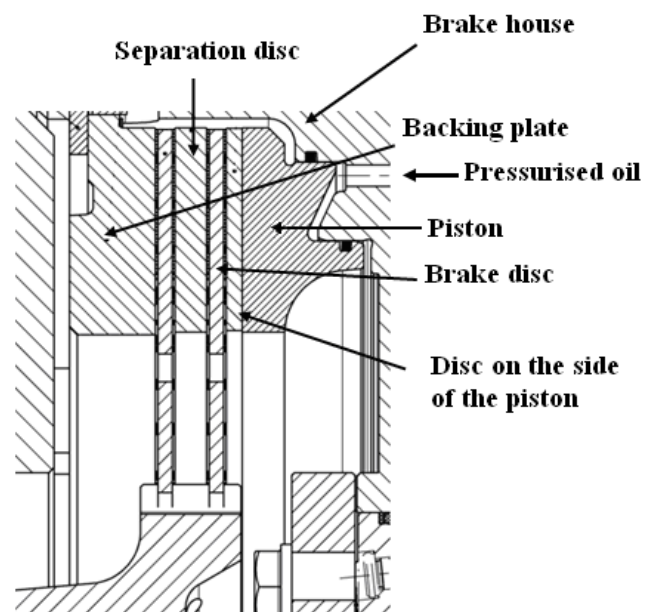


Figure 1 – Main elements of the braking system found in the hub.

The two brake-discs are made of steel, the supporting disc, the separating disc and the disc on the piston-side is made of grey cast.

The brake discs were supplied on both sides with a special 1-mm thick paper. The paper layer is made of fibrous sheets which are soaked with resin and there is friction-modifying additives being added. The main task of the fractioning layer consists of assuring the big friction factor.[8]

The fractioning substances are paired with cast iron, steel, aluminium counter-surface. The heat-resistance and wear-resistance are highly required. The fractioning substances shall be of high solidity. The friction factor and the size of the fractioning lining may vary at the smallest possible extent in function of the temperature. [2] The wearing of the brake-lining are influenced by the

same parameters like the friction (burden, speed, temperature) [6]

2. Measuring at the trial bench, measurement results

The measuring took place on a Greening bench that examines the fly-mass wheel-brake structure and braking effect. The equipment can be used to examine the braking effect of the undercarriages with an axis burden of 2-13 tonne occurring within the realistic operational circumstances, simultaneously with the comparing wear measuring. The data recording took place with 16-channel data-recording equipment of type Hottinger Spider Mobil.

As a study unit there is the half of a bridge-house closed with a holding disc, and the bearing-hub structure is fitted onto the equipment. The bridge-house half is situated in the stator of the equipment.

The external cooling with air, the „counter-wind” cooling effect is assured by the air that is flown by a ventilator through the piping system with a cross section of 0.4 x 0.6 meter.

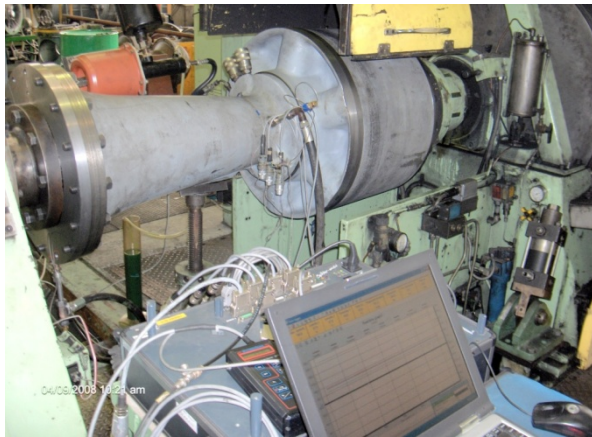


Figure 2 – Bridge house prepared for measuring

During the examination the temperature was measured on the separating disc. The separating disc is 12 mm thick. It contains two heat sensors in a 50-mm deep bore with a 3-mm diameter.

The first heat sensor was built into the middle of the separating disc, meaning at 6 mm from the edge, the other heat sensor is 3 mm from the disc-edge.

3. Determining the friction factor occurring between the blades of the brake system

3.1. Problems of determining the friction factor

The friction factor can be determined by using measurement data. Practically it is impossible to calculate, at least in the case of such a complicated structure.

The brakes can be categorised in the group of structure that are sometimes slipping and are sometimes steady. [4] The value of the friction factor is varying during the braking.

The value of the friction factor is determined by the following main factors – without trying to list all of them:

- structure of the fractioning equipment
- heat-condition of the equipment
- data of the vehicle's moving (speed, deceleration)
- substance of braking discs, surface characteristics, machining, etc.
- oil features
- braking frequency
- speed of surfaces slipping on each other
- the thickness of the oil-membrane between the surfaces, its temperature, carrying capacity, quality of the friction process (dry, semi-dry, clean (full) fluid-friction)

It can be proved that the temperature of the cooling oil that is touching directly the surface of the brake disc is identical in the border layer with the temperature that occurs due to the friction of the brake disc.

The author made some experiments to determine the temperature where the cooling oil is getting damaged or getting decomposed due to burden at a certain temperature. [3]

3.2 Specifying the friction mode

In our satiation it is not possible to determine the friction mode in full according to the greasing status. When considering the current structure it is most probable that we are talking about a mixed friction.

Due to the vehicle's travelling and the rotary motion of the discs there is always cooling oil flowing in between the brake discs, but it is rather likely that it can't cover uniformly the entire surface of the brake discs. During the braking when the discs are closing, a significant part of the brake-fluid is leaving through the oil canals established on the brake-discs, but because of the very short braking time not the entire oil quantity can leave from between the discs.

That is why the brake-disc has a part where there is border-friction.

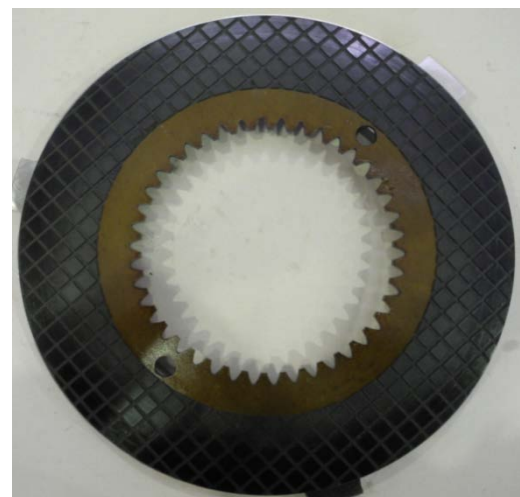


Figure 3 – Outer side of the brake-disc supplied with a fractioning layer

In the case of **border friction** the surfaces are separated by a thin absorbed lubrication layer of the magnitude of 0.01µm. [1]

The lubrication substance with a thickness of a few molecule layers prevents the metallic contact. It has a high pressure resistance and similarly to the crystalline substances it is capable to vary its shape. It has a wedging capacity [6]

At the part of the brake-disc where the cooling oil has left in full, there is dry friction between the brake discs. In the case of the **dry friction** there is no lubrication between the surfaces that participate in the friction. This is when the biggest wearing appears. In such situation the rutting is rather frequent.

At the end of the 17th century Amonton described the classical friction law for the dry friction, that is the Coulomb law:

$$F = \mu \cdot N$$

where μ – friction factor

F- friction force

N- force that is perpendicular on the surface

Due to the grooved structure of the brake disc it is rather possible that the occurrence of fluid friction is very rare. Its presence is rather disadvantageous for us. Even the grooved version was introduced for avoiding this.

In the case of **fluid friction** there is fluid or a gas layer between the surfaces. The fluid respectively gas layer between the two machine elements can move freely but the friction provided by them is possible only in the case of certain conditions. (e.g. at certain pressure level)

In the case of clean fluid friction the thickness of the lubricant is bigger than the unevenness of the fractioning surfaces. There is no wearing in the case of the fluid friction except when there are abrasive substances between the fractioning surfaces or if the hydro-dynamic tensions, pressures occurring in the lubrication substance are so high that the material of the fractioning elements can't bear for long. [6]

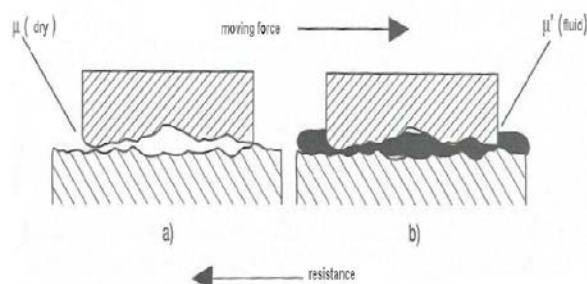


Figure 4 - dry, rough friction (a), fluid friction (b) [5]

In the case of the disc-based brake system it is rather likely that a combination of the above-mentioned friction modes is occurring.

There is **mixed friction** when the free-moving fluid is present at certain parts of the touching surfaces. This may happen only when the conditions required for the realisation of the fluid or gas friction do not occur. [1] This time the metallic surfaces are getting so close to each other that they can touch metallically at certain protruding points. This friction mode has three versions:

1. Light, partial fluid-friction when the effect of the fluid friction is not significant yet. The metallic touch of the protruding points is momentary. The speed of dislocation, the specific pressure is low.

2. High-heat partial fluid friction: due to the high friction heat. The temperature of the instantaneous contact can be rather high due to the moderate cooling effect, it may cause a minimal local melting. It is likely that this case occurs in the examined brake system.
3. High-pressure partial fluid friction: occurs in the case of the high specific pressure, small dislocation speed. [6]

The list shows how the occurring circumstances influence the occurrence of the friction. It is almost impossible to take these into consideration through calculation. It is made complicated because here there are slipping and parallel surfaces, thus the classical carrying oil-membrane (such as in the case of the classical slipping bearings) may not get formed. In certain, simple situations by complying with the simplifying conditions the friction factor can be calculated, but it is always safer to determine it through measuring.

4. Determining the value of the friction factor

Szántó [6] is defining the rotary friction (which is actually a special version of the slipping friction) as follows:

We are talking about rotary friction when all the touching or relatively touching points of two bodies are describing concentric trajectories around a rotary axis.

Per Szántó in this case the friction factor can be specified as follows:

$$M_s = F_N r \mu$$

Where:

M_s - friction momentum

r- radius of the rotary body

μ - friction factor depending on the operational conditions, between 0.005-0.14.

F_N -compressing force

The creation of the friction is a dynamic process, changing in time, e.g. the oil can be squeezed out from the surfaces which is varying in time and we consider it static when taking into account the capacity of our measurement devices, naturally within one dimension.

We are writing the friction output for actually determining the friction factor

P is the pressure exerting onto the brake-disc element which is considered constant in function of the radius. Supposing the completely parallel surfaces and the even position.

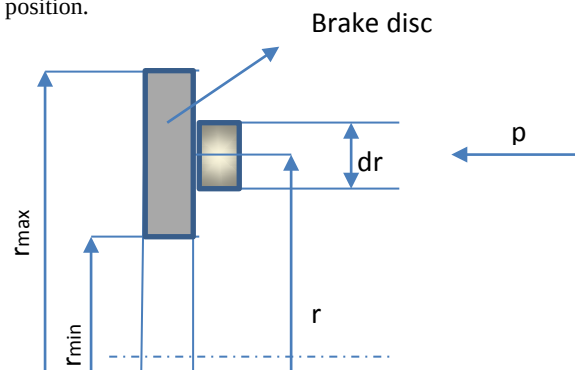


Figure 5 – Figure helping to determine the friction factor

The elementary friction momentum

$$dM_f = 2 \cdot \pi \cdot r dr \cdot p \cdot \mu \cdot r$$

where r is the arm of the momentum

$$dF = 2 \cdot \pi \cdot r dr \cdot p$$

pressure force applied onto the element

$dM_f = 2 \cdot \pi \cdot p \cdot \mu \cdot r^2 dr$ Since the radius is changing, it has to be integrated

$$M_f = 2 \cdot \pi \cdot p \cdot \mu \int_{r_{\min}}^{r_{\max}} r^2 dr = 2 \cdot \pi \cdot p \cdot \mu \left[\frac{r_{\max}^3}{3} - \frac{r_{\min}^3}{3} \right]$$

The friction momentum is known from measurements, the pressure exerting onto the disc is known, the geometrical dimensions rmax and rmin that is the biggest and smallest radius of the disc are also known, thus the μ friction factor can be determined, with the following specification:

Regarding the friction momentum known from the measuring the brake system has two discs, a brake disc has 2 friction surfaces, thus altogether 4 friction surfaces are creating the momentum value defined through measuring.

According to the above-mentioned since the value of the measured M_f friction momentum derives from the 4 friction surfaces, the value of M_f needs to be divided by 4. Thus:

$$\mu = \frac{M_f}{4 \cdot 2 \cdot \pi \cdot p \cdot \left[\frac{r_{\max}^3}{3} - \frac{r_{\min}^3}{3} \right]}$$

The surfaces of the hydraulic piston (onto which the p_d pressure is being applied) and the discs are different, the surface of the discs is bigger, thus the pressure exerted on them is decreasing thus the pressure applied on p is as follows:

$$p = p_d \cdot \frac{A_d}{A_t}$$

where:

A_d – surface of the piston

A_t – surface of the disc

The final relation:

$$\mu = \frac{3 \cdot M_f}{8 \cdot \pi \cdot p_d \cdot \frac{A_d}{A_t} \cdot (r_{\max}^3 - r_{\min}^3)}$$

Geometrical data:

Piston diameters:

$D_{d\max}=0,4241$ m

$D_{d\min}=0,365$ m

$A_d=0,0367$ m²

$A_d/A_t=0,41943$

Disc diameters:

$D_{t\max}=0,44882$ m

$D_{t\min}=0,3$ m

$A_t=0,0875$ m²

Summoning the constant values:

$$\mu = 35,93 \frac{M_f}{p_d}$$

This final relation is valid for the given brake equipment only.

(the p pressure shall be specified in Pa, that is N/m²)

Before beginning the presentation and analysis of the measurement results let's have a look at the so-called Stribeck curve (figure 6) with which the measured results can be understood better.

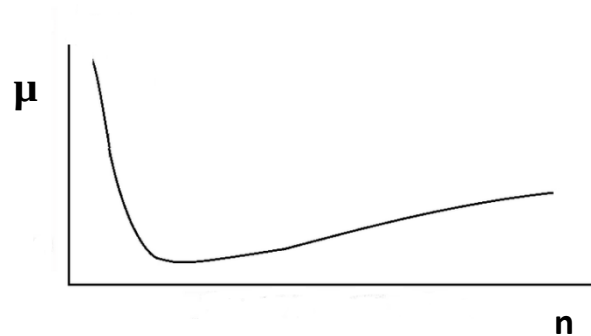


Figure 6 - Stribeck curve

The Stribeck curves [7] are measurement results based on experiments where the bearing's μ friction factor can be seen in function of the slipping speed of the bearing (rotation number). The friction factor achieves minimal value in function of the bearing's rotation then the friction factor is increasing again if the rotation is increasing or decreasing

There is mixed friction in the field left from the minimum point of the friction factor (that is why the μ is increasing), respectively there is border friction, and there is fluid friction in the field in the right. [9] In the field on the right side the friction factor is increasing despite the fluid friction since the speed gradient is increasing when the circumferential speed is increasing which is causing the increase of the slipping tension (σ) occurring on the oil-membrane and the increase of the μ friction factor.

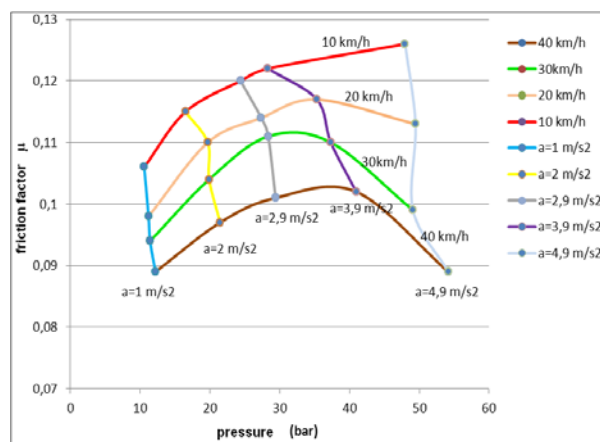


Figure 7 – friction factor - pressure diagram

According to my measurements the figure 7 shows the μ friction factor in function of the brake pressure, the parameter is the travelling speed 8km/h) and deceleration of the vehicle. When the travelling speed I decreasing, the friction factor is increasing, since due to the low travelling speed of the vehicle respectively due to the low rotation of the brake system and the small diameter of the brake disc the operational point is left from the μ minimal value on the Stribeck curve, and this is causing the increase of the μ . The increase of the friction factor is between 0.17 – 0.35 when the travelling speed is decreasing.

At the first approach the friction factor is constant, the change in function of the brake pressure 8the force that is compressing the brake discs) is around 10-20%, it is less than during the variation of the travelling speed. This can be justified by the fact that the friction factor is primarily a substance factor. (frictioning pair of substances, surface quality, machining, etc) and secondarily it is a flowing phenomenon, naturally the latter one can be neglected. When the travelling speed is increasing the friction factor is decreasing when the deceleration is constant. The decrease of the friction factor (with a constant deceleration) can occur only if the force that is compressing the brake discs (that is the brake pressure) is increasing. In my measuring sessions this does take place, the brake pressure is incr4easing by 10-35% when the travelling speed is increasing. With a constant

deceleration the decrease of the friction when the travelling speed is increasing can take place only if the operational point of the braking is left from the minimal point of the Stribeck curve, as we have already proved earlier. It is clear that basic conclusions can be drawn from the Stribeck curve. That is why it was reasonable to present the Stribeck curve before the analysis if the measurement results.

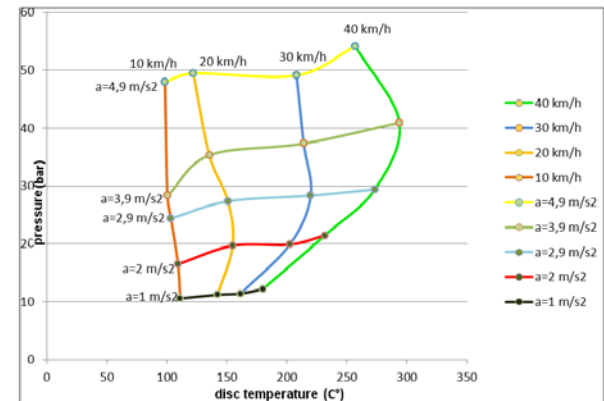


Figure 8 – Pressure temperature diagram

Figure 8 shows the thermal results of the braking process where the brake-pressure can be seen in function of the disc's temperature (actually the temperature of the border layer of the lubricant oil between the discs). Deceleration and the vehicle speed are the parameters. The results are clear. The higher the travelling speed and the bigger the deceleration is during the braking, the higher the extent at which the temperature of the brake-discs is increasing. The viscosity and simultaneously the friction factor are decreasing due to the increase of the temperature of the oil-border-layer. This can be compensated with the increase of the brake-pressure only which takes place definitely. Similarly when the deceleration is increasing then the heat relieved in the unit of time is increasing, the temperature of the disc during the braking is increasing, the viscosity and the friction factor are decreasing. Naturally these thermal processes are also influenced by the fact that in order to have a bigger deceleration there is need for bigger brake-friction momentum meaning the bigger brake-pressure.

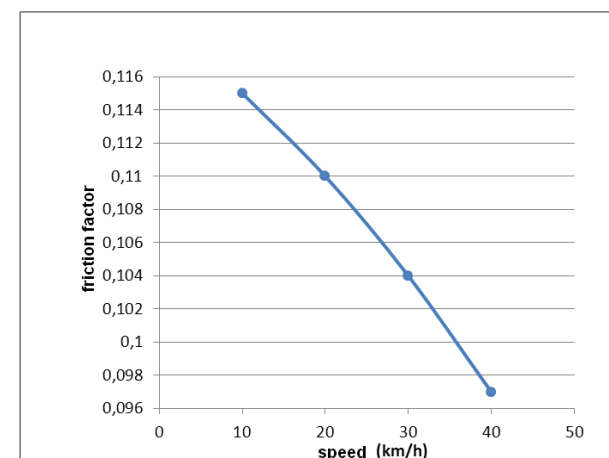


Figure 9 – variation of the average friction factor in function of the travelling speed

According to figure 9 the average friction factor is evidently decreasing when the vehicle's speed is increasing. This figure was prepared with the measurement results of figure 7. This also proves that the operational point of the braking is situated left from the minimum point of the Stribeck curve.

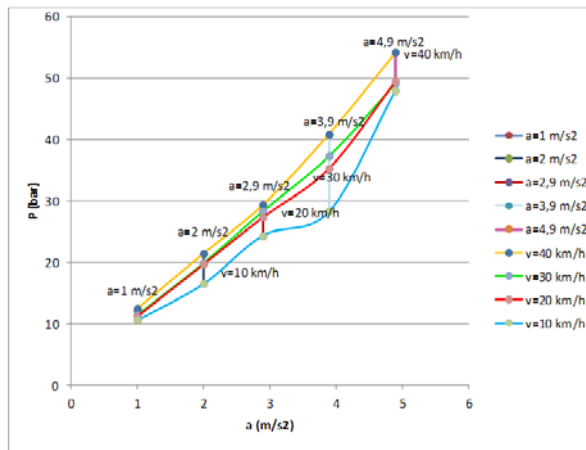


Figure 10 – Presenting the travelling speed of the vehicle in function of the deceleration and pressure

Figure 10 shows the various operational features of the braking. It is conspicuous that the higher the speed of the vehicle, the bigger brake pressure is needed for establishing the given deceleration. Due to the increase of the vehicle's speed the temperature of the oil-border layer stuck to the brake-discs is increasing, the viscosity is decreasing, the lubrication capacity is decreasing, the friction factor is increasing that can be compensated only with the increase of the brake-fluid's pressure.

A similar thermal braking phenomenon can be observed along a steady travelling speed when the deceleration is increasing. In this case the heat quantity relieved in unit of time is increasing, the temperature of the oil-border layer is increasing, the lubrication conditions are worsening, the friction factor is increasing, which can be compensated by increasing the brake-pressure.

5. Summary:

The study is examining the friction-thermal-energetic phenomena that occur during the braking of heavy-weight and slow vehicles. Considering the vehicle's big-diameter rubber-balloons and the slow travelling speed. The rotation of the wheel is rather moderate thus in order to achieve the required brake momentum they use several braking discs. Due to the above the operational point of the braking is left from the minimum point of the Stribeck curve, in the range of the low rotations respectively slipping speeds.

The objective of the study consists of determining the μ friction factor occurring during braking, since with such complicated friction circumstances the theoretical definition of the friction factor is practically impossible.

The introductory part of the study first defines the relation with which the μ friction factor can be calculated from the braking results (friction momentum, brake momentum, temperature). The variation of the

measurement results and the friction factor that can be calculated from them is rather identical with the conclusions drawn from the Stribeck curve.

The value of the friction factor is between 0.09-0.125 in function of the operation state of the braking. When the travelling speed is decreasing and the brake pressure is constant its value is increasing by 15-25% while when the brake pressure is increasing it is increasing when the travelling speed is low, while in the case of higher speeds it is constant at the first approach when the change is parabolic.

The average friction factor is decreasing when the travelling speed is increasing (slipping speed of the brake-disc)

During the braking from a higher travelling speed and when the deceleration is increasing the temperature condition of the brake system, primarily the temperature of the oil-border layer is definitely increasing. Its influence can't be neglected in connection with the variation of the friction factor.

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THE EFFICIENCY OF AUTOMOTIVE VEHICLES BASED ON INTELLIGENT ONBOARD SYSTEMS

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Abstract: Broad automotive engineering in modern agricultural technologies results in the need to improve the operational characteristics of internal combustion engines. In this regard, the internal combustion engines are increasingly stringent requirements in terms of energy conservation and environmental safety. Improving the efficiency of operation of the engine is reduced to the complex optimization of the main variables and parameters of motors with absolute quality assessment used in these fuels. For a comprehensive optimization should be linked all the characteristics of the engine through certain values and parameters. When using fuels of different quality formulated problem is modeled as a multiobjective multi-parameter optimization. One way to solve this problem is the application of the guideline systematic approach - the principles of hierarchy. Management of automotive equipment by using on-Board devices, the functioning of which is considered at the level of subsystems of the engine. The basis for the partitioning of the engine on the levels is the structure, the relationship between the elements and features of their functioning. The interaction of the subsystems is reduced to the implementation of vehicle specified performance properties of the command signals from the electronic engine control systems. Decomposition of the hierarchical structure of the engine should be limited to three levels. During the development of the automated engine management system used in the dynamic system of the engine as the control objects, simulation, mathematical optimization techniques, special simulation setup and debug systems. In the result, we developed several technical solutions: automated system bench testing of engines and simulation of dynamic stand electronic control systems for internal combustion engines.

KEYWORDS: ADAPTIVE CONTROL OPTIMIZATION OF THE INTERNAL COMBUSTION ENGINE, ELECTRONIC CONTROL SYSTEM, THE EVALUATION SYSTEM OF FUEL QUALITY, AUTOMATIC CONTROL.

Introduction

The fuel used in automobiles and tractors transport enterprises, has a certain level of quality, strong physico-chemical and performance properties. These properties provide some level chemotology reliability equivalent to a certain amount of useful work (groundwork). The energy conversion system of the engine is characterized by thermodynamic and workflows teplovydeleniya and heat loss, which is based on the chemotology the processes of conversion of fuels that determine performance characteristics. At high content of contaminants, sulfur and nitrogen can form sulfur dioxide, sulfates, and oxides of nitrogen, problems of environmental pollution sredy. Currently represents bolsta difficulties determination of properties of potential fuels for future engines. Therefore, it is impossible to accurately assess their physical and chemical properties. Nevertheless, in the literature [1], data analysis of the nature of primary energy sources, as well as characteristics of processes for producing fuels we can make a clear performance about the properties of future fuels. A significant number of existing qualitative and quantitative methods of control of certain properties of fuels are time consuming and expensive and require organizatsii specially equipped laboratories, which requires significant expenditures for their maintenance. To improve the reliability of automotive engineering and ensure its quality fuel it is necessary to develop universal methods of quality control of fuels in the formation of its physical and chemical properties directly on the engine.

Preconditions and means for resolving the problem

The main objectives of the rapid assessment of quality indicators of fuel are:

- the definition of an integrated indicator for subsequent exposure to the operated object to increase its life and reliability of the work;
- the regulation of the fuel injection equipment of the engine of automotive engineering for optimal performance when using a certain brand of fuel;
- improving the quality of fuel entering the engine, by forming the optimal physico-chemical composition.

The indicator of fuel quality is a quantitative characteristic of one or more properties constituting the concept of "quality No. defined in absolute or relative terms. The properties and performance of lower level are an integral part of the complex index of quality. A comprehensive indicator of the quality expressed by the function:

$$Nk^1 = f(N_1^2 N_2^2 \dots N_k^2) \quad (1)$$

For the additive model of comprehensive quality index can be calculated by the formula:

$$N^1 = \sum N k^{1+1} \alpha_k \quad (2),$$

Where α_k - is the weighting factor of quality score.

The proposed method is based on an integrated approach to the evaluation of product quality based on the use of weighted-average. Using the expression (2), we get:

$$N = A_x B_y C_z \int_{\psi_0} \int_D \int_D \alpha_y dz dy dz = \varphi_0 \int_D \int_D \alpha_x dx dy dz \alpha \quad (3)$$

where α_y - integrated quality score characterizing performance of the fuel; α_x - is the unit quality indicators received during testing of fuels; A_x - the weighting factor of the i group quality indicator; B_y - the weighting factor of the i complex indicator of quality; C_z - is the weighting factor of the i single quality indicator; ψ_0 - a certain range of values of indicators of the quality of fuel of this type, regulated standards.

Composite measure of quality is difficult to determine, so the spacecraft is unknown analytical expressions quantitatively describing the inter-relationships of different nature processes and phenomena. Revealed that the most extensive factor contributing to the quantitative and qualitative characteristics of energy conversion in internal combustion engine, is developed by the fuel utilization factor k_i :

$$K_i = \frac{\lambda N_e}{q_c} \quad (4)$$

λ - the coefficient characterizing the energetic properties of the fuel, the efficiency of conversion of heat into mechanical work;

N_e - the effective power of the internal combustion engine;

Q_c - cycle fuel.

This composite measure of quality of fuel was developed in the aim of selecting and using the different fuels, which has the potential in energy and environmental respect.

For the rational implementation of quality indicators used fuels necessary operational control of its main energy

indicators, which ensures reliable operation of the engine of automotive vehicles. Conclusion on the compliance of fuel quality standards is not given by all indicators, but only on the fuel utilization factor. The best way to implement the quality control process of the fuel's physical and chemical composition is the adjustment of the operation of the engine by adjusting the fuel system using a feedback system that will protect the engine, its parts and components from premature wear. Generalized scheme of the principle of feedback control system and assess the quality of the fuel based on detection of the deviation of the actual state of the object x from a given state y and convert it into a control action u , is presented in figure 1.

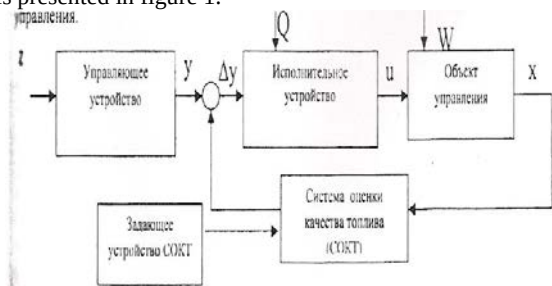


Figure 1. The scheme of the control system of fuel quality control with feedback

z – effects, y – control effects, Δy – deviations, Q – additional external energy, u – increased operating influence, W – the disturbance, x –the actual state of the control object.

More clearly the measurement determination process can be represented as a three-tier management information model for assessing the quality of fuel on the tractor, is presented in figure 2. In this case, the control system of assessing the quality of fuel can perform the functions of a local controller at the first level of the single multi-level system of governance.

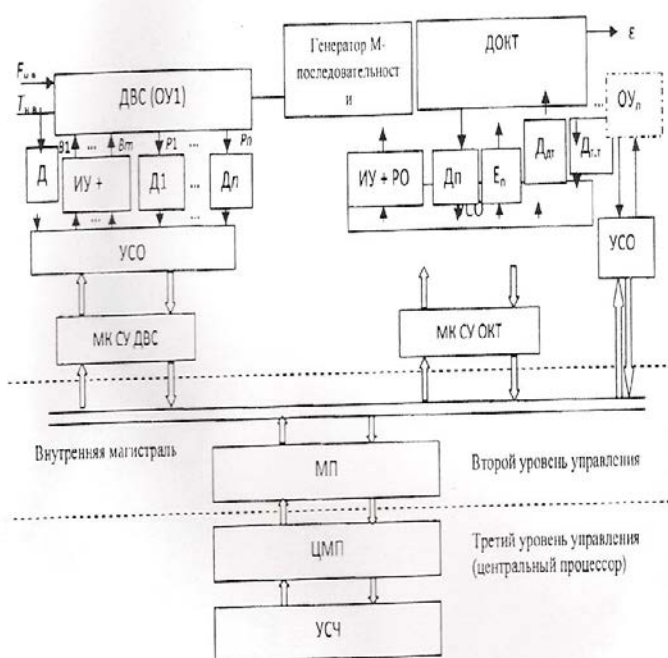


Figure 2. Three-tier data management model system for the evaluation of fuel quality on the tractor.

On the first level is the management of local objects that control the subsystems, which can be various kinds of regulators. The second microprocessor control system provides comprehensive coordinated management systems of the car. In such systems includes power unit, power system, power

transmission, lighting equipment, salon equipment, security systems and accessories. On the third level of the Central microprocessor control system is an automated control system, connected through interfaces to a person. These devices are indicators and controls that are used by the driver when steering the tractor. By the fourth level control, not shown in figure 2, are the systems used by the driver and maintenance personnel in the operation of the vehicle and its maintenance. One of the main objects of management is the DBC.

Its parameters are determined by the sensors D1-Dtg. After agreeing on all the parameters in the management of the evaluation system (UCO), signals are sent to the microcontroller of the control system of the internal combustion engine (MK CY DBC). Control commands via UCO do n actuators IU and regulators of PO for the impact on the engine and its systems. The objective of UCO is for the conversion of analog signals into a corresponding code, and the coded signals at the input of the microprocessor into analog signals.

The second control object in the diagram is the system for evaluating the quality of fuel (COK). The parameters obtained from the temperature sensors fuel Dtg, evaluation of fuel quality Dn, the voltage of the generator En, microcontroller system for the evaluation of fuel quality controls the parameters of fuel injection and ignition timing of the internal combustion engine. If necessary turns on the generator M-sequence that provides the conductivity of the fuel, which facilitates the operation of sensor evaluation of fuel quality. MK SU OKT can program to carry out the manipulation of fuel, given the performance of the fuel. This system greatly facilitates the operation of automotive tools and prolongs its service life. Standardization of interfaces (exchange protocols) communication channels and selects the best Protocol in upravlaushiy subsystem is the most important challenge in designing information control networks for road transport information and control network.

Considering the developed scheme for hierarchical adaptive MPCU with assessment of fuel quality (COKT) the engine automatic control of motor parameters (set of adjustable parameters in relation to diesels reduced) (figure 3), the control unit calculates the motor parameters according to the position of the regulating sleeve, fuel temperature (DTT) and sensor evaluation of the quality of fuel (DOKT). The need for a system of assessing the quality of fuel (COKT) were evident in the Troubleshooting of electronic control systems in diesel engines. System of automatic control of parameters of the engine with a system for evaluating the quality of fuel (COKT) is presented in figure 3 two typical additional systems - closed and open. The first is the system of regulating the pressure of fuel which is formed by a pressure regulator and a channel of the motor, which converts electrical output signal of pressure signal u_d in the fuel pressure p . In the system of regulation of advancing of the injection fuel injection Q is formed founded regulator fuel with the output signal and secure channel engine.

Considered part of the control system (set local system management parameters) provides the engine with a given accuracy maintain its parameters in steady-state modes and necessary or even optimal duration and the maximum deflection of the quality of transient processes of control of engine parameters, primarily by the frequency of rotation.

The system of automatic regulation of frequency of rotation is not only important, but also the most advanced in terms of accuracy and speed local MPCU system of the engine. She plays a unique role in adaptive management, as produced by it managers influences the output signal of the regulator and its derivatives are used at all levels and in all types of adaptation.

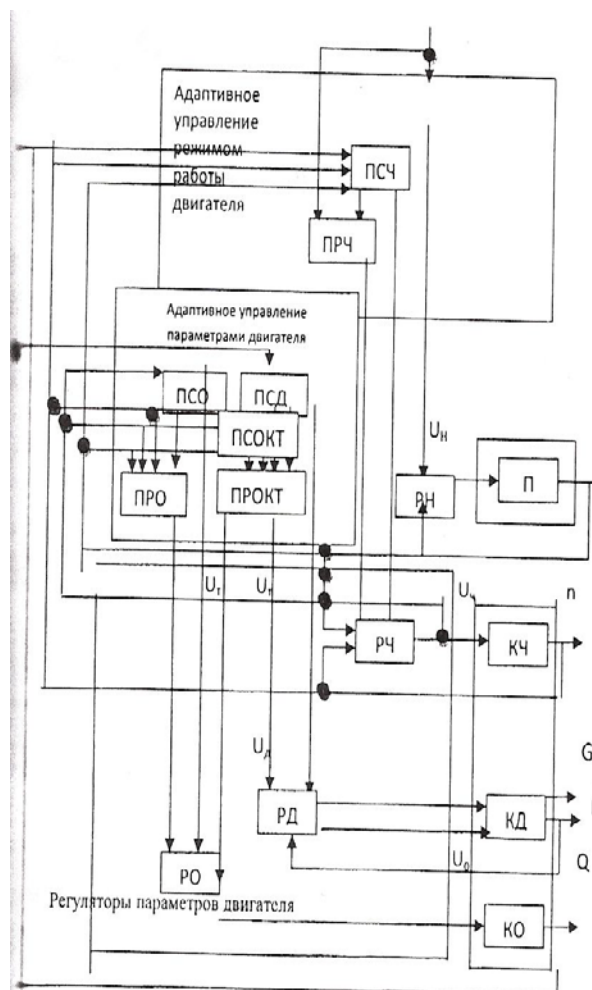


Figure 3. A block diagram of a hierarchical adaptive MPOs engine with automatic control of motor parameters with the system of evaluation of the quality of the fuel

The channel forming the rotational speed starts in the engine fuel system, which converts the output control signal of frequency u_c in cyclic supply of fuel. In KC consistently also includes a thermal link that convert fuel into torque, and a mechanical link to the engine that converts the difference between torque and moment of resistance in the frequency change rotation.

System of automatic control of engine parameters with the system of evaluation of the quality of fuel is closed, the current residuals, i.e. the difference between the specified and actual values of COKT filed at the RO and RD. The deviation of the measured parameters conductivity, respectively, the control algorithm is RO and RD forms u_d and u_o until then modifies this signal until installed them the fuel feed and the advance angle of injection into the engine is not going to come with a given accuracy to a value necessary for the optimal operation of automotive vehicles using different fuels. Such regulation (figure 4) provides high precision evaluation of fuel quality and achieve optimal management areas through a DOKT, as this reduces fuel consumption and improves performance.

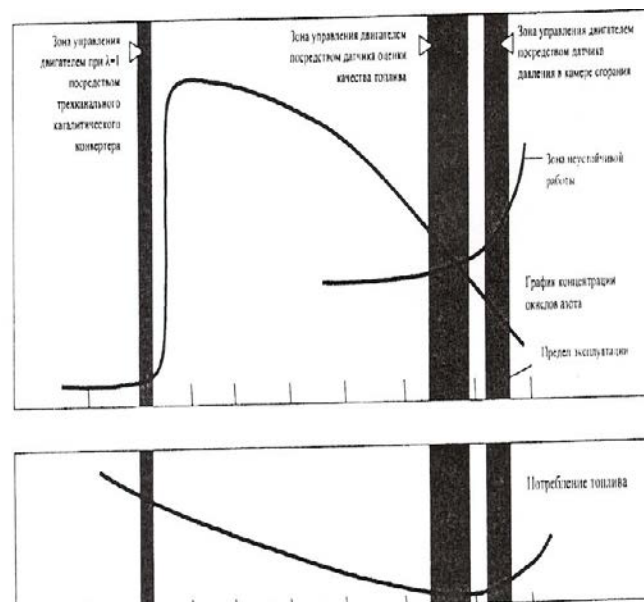


Figure 4. Functional diagram of the adaptive control optimization of the internal combustion engine based on an assessment of fuel quality in different operational modes

Conclusion

Thus, in a closed system changes u_t is the reaction of RD and RO for any made to system perturbations. This signal is most informative, as quickly and accurately expresses what is happening in MPCU processes. Since the fuel supply to the cylinders is proportional to..., then it is proportional and torque of the engine. Of course, the numerical value of the proportionality factor depends on fuel quality, combustion efficiency, speed, etc, therefore, it is impermanent. But to a first approximation, especially when sufficient stability of these factors, u_t reflects the instantaneous values of torque and power fuel (the most common optimality criterion), it can be used as a criterion for the optimal management of adaptazii engine, for that matter, and for other purposes. As a carrier of information about torque, fuel consumption, u_t eliminates the need for installing the engine sensors these parameters is quite complicated and expensive.

Search engines determine the changes in the job controller of the motor parameters needed for more accurate than software-adaptation, self-optimization mode. The search is performed by trial changes jobs appropriate regulator's assessment of the quality and fuel consumption caused by these changes.. For more options of changing cyclic fuel feed, the search engine in General need to control the fuel composition. These include the shape of the injection characteristics. As the optimality criterion in the quality of fuel at the SEMA used total (hour) fuel consumption and the efficiency of fuel use by the engine. In some cases, in the search device, you can use the battery based supply cycle from the pressure of the fuel in accumulator, with the limitations associated with the assessment of fuel quality on the output signal with the influence of the temperature of the fuel. When hard software control of the main parameters of the engine output the control signal to the fuel pressure quite clearly linked with them. Therefore, in a first approximation from can also be used for search engine adaptation by any parameters.

Once the search is completed and the output of the engine to the point of minimum flow adaptive system (Fig.4) according to the obtained data it updates the software algorithms and analysis of adaptation in the assessment of fuel quality (the content of the tables or coefficients of the analytical dependences). This allows to improve the accuracy of optimization during software adaptation engine depending on chemmology properties of fuels of any particular sample and its application conditions.

A set of programmers and search engine management settings, engine forms the main (first) level of adaptive control optimization for internal combustion engine the assessment of fuel quality. Along with the optimization of the parameters of the motor in each mode there is a problem of choosing the optimal mode of operation of the engine. This task is solved at the second level of adaptive management.

Thus, adaptive optimization engine to assess the quality of fuel in the modes defined by the achieved speed and prilozenoj load produced by the circuit of Fig. 3-4 adaptive control device for which the control object is a set of local management systems options. The adaptive device is a second level in the structure of the management system, performing coordinated adaptive management of all controlled parameters of the engine. It is implemented as regulators of local systems in the microcontroller and consists of programmers and search engines. The programming is performed and the necessary amount of analytical adaptation. They choose the jobs regulators of engine parameters and perform software adaptation; job each of the regulators are formed by individual programmes in function of the actual rotation frequency applied to the motor load, other monitored parameters of the engine and the environment, as well

as the output signals of the regulators of other local systems. Search engines are presented in the channels of pressure control and ahead, acting mainly in steady-state modes. Fundamentally search process as possible and in transients, but this is due to the need to increase the accuracy and performance of hardware and software. Therefore, the feasibility of their implementation requires in each case a special analysis. To optimize transient effective corrective actions on derived. The calculation of derivatives of the signals are organically present in the microcontroller, the most rational. The allocation is as optimized leading causes to the speed and accuracy of the systems of regulation of engine parameters when using the system for assessment of quality of fuel and maximum utilization of the output signal of the pressure regulator and its components at all levels and in all types of adaptation provide the greatest possible effectiveness of adaptive management.

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CONCEPT OF A NEW PRO ECOLOGIC MANIPULATOR OF THE SPECIALIZED TRACKED VEHICLE

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Abstract: This paper presents a new concept of the manipulator of the specialized tracked vehicle, designed within the project “WND-POIG.01.03.01-00-164/09 & UOD-DEM-1-145/011”, to be applied for conservation of the protected wetlands. The flail mower, cutting disk for trunks of the trees and/or new version of cutting head are to be interchangeably fitted at the end of the manipulator. It should be more functional in use and more efficient in cutting and removing small trees or bushes, or shredding them on spot. The new cutting head, described in this paper is dedicated to remove and transport branches of bushes, as well as single small trees with a diameter up to 140 mm and weight up 400 kgs on 3.2 m length arm. The paper presents the results of the kinestatics and strength analysis of the virtual model of the new version of the manipulator. Real model of the new manipulator will be made from the steel S355 and its mass without tools should be around 350 kgs. The manipulator will be tested during field tests that are planned in the summer 2015.

Introduction

The Industrial Institute of Agricultural Engineering (PIMR) has designed a new version of a manipulator intended for the removal of young trees from wetlands with the use of a special cutting head presented in Fig. 1 [4, 5]. The new manipulator is expected to provide greater functionality and take up much less

space on the vehicle [1, 2]. Kinematic analyses were used to determine forces acting on the servos and forces present in the nodes. The results obtained allowed for the running of strength analysis with the use of finite element method.

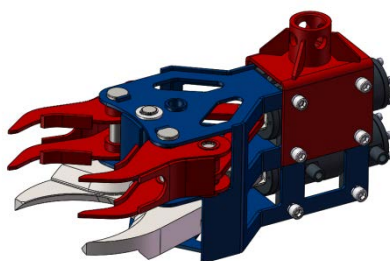


Fig. 1. The model of cutting head designed at PIMR (PIMR-BE archives)

1. Description of the manipulator model

In view of the need to reduce the mass and size of the design, a decision was made to use profile sheets with various thickness, depending on the load, instead of ready-made foundry shapes available in the market. The individual components were connected with the use of pins, and a hydraulic system was used as their drive mechanism. The designed manipulator, visible in Fig. 2, has six degrees of freedom. The manipulator base is

mounted on a turntable with the maximum axial load of 9 kN, fitted on the vehicle body and driven by a hydraulic roll servo with a rated torque of 1 kNm, allowing for a roll angle of 180°. The further part of the jib consists of three arms and a wrist controlled by hydraulic servos. The wrist has another roll servo mounted, with the maximum torque of 2.48 kNm and roll angle of 100°.

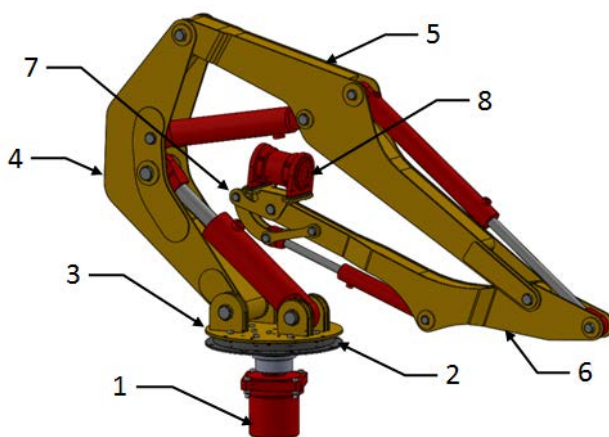


Fig. 2. A geometric model of the manipulator (PIMR-BE archives)
1 – roll servo I, 2 – turntable, 3 – base, 4 – arm I, 5 – arm II, 6 – arm III,
7 – wrist, 8 – roll servo II

The assumed lifting capacity should equal 400 kg at the maximum reach of 3.2 m. Fig. 3 shows the working space of the designed manipulator.

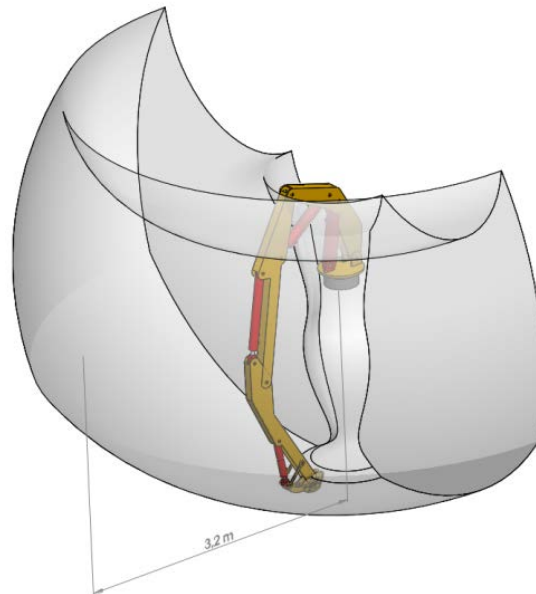


Fig. 3. The working space (PIMR-BE archives)

2. Kinetostatic analysis of the manipulator model

The analysis was run in the SolidWorks environment excluding friction forces, and a simplified manipulator model was made as visible in Fig. 4. In the simulation, the variable parameter was the length of piston extension in servos S1, S2, S3, S4 and roll angle in

the SO1 servo. The assumed deviation of the manipulator base off the axis of rotation was 10° , and the analysis was run for the full range of servo positions in the assumed working space. For the purposes of the simulation, the jib was loaded with a mass of 400 kg.

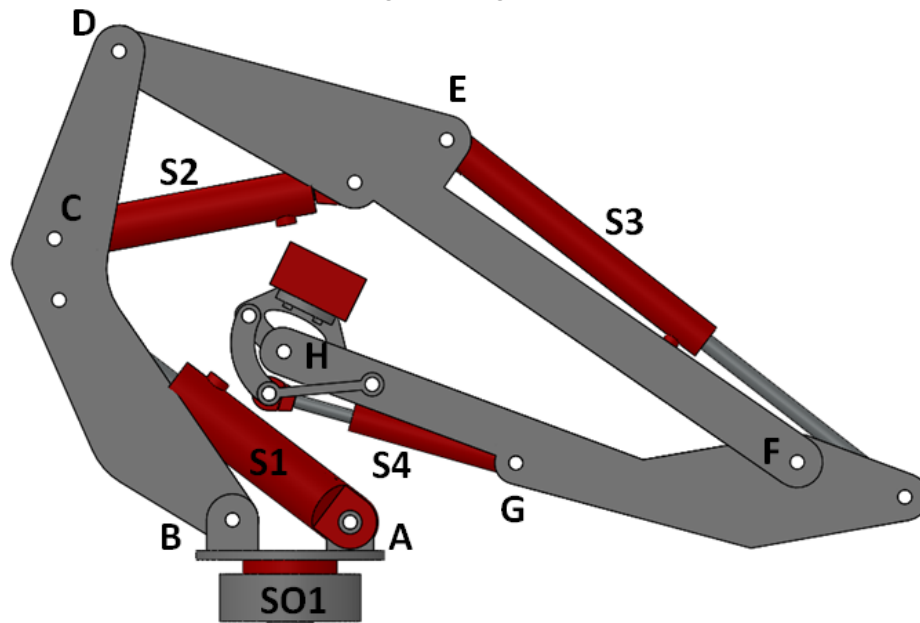


Fig. 4. The kinematic manipulator model in its collapsed position (PIMR-BR archives).

Fig. 5 displays the course of forces required to extend the hydraulic cylinder piston, and Fig. 6 shows the course of torque for the SO1 roll servo.

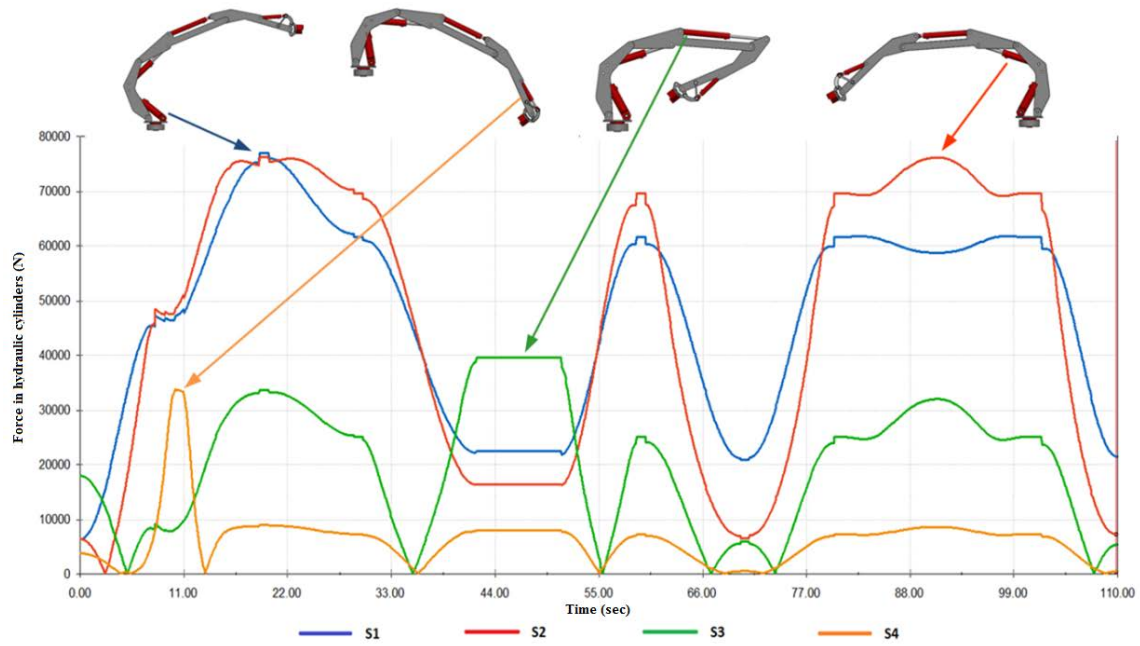


Fig. 5. The course of servo forces (PIMR-BR archives)

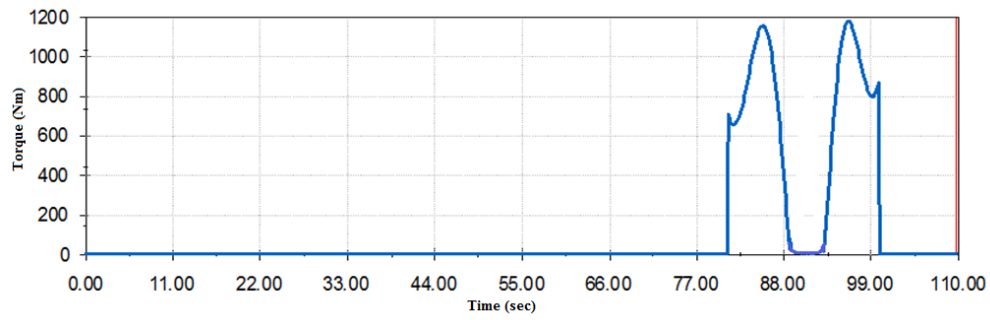


Fig. 6. The course of torque for the SO1 roll servo (PIMR-BR archives)

On the basis of the obtained force courses, appropriate sizes of servos were selected. During the analysis, node forces were determined too, which thereafter served as input data for the adoption of appropriate loads in the MES analysis.

3. Strength analysis

The manipulator was made of structural steel S355. In order to secure the right operation of the equipment and taking into account

the nature of its work, the adopted safety factor is 1.6 (0.6 Re) [3]. It means that adopted permissible stress values equal approx. 220 MPa. As the kinetostatic simulation revealed, the base and each of the manipulator arms were most stressed in different positions. Therefore, the finite element stress analysis was run separately for each of the analyzed components. Table 1 presents loads in specific nodes, as assumed on the basis of the previous analysis.

Table 1. Node loads assumed on the basis of kinetostatic analysis.

Node		Direction X [1]	Direction Y [N]
Base	A	-55000	-55000
	B	55000	50000
Arm I	C	73000	40000
	D	-73000	-35000
Arm II	E	-40000	-5000
	F	-42000	1000
Arm III	G	-40000	4000
	H	15000	-15000

After the preliminary analysis, some components of the structure required to be modified, for example sheet thickness in the arms as well as arm geometry. It was all needed in order to obtain

an even state of stress in the jib. Figures 7 - 10 present the distribution of stresses reduced in keeping with the Huber-Mises-Hencky hypothesis, in specific components of the structure.

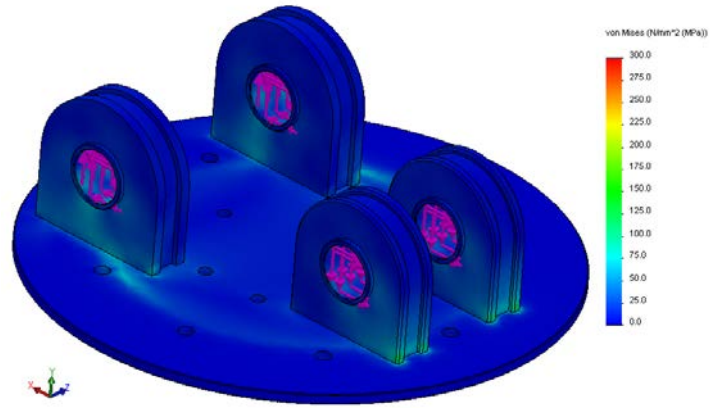


Fig. 7. Distribution of von Mises stresses in the base (PIMR-BE archives)

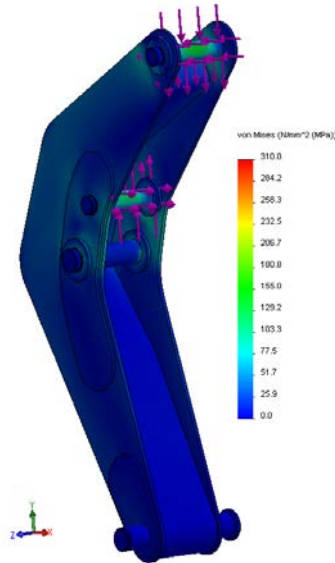


Fig. 8. Distribution of von Mises stresses in Arm I (PIMR-BE archives)

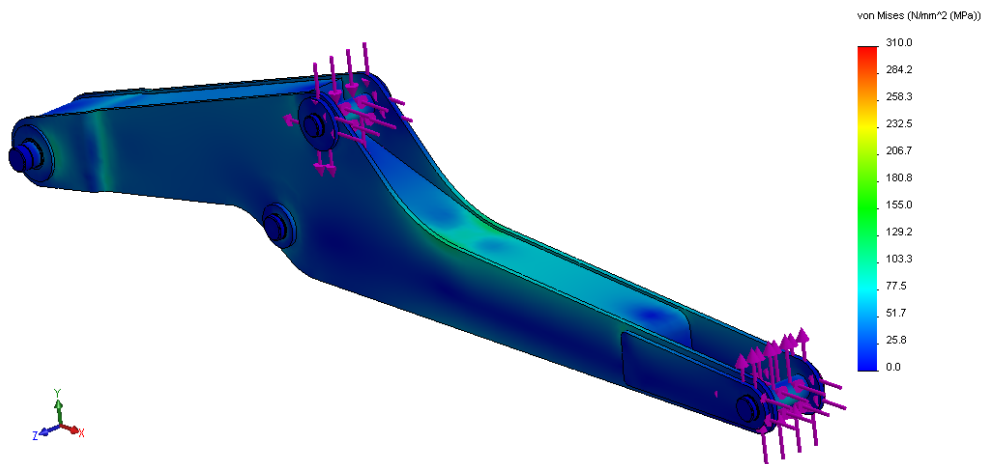


Fig. 9. Distribution of von Mises stresses in Arm II (PIMR-BE archives)

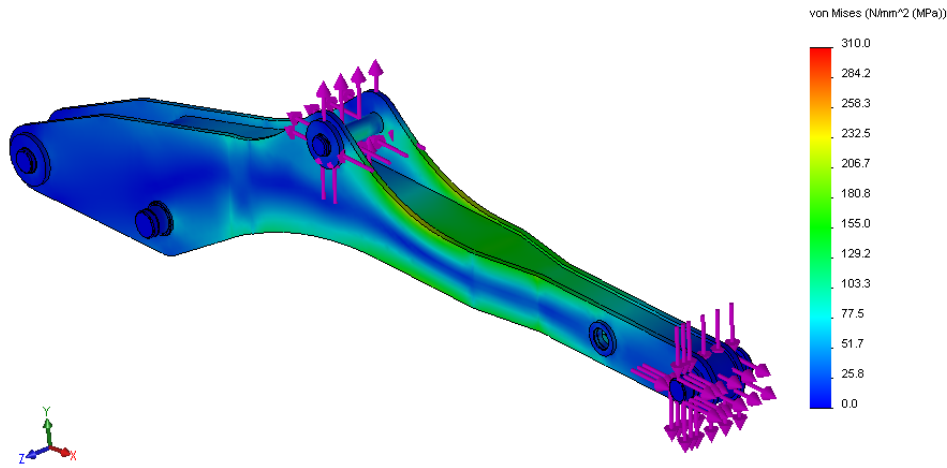


Fig. 10. Distribution of von Mises stresses in Arm III (PIMR-BE archives)

The maximum stresses generated in the simulation amount to approx. 225 MPa. Thanks to the application of various sheet thickness and a clever geometry of the jig a very even distribution of stresses was achieved. The maximum bend values for arms I, II and III amounted to 2.7, 2.7 and 8.5 mm respectively, which is fully acceptable taking into account the nature of work done by the equipment.

4. Conclusions

Application of a design assistance software allowed for the mapping of the structure's behaviour during its operation and for the selection of appropriate sizes of its hydraulic drive mechanisms. The final outcome of the design and analysis performed is a manipulator unit with six degrees of freedom, lifting capacity of 400 kg at the maximum reach of 3.2 m and roll angle of 180 degrees. The assumed mass of the unit and its hydraulic gear (excluding the tool) amounts to ca. 350 kg. Apart from cutting brushwood with the use of a cutting head, the manipulator may also serve the purposes of tree residue removal with a stump cutter or vegetation mowing with a small flail mower.

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DESIGN AND BUILD VEHICLE WITH SOLAR DRIVE FOR WORLD SOLAR CHALLENGE COMPETITION

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Abstract: The paper shows problems and examples finishes solutions applied in the motor industry which be used by solar car production to competition World Solar Challenge. The subject matter will contains the mechanical matters connected with endurance of materials, the wheel set and aerodynamics as well as the electric questions relating the photovoltaic and conversion of electric energy on mechanical energy.

Keywords: SOLAR, MOTION RESISTANCE, COEFFICIENT, CHASSIS, VEHICLE.

1. Introduction

Request for energy grows with development of civilization. Prognoses provide that about 2050 year to the reserves of petroleum are exhaust. The continuous growth of prices of fuels is consequence of this. Environmental considerations was aimed to decrease of consumption of conventional fuels also. Therefore it conducts on the world policy having on aim the development of alternate sources of energy. The sunny radiance is one from renewable natural resources forms of energy. Except the new sources of energy were look for higher efficiency of devices and the most effective utilization of energy. The international competition World Solar Challenge is one of helping such development initiatives.

The participants of competition be divided on 4 class: Challenger, Cruiser, Adventure and Evolution. The students from Scientific Wheel of Lovers of Motorization of Lodz University of Technology undertook the construction in Cruiser class with solar drive. The main aim of vehicles build in this category is design the innovative components which can be applied in mass production of motor industry. This marks that not efficiency but also functionality, safety and comfort depends

The machines constructors try to eliminate friction dry, replacing it more advantageous fluid friction. Because co-operating surfaces are not ideally smooth, on the top of irregularity of surface could be condition of dry or boundary friction and cavities are fill by lubricant. In such conditions the friction in the rough contact surfaces is the mixed friction.

2. The power gained from solar panels

The optimal angle of inclination of solar panels mounted on the vehicle was choosing by program written of the incidence analyzing angle on rout of competition (3000[km] from Darwin to Adelaide). Road by Australia in large part leads in south direction, which marks that the sun in zenith will be under angle 65-85^[°] to level with northern direction, then for obtainment optimum power sunny panels should be the most horizontal. This be caused this, that in wounded hours and afternoon the sun shines properly from northern - east and northern - west. Therefore the use of panels oblique under angle 25^[°] driving in morning hours in directions south-eastern and on geographical width 24^[°]S (about half of rout) it would generate power about 24,8 [%] smaller than using the flat panels. It is this the essential information near constructing the figure of body. The current, which flows in circuit near conversion of sunny energy on electric we mark from equation:

$$I_{sl} = I_{slo} \left(\frac{S}{1000} \right) + J_0 \cdot (T - T_{odn}) \quad (1)$$

where: I_{sl} - Fault current for insolation [A], S - Power of solar radiation [W/m^2], T - Working temperature of cell [K],

T_{odn} - Fiducially temperature [298K], J_0 - Temperature coefficient [A/K].

The angle under which sunny radius fall down on cells in dependence from their inclination it is possible to assign from equation:

$$\begin{aligned} \cos \theta &= \sin \delta \sin \varphi \cos \beta - \sin \delta \cos \varphi \sin \beta \cos \gamma + \\ &+ \cos \delta \cos \varphi \cos \beta \cos \omega + \cos \delta \sin \varphi \sin \beta \cos \gamma \cos \omega + \\ &+ \cos \delta \sin \beta \sin \gamma \sin \omega \end{aligned} \quad (2)$$

where: γ - Azimuth of receiver, β - Inclination angle of cells, ω - hour angle, δ - sunny declination approximate by Cooper rule, θ - latitude.

$$\omega = 15 \cdot (\tau - 12) \quad (3)$$

$$\delta = 23,45 \cdot \sin \left(360 \cdot \frac{284+n}{365} \right) \quad (4)$$

where: τ - hour of the day, n - number of the considered day of year.

The next thing what would belong to take under attention is the fact of undistortable panels characterize with higher efficiency and the individual modules should be under equal angle the inclination of sunny rays. From preliminary analyses appears that the panels about maximum surface provided for regulations of competition are able to generate the power of line 1,2 [kW].

3. Resistances

Resistances make up one of the most essential connected questions and this project with regard on limited and relatively small power which is possible to acquire from sunny panels. Maximum weight and capacity of the batteries is closely definite in regulations of competition.

In order to reduce the consumption of energy was aimed in cars to:

- Increase to efficiency of engine,
- Decrease vehicle weight,
- Decrease the motion of resistance of vehicle,
- Decrease the rolling resistance.

4.1. Aerodynamic resistance

Aerodynamic resistances make up the largest component near settled drive all resistances with constant speed therefore decrease their value is priority. The analysis of flows are carried out by finite

element method helps. Aerodynamic tunnel was designed in simulating program, for which Ahmeda and conditions shore mesh be made models on basis of investigations of real clod (Ahmed Bauds). The investigation of vehicle body is the next step. The assumption is obtainment the value of coefficient of resistance air (c_x) on level 0,15 for side face 2 m². The average city car example. the Kia the Cee'd get the coefficient of resistance of air on level 0,30 with side face on level 2,5 m², that means the constructed solar car will generate 40% less losses connected with resistance of air.

Necessary power to defeat the resistances of air was marked from equation:

$$P_a = c_x \frac{\rho v^2}{s} s \quad (5)$$

where: ρ – thickness of air, v - vehicle speed, c_x – side face of vehicle.

The next task connected with aerodynamics was obtained on front of construction the centers of high pressure and low on the end which possible autonomous flow of air was through cabin, which will assure the suitable ventilation for drivers without necessity the assembling of additional systems. This is essential from consideration on high temperatures current in Australia holding in period of competition and construction heating.

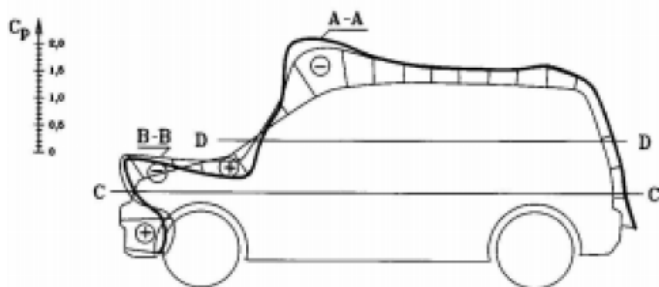


Fig. 1 Pressure distribution of body construction during vehicle movement.

5.2. Rolling resistance

The resistances of rolling first of all are connected and generated through tires losses. They be caused by hysteresis of springy deformation of coat tire, the friction and deformations of elements of tread in trace of contact point of tire with road, the adhesion of tread of surface, the losses of hitting of elements tread of road surface and losses of inertia formed on result surface the existence of "standing wave". The losses are negligible small taking under attention relatively small speed with which car will be driving. In reality about 90% losses comes into being on result of hysteresis of deformations. The state of roads in Australia are good but the terrains of tropical dry climate. The sand throwing by the wind on the road generates additional resistances included in calculation to connected with deformation of surface losses.

Radial relatively wide tires are producing the little losses (adapted to mass of car), from possibly large surface of contact point tire with surface of road, so to the angle the characterizing degree of bending the tread are so smallest. Pressure in tires should be the highest what should was consider during projecting suspension. The high temperature of environment near suitable doping of rubber mass causes the only fall of losses of hysteresis deformations. The also higher degree of waste of tire reduces the coefficient of resistance of rolling.

The aim will be use tires with coefficient of rolling on level = 0,0045-0,005. Good class tire has on level 0,01 this coefficient.

Transverse section such designed tire especially tire is approximate to rectangle for obtainment the maximally large

surface from surface of tire contact with road surface. This is slick type tire which able to decrease the friction with subsoil and loses caused by hitting blocks on the surface. The tire characterizes the endurance permitting on inflating her to 7,7 atm (for average car tire - 2,2 atm.).

The necessary power on defeat the resistance of rolling was marked:

$$P_T = (0,278) \cdot c_T \cdot \left[1 + \frac{v}{161}\right] \cdot G \cdot v \quad (6)$$

where: v – speed of vehicle, G – vehicle weight.

The resistance connected with rolling the vehicle come also from bearings and they are proportional to vehicle speed. To reduce it is possible by use of dear ceramic bearings. Losses connected with movement of power transmission system and the continuous recruitment of relatively large current, about 10%, through electric engine near generating the little powers. It is possible to reduce by cycle accelerating vehicle to set speed and the declutch the drive and switching off the engine. The characteristic of dependence of resistances after regard all resistances was got from velocity from which got the necessary power to the keep solid speed on level 65 km/h carries out about 1,5 kW. However car, with safety considerations and possibility efficient accelerating should dispose several higher power.

6. Construction of chassis

Suspension isolates influence of surface body for vehicles. The harmful influence of trembling's and vibration be eliminated on element of building of car, his endurance and time of exploitation. Moreover the aim of suspension is provide continuous contact tire from surface during usual drive and maneuvers connected from turning and turns round. Suspension also have considerable influence on safety directing and his concentrations.

Requirements for designed suspension for solar vehicle are:

- The mass of the solar vehicle the is considerably lower from average of size of car for everyday use. The car of mass bout 400 kilograms aim of this project.
- The simplicity of suspension is the important element of the possibility easy repair.
- Elasticity, possibility of control and adapting for not only European surfaces, also Australian,
- The easiness of turn wheels in case of steered axis by steering system,
- The mass of only elements of suspension with this regard that every kilogram of additional mass causes the growth of motion resistances and it co growth of necessary energy for this goes on accelerating the vehicle
- The comfort and quality of driving and , keeping safety in turnings.

Suspension with double transverse control arms preform above mentioned requirements solution. Upper arm, bottom arm, spring and shock absorber in composition this type of suspension comes in. The control arms are fixed by ball joints with steering knuckle for front steering axis and by bearing hub for rear axis. The idea of independent suspension is important notion. The whole geometry of independent suspension with two control arms makes possible the realization of following requirements placed already in the kinematic-dynamic exact analysis.

- Placing on any required height the center of rotation,
- Use of geometry should make possible so called preventing the "diving" of car,
- Possibility of installing the stabilizer,
- It should limit the influence of inertia of mass body and strengths influencing across compensating him by vertical movement of set of suspension,

- Every of wheels makes possible independent amortized work on different kind roughness by drive is more stable,
- Operating with only geometry, mutual span of arms is possible to reduce in joints the appearing strengths and the fixing in body.

The basic foundation to see the full figure of suspension work is his behavior that all components and joints entering in his composition are stiff including the joints and elements of fixing. Adding this to already exchanged higher requirements possible the creation of dynamic scheme of considered suspension is. All the most important elements of suspension on scheme were contained.

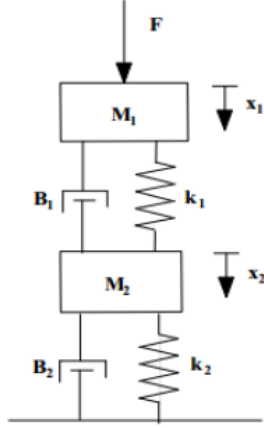


Fig. 2 Simplified model of shock absorbers working.

The springing mass is the weight of the vehicle influencing on the considered mechanism. Above mentioned scheme takes into account stepping out first of all on joints friction and in amortizing element. Under idea of springing mass whole mass of all elements of suspension is understood. Additionally properties of dampen and springy of tires are considered.

This is important because ability of tires able to dampen of trembling resulting of microstructure of surface majorities. The remain part of trembling are passed on plastic elements of suspension.

After writing suitable dynamic equations simulation model are created.

This will permit on calculation on basis of exit data extortions required in projecting coefficients which in more far part will permit on creating the already concrete geometrical models of suspension and received values of strengths will be to stamina enumerations basis.

The dynamic equations describing the scheme of suspension:

$$M_1 \frac{d^2 x_1}{dt^2} + B_1 \left(\frac{dx_1}{dt} - \frac{dx_2}{dt} \right) + k_1 (x_1 - x_2) = F \quad (8)$$

$$M_2 \frac{d^2 x_2}{dt^2} + B_2 \left(\frac{dx_2}{dt} \right) + k_2 x_2 + B_1 \left(\frac{dx_2}{dt} - \frac{dx_1}{dt} \right) = 0 \quad (9)$$

After rearrange an equations:

$$\frac{d^2 x_1}{dt^2} = \frac{1}{M_1} F - \frac{B_1}{M_1} \frac{dx_1}{dt} - \frac{k_1}{M_1} x_1 + \frac{B_1}{M_1} \frac{dx_2}{dt} + \frac{k_1}{M_1} x_2 \quad (10)$$

$$\frac{d^2 x_2}{dt^2} = - \frac{(B_1 + B_2)}{M_2} \frac{dx_2}{dt} - \frac{(k_1 + k_2)}{M_2} x_2 + \frac{B_1}{M_2} \frac{dx_1}{dt} + \frac{k_1}{M_2} x_1 \quad (11)$$

Where:

M_1 - springy mass,
 M_2 - non-springy mass,
 x_1, x_2 - dislocation masses,
 k_1, k_2 - spring constant,
 B_1, B_2 - damping coefficient.

Below is the operating scheme of the arrangement

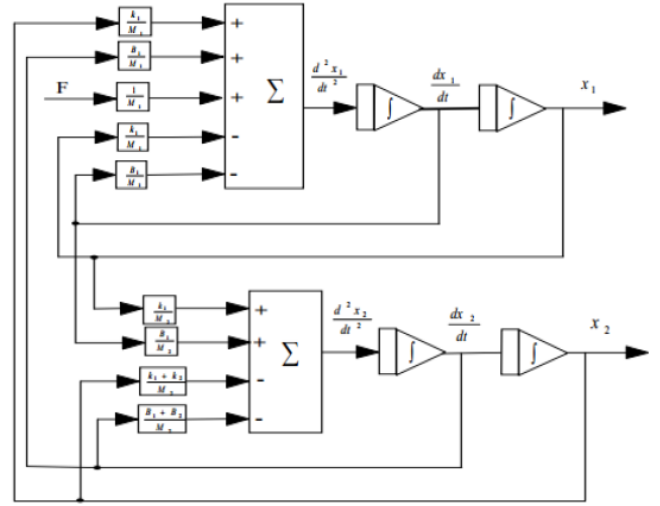


Fig. 3 Scheme of the mechanical operation system.

7. Selection of materials and technological process of production body

First stage of process of projecting the proper selection of factor of safety suitable optimization of material structure and planning the technological process. This obtainment will assure of desirable stamina properties of body and weight. During carrying out of stamina analysis it is essential element the selection of the most profitable factor of safety to the relation of safe stress to permissible do not cause the increase of mass of vehicle. The reduction of mass will cause visible decrease the tires resistances of friction about surface and decrease the losses of energy. The stamina analysis will becomes conducted near help of ANSYS programme. The correct realization of solid figure is in programme the basic condition of realization of investigation of stress of construction the CAD. It is possible to transfer without problem to programme ANSYS and to achieve analysis such model. The good creation of model is important to effective and correct realization by programme of mesh of elements. The last stage of stamina projecting is subtract the degrees freedom and correct applying forces.

In the end of XX century become a growth of interest of composite materials. This results first of all with advantages which they possess such as:

- low proper weight; they used to production of catamarans, rockets, airplanes,
- low thermal conduction,
- resistance on corrosion,
- easiness in creation of difficult constructions from composite materials,
- great resistance on cracking and local damage.

From this regard constructions from composite materials are suitable to the production of body of car taking part in competition World Solar Challenge ideally. The main aim of them use is easy imitation of complicated shapes, mass reduction and large mechanical endurance. The body will monobuilt construction (monocoque) created from composite fibrous materials.

Characteristic mark of every composite is Young module defined by:

$$\frac{1}{E_k} = \frac{f_0}{E_0} + \frac{f_w}{E_w}$$

Where:

E_k - Young's modulus of composite material, E_0 - Young's modulus of matrix, E_w - Young's modulus of fiber.

Use of such construction possible the reduction is the mass and assurance of suitable stiffness of vehicle. Elimination frame will permit on better use space inside the vehicle. The use of composite materials to building the body will not permit to installing other components to the suspension. The only one solution is applying of auxiliary frame to which the elements of suspension will be mounted.

The body will created from laminate. This will be sandwich construction which have good stiffness and endurance of construction. The quality of laminate is important of his thickness. As laminate is fatter then values of compressive and tensile force are smaller. Such composition consists from layer of coal fiber, sandwich and kevlar fiber.

All these layers are joint by resin. The coal fibre comes into being in result the pyrolysis. It be produced from artificial polymers or natural, tar and phenol resins. Coal fibres have very high tensile strength which is about 1800 [MPa]. They are built from arrayed in two-dimensional layers hexagonal arranged in stacks about thickness to 10 [nm].

Tab.1 Properties of most often using fibres.

Fibres	Density [Mg/m ³]	R _m [MPa]	E [GPa]	Fusion temp. [°C]
Polymer	1,44	4,4480	124	86
Kevlar	1,14	825	2,8	2,46
Metallic				
Wolfram	19,40	4,00	3,410	21
Glass fibre	2,55	3,450	<1,725	28
Carbon fibre				
HS (high resistance)	1,75	5,650	3,700	158
HM (high stiffness)	1,90	1,860	3,700	279

The sandwich have honeycomb structure. Honeycomb are polypropylene materials and use them to production of motor truck building. The sandwich is built from aluminum core of hexagonal shape cover from up and down thin metal foils, which protect before getting through resin inside of core. This permits on full control of process laminating and assures the obtainment the put mechanical properties. The small mass is advantages of this type of sandwich by behavior of high quality of construction and high the stiffness.

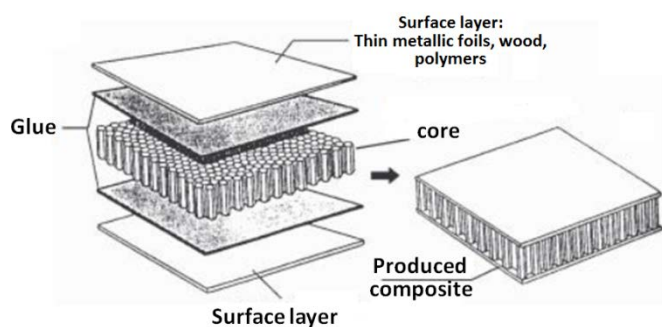


Fig. 3 Scheme of composite building of honeycomb structure.

The aramid fibres are the strengthening fibres, the built from linear, regular and stiff chains of para-fenylene terephthanlamide particles. They have very extremely arrayed coating joint with very strong hydrogen bonds structure. The structure of aramid fibre have high physics-mechanical proprieties and high the thermal resistance. Kevlar fibres possess unfortunately small endurance on compress therefore they are strengthened by example coal fibres or glass fibres. They have good fatigue strength, resistance on grinding, large energy of destruction and good electric proprieties. Resin is last element of laminate, which is mentioned above is a part of adhesive. Epoxy resin will be applied which is built from polyphenols, epihlorohydrin and oligomer which have on the ends enrolment formations. Resin have the structure of sticky liquid after

confusion with hardener and becomes indissoluble and infusible after congealing.

The technological process of production of body consists from several stages, which every requires the exact preparation as well as efficiency manual. First part of whole process depends on producing foamed polystyrene form. The foamed polystyrene blocks of links oneself in one cuboid with the help of the suitable binder.

This binder is sewed on the centers of blocks to during formation of block from foamed polystyrene by the hot resistor wire did not happen break of continuity of his movement. To get suitable shape, model is polished and spatula is sewed on him. The putting on him the ground coat and lacquer is the next stage of creating of form. In aim preparation to laminating one should to degrease and to put on external surface of form the funnel. This will assure easy break of form made from fibre glass and gel coat from foamed polystyrene model. Gel coat is he outside part of polyester glass laminate. He is useful high durability, aesthetical appearance and resistance on atmospheric factors. It is proper to mark it that before laminating on form should draw the line of section of form to receive the bottom and upper part of model. After end of laminating need to degrease and to plot on half of form the distributor again. The last stage of building of body is realization of laminate is from coal fibre, separator and aramid fibre. In this point on fabric made from coal fibre put to form and moisten with resin. Then in earlier moisten with resin in indicated places add separator which also moisten resin. Next phase of laminating is position earlier moisten resin of sheet from aramid fibre. To receive the dull internal surface of body on kevlar put delaminate. Whole need be cover cotton-wool and foil. By compressor the air is siphon off so whole excess of resin could sink and during coagulation of resin it do not come to cramp of laminate. After realization both half of body of links oneself it from internal side the cellulose glue.

Acknowledgement

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RECOMMENDATIONS ON CLIMATIZED CABINS AND SEATS

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Abstract: In view of the high risen demands on the machine operator to a safe and high efficient guidance the best possible "workplace situations" must be available. Beside assisted vehicle operation and ergonomically optimized machine interaction particular importance must be attended to individual adjustments as well as climate management. Though for a good climate in the cabin the newest technologies are applied, still the perceived comfort can become disagreeable in spite of air-conditioning. On longer terms the heat as well as the humidity produced by the driver accumulate in the seat and lead to negative sensations, concentration interferences, tiredness and consequently performance losses. Thus the operator's seat sets a great challenge for agricultural and forestal automotive vehicles already in the matter of ergonomics and safety, concerning hygro-thermal functions however it is probably one of the most complicated development topic. Apart from general interactions between climate situations and best human work performance, assessment and measuring aspects for climate and comfort as well as constructional details for optimized heat and sweat management on drivers's seats have to be respected.

Keywords: SEAT, CLIMATE MANAGEMENT, CLIMATE COMFORT, THERMAL STRESS, SWEATOR

1. Introduction

Comfort is a multifactorial issue and can be categorized into biomechanical and climatic aspects, influenced by emotional as well as individual situations. It must be realized that various interactions are existing between the comfort spheres, like changes in mechanical properties due to increasing humidity or low convective heat exchange. Additionally the exposed time will change the importance of the comfort factor: short-term discomfort is determined mainly by biomechanical features while with increasing time the climate perception becomes cardinal. But anyway discomfort reduces the work performance, the quality, the safety and endangers at least the worker's health.

2. Thermal Stress

To assess thermal stress the physical workload, the environs climate, the individual capabilities and the clothing as well as the supporting systems have to be regarded. In most articles and references it is assumed that "thermally comfortable" is correlated to core- and skin-temperature or to summarized values (i.e. Ramanathan temperature). However it is not considered that extreme climatic conditions on body parts will significantly influence the global perception, like during sitting.

The driver's cabin of forestal, construction or particularly agricultural machines sets a very special situation, because of big windows for a good overview, hermetic sealing against dust, leaves and flakes, periodic changes of work position and various weather conditions. Therefore a climatized cabin should be supported which ensures an acceptable temperature in the range of 19 to 23°C (at least 26°C, resp. lower 30°C) as well as a relative humidity between 40 and 70% according to the comfort requirements. If the temperature exceeds that range and the clothing system is not adapted capability and motivation will decrease. The humidity should be controlled with respect to their influence on the temperature perception, to ensure the evaporative heat transport and to avoid breathing problems [1].

Though the latest technologies are available for achieving a high degree of climate comfort in the cabin's interior, the feeling of well-being can be impaired in spite of the presence of an air-conditioning system. Over longer time, the heat as well and the humidity produced by the driver accumulate in the seat and lead to negative sensations, impairment of concentration, tiredness and reduced performance. Consequently, the operator's seat itself is challenging enough for the agricultural automotive industry in terms of ergonomics and safety, but when hygro-thermal functions are taken into account too it is probably one of the most complicated development tasks.

3. Optimized Seat Climate

3.1 Methods

By long years of experience collected via studies on the climatic wearing comfort of clothing and as a result of numerous cooperation projects with well-known seat manufacturers, in a joint venture of the ergonomic laboratory at Munich University of Applied Sciences, the c.russ-NETCONSULT and the Institute for Applied Ergonomics the THG-SeatView and the SWEATOR system have been developed to industrial standards.

The THG-SeatView allows two and threedimensional temperature and humidity distributions to be measured over time in optically invisible layers such as in the contact area of human and seat and/or backrest in particular. The results are not adversely affected by the measuring technique and are displayed graphically in compressed form (Fig. 1).

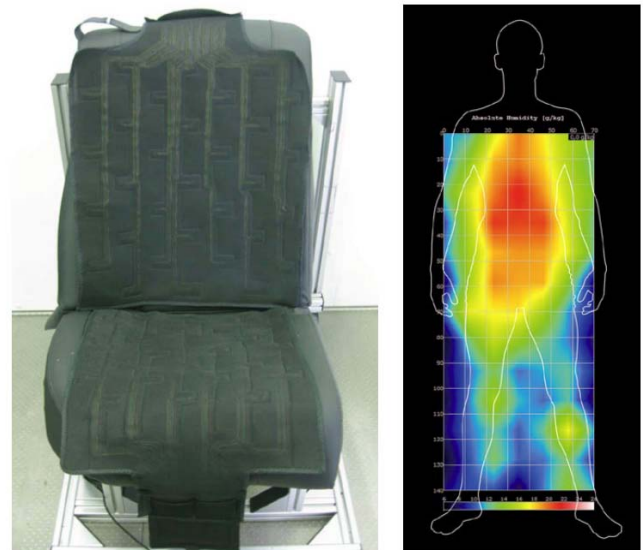


Fig. 1: Test seat with THG-SeatView and thermo-hygro pattern.

The SWEATOR is a static, quantitatively reproducible source for humidity and heat which can simulate thermoregulation processes with virtually every test-body profile. This enables a broad range of scientific institutes, R&D departments as well as test and certification centers to easily conduct highly reproducible textile-technical and thermoregulative-physiological parameters. The basic skin model (Fig. 2) allows the examination or comparison of textiles or textile sandwiches as well as complete products like

seats or laying systems just by setting the active penetration field on the probes. The transported amounts of heat and humidity are tracked and lead to a prediction and categorization of climate comfort.

By use of the TRG-SeatView and the SWEATOR skin model a climatized (by active ventilation) seat has been optimized according to heat and sweat transport capabilities (Fig. 2) and to the control strategy.

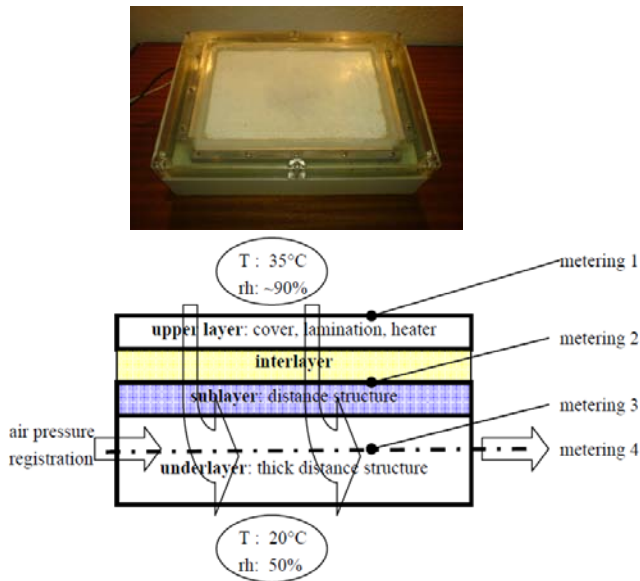


Fig. 2: SWEATOR skin model as heat and humidity source to analyze transport mechanism of climatized seats.

With the goal to specify the climatic comfort on driver seats by measurement of the contact climate as well as by query of the user's perception a suitable test setup was developed with standardized conditions, i.e. in a climate chamber. Additionally a data processing method, called clustering, has to be established to get valid test indicators.

The tests were carried out under fixed climate, i.e. 28°C and 60% relative humidity, with the climatizeable seat (Fig. 1). A task simulator guaranteed the reproduction of the movements and stress situations appearing in a real operating situation. After 2-hour test time the ventilation of the seat was activated. The preselected and instructed test persons (n=15) carried underwear as well as cotton trousers, cotton shirt and sports shoes. After a short preconditioning the test person was seated on the seat equipped with the THG-SeatView measuring mats (see figure 1) and the 3-hour test was started. Every 30 minutes the person had to judge her subjective climate perception. For this 5-stage scales were used for dampness (1:convenient to 5:humid), comfort (1:comfortable to 5:uncomfortable) as well as for the temperature sensation (1:convenient to 5:warm). A cold sensation did not appear according to the selected test climate.

3.2 Results

Beside the big data amount, which is produced by the THG SeatView system, individual factors like body height, contact area as well as sitting position complicate the automated extraction of valid indicators, which determine the climate and its perception. An analysis of the measurements required first a grouping of the test subjects in small and big people, strong or weak sweating as well as men and women. Afterwards their temperature distributions and humid distributions were evaluated statistically to specify the sensors or sensor areas which show prestigiously the microclimate with the appearing maximum values and do not average them. Thus a cluster procedure could be defined with specified sensor areas on seat and backrest, in which the climatic interaction is best represented for all experimental subjects and test terms. Figure 3

shows exemplarily humidity distributions at seat and backrest as well as the developed clustering methodology [4]. For the following assessment of the climate interaction the clusters S2 and L2 are used.

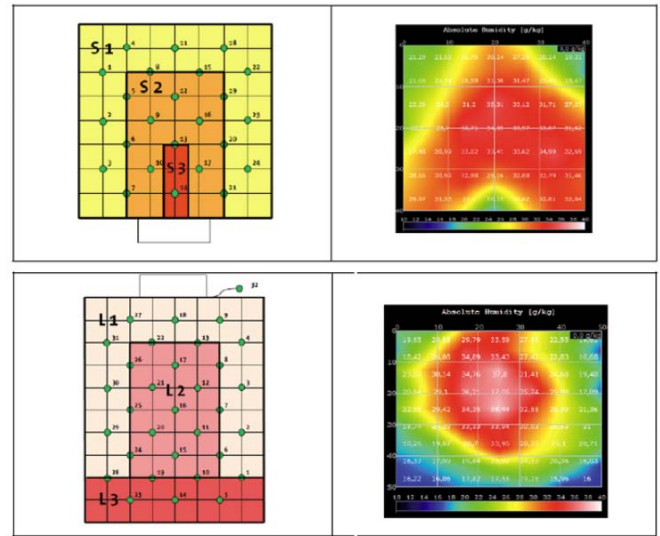


Fig. 3: Measurement patterns with clustering.

To correlate the climate perception and its effect on the comfort feeling only the test results at the end of each 30 minutes interval are used. Thus a huge data reduction is achieved despite of an enough precise record of the test dynamics. Figure 4 shows exemplarily for a test group the averaged climate values of temperature, relative and absolute humidity with the corresponding perceptions. The dependence between subjective and objective indicators is clearly recognizable and statistically significant and shows the positive effect of the seat climatization.

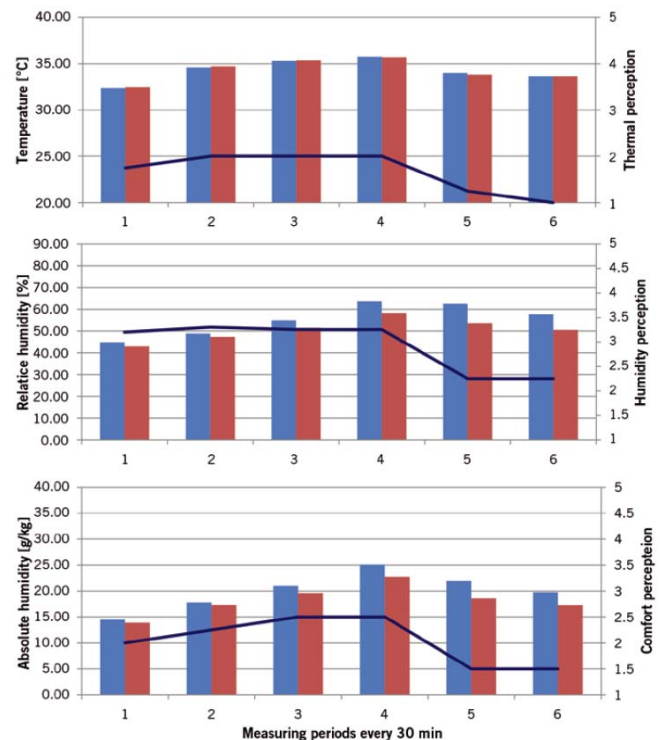


Fig. 4: Climate (red: seat, blue: backrest) and perception with ventilation after 120 minutes of the test (period 4 on time axis).

With respect to the central issue „comfortable or not“ most of the test persons specified a “perception switch” to the value 3 for humidity, temperature and comfort. By means of these limits it is possible to deduce suitable temperature and relative or absolute humidity values, where the comfort will significantly change. Despite of individual differences in thermoregulation and climate

sensation the evaluations of all test results show a consistent dependence between measures and perception. Based on the perceptual discomfort grade 3 the following values of the climate factors could be established:

- temperature: 35.5°C
- relative humidity: 60% rh
- absolute humidity: 23 g / kg

These limit values are found in good correspondence with various scientific investigations on other body regions or clothing components [2,3].

Finally, of special interest is the question, „which change of climate measures leads to a valid perception change“, so the question after the perception sensitivity. From former studies could be determined that the individual differentiation of the perception correlates with a change of 0.5 steps in the individual grading. Based on all collected data the following, global perceptive resolutions are determined:

- discernable temperature change in the area of 30-35°C: 0.4 – 0.5°C
- discernable change of the relative humidity: 5% rh
- discernable change of the absolute humidity: 2-3 g / kg

Any developer thus has climatic limit ranges at his disposal which determine the transition to discomfort in case of normal perspiration behavior in the test condition described.

4. Summary

With the goal to specify limits or ranges for a good climate comfort on vehicle seats in well climatized environs (cabin) measures were correlated with subjective perception statements in various tests with regard to warmth, humidity and comfort. To compress the extensive measuring data a suitable processing procedure was developed by use of clustering methods, using not only single measuring values or global averages but sectoral characteristics for further calculations and evaluations.

The results demonstrate a good intraindividual correlation between measures and perception values, in particular with regard to temperature and heat sensation or absolute humidity and comfort perception. This enables the fixation of assessment standards for the climate comfort on vehicle seats. However, these are still to be verified for other climates or seat constructions.

By use of the SWEATOR technology the microclimate e.g. on vehicle seats can be simulated according to the human thermoregulative processes. To investigate the required control and setpoint values achieving a valid comfort prediction will be one of the following research goals (Fig. 5).

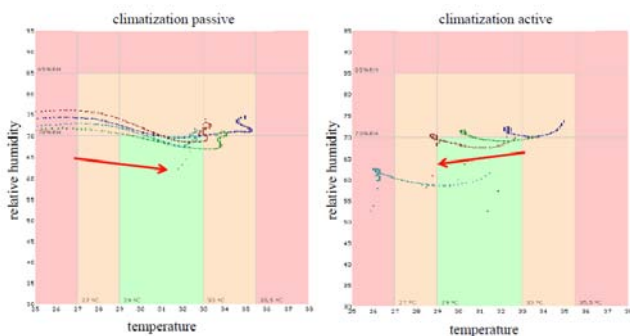


Fig. 5: Climate (red: seat, blue: backrest) and perception with ventilation after 120 minutes of the test (period 4 on time axis).

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WORK SAFETY AND HEALTH PROTECTION IN MAINTENANCE AND REPAIR

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Abstract: Based on current stress situations in the repair section of a big German truck and bus company procedures for force measuring have been developed, methods for risk assessment are selected and applied and proposals for improvement of the work performance are discussed. In addition to the technical component of the force measurement with a specially designed device and the organizational component in a project with representatives of various disciplines the specific differences between service and production are to be respected. Most of the approved assessment tools like COBRA, KIM (LMM) or EAWS for physical work situations with critical body and spine loads can just be applied with restrictions. By use of a special documentation systematic the results of risk analysis of selected activities are evaluated and solutions developed according to the TOP principle with respect to economical, technical and organisational feasibility. Effort and practical acceptance of the project are mainly determined by the multidisciplinary staffed working group.

Keywords: ERGONOMIC ASSESSMENT, LOAD HANDLING, LOAD MEASUREMENT, WORK DESIGN

1. Introduction

Apart from communication and internet of things the third global megatrend is services. However the ergonomic methods for work design are primarily focussed on production. This discrepancy appears particularly on machines and vehicles with respect to many repetitive processes in production and high process variety in maintenance. So the approved assessment tools for physical work situations with critical body and spine loads like COBRA, KIM (LMM) or EAWS can just be applied with restrictions. For example the valuation of the necessary muscle force during mounting of heavy spare parts, to be lifted completely or even partly, is difficult and mathematical simulations are not available. To find solutions for the worker's situations in the garages and workshops, to improve the work performance and to select matching work supporting tools the joint venture project with a big bus and truck company (MAN) has been conducted especially for the repair and maintenance section.

2. Methods

With the goal to analyze the working conditions in the service department of heavy load vehicles and to improve work place ergonomics in the context of demographic change, the company composed a team with following participants:

- corporate management representatives
- employee representation
- experienced staff from the service area
- skilled personnel for the assessment of activities (e.g. by occupational physicians, specialists for occupational safety as well as for integration management)
- deputies of occupation cooperative and health assurance (e.g. physiotherapist)
- ergonomics expertise of Munich University of Applied Sciences.

2.1 Work Analyses

First the main activities were analyzed with respect to their frequency and significance to assess the conditions in the service department. It was shown on the part of the company that, despite the variety of the tasks in this service sector, some tasks have a high share in the daily working time. It was therefore decided to analyze these frequent activities in detail. As part of the analysis, it turned out that particular attention must be paid to the strain on the back and spine during the maintenance and repair of vehicles. Stretched or flexed postures as well as high action forces due to the heavy vehicle parts were identified as main risk factors.

2.2 Force Measurement and Posture Analysis

For analysis of body postures the CUELA measurement system (Ellegast et al. 2010) was used by representatives of occupation

cooperative of wood and metal. At the beginning of each test series the worker was equipped with the CUELA system. To establish standardized conditions and to obtain objective data, the activities have been carried out strictly in accordance with the repair instruction manual.

For the analysis of the reaction forces occurring, a measuring system for use in the field has been developed. The application of the system and the interpretation of the measurement data should be as simple as possible. It should be ensured that the reaction forces can be properly assessed, for example when pressing or holding and when lifting heavy parts. Finally, the measurement device itself should not influence the result or the work performance too much. After evaluation of the prototype the force measuring device (see. Fig.1) was integrated into a glove (Mujic 2014). The unit can measure axial forces up to 300 N per hand with an accuracy of ± 3 N, transverse forces are suppressed by the measurement system. In the tests the force measurement was carried out only in simplified operations, in which a component weight with exceeding 5 kg occurred. For this, the activity was temporarily suspended in order to apply the force measuring system. In addition, heavier parts were measured with separate hand scales.

For later analysis, the activities were documented by video recording so that a clear assignment of forces and postures was possible.



Fig. 1: Force measuring unit and evaluation with various load situations.

2.3 Risk Assessment

In the service section occur different strains with quick sequence, making it difficult to assess by means of key indicator method of BAuA (=LMM: lifting, holding, carrying), which is used actually nearly as a standard. At least to get a strain indicator of lifting and carrying and pulling and pushing the multiple loads tool of the KoBRA project (Kugler et al. 2010) has been used and the corresponding results were tabulated.

3. Results

In addition to the measured values of the hand forces a particular focus was in the assessment of body postures. The CUELA analysis allowed on the one hand a differentiated presentation of critical body postures over time (the results are not shown here) on the other hand, it was possible to assess the classifications of the posture with the multiple loads tool and to discuss the registered data with the specialists the occupation cooperative.

The main stress activities were identified as (Fig. 2):

- huge action forces combined with unfavorable body postures
- head inclination towards the rear (by overhead work under the vehicle)
- static postures with body bending and twist (due to bad accessibility of the work area and cramped conditions)
- inflected torso (work in a bent position)



Fig. 2: Selected work situations during service activities (with CUELA system)..

In addition to daily exposures also singular activities could be analyzed in more detail. Figure 3 shows an example of a part replacement, which weighs 13.5 kg and has to be held in an unfavorable posture for about 46 s.



Weight/kg:	13,8
Duration:	104 sec
Body posture:	6
Working conditions:	3

Fig. 3: Work assessment according to KoBRA multiple loads tool.

After the analysis the collected ideas of the participants were registered in a standard form, which has been developed for the team work, and are categorized according to the TOP-principle, thus differentiated by technical (lifting aid), organizational (help from a second person) and personal action (improving posture or appropriate physiotherapy exercises). At the end of the standard form the possible activities are valued with respect to their contribution to reduce the strain and the corresponding risk indicator (Fig. 4). Very promising are primarily:

- suitable headroom adjustment in the pit
- posture supports in worse accessible sections and for fine motor skills
- optimization of the used tools and their accessibility
- organizational and physiotherapeutic action
- use of lifts

Following the principle of cost and benefit first action are prioritized and recommended for implementation.

Fig. 4: Standardized documentation sheet for categorization, assessment and prioritized actions with evaluation of effects on strain reduction.

Analysis & Assessment									
Task: Replace water cooler Date: 26.05.2014									
Picture & risk factors for the KoBRA tool for tasks > 5 kg 	<table border="1"> <tr> <td>Weight/kg:</td> <td>13,8</td> </tr> <tr> <td>Duration/sec:</td> <td>104</td> </tr> <tr> <td>Body posture</td> <td>6</td> </tr> <tr> <td>Working conditions</td> <td>3</td> </tr> </table>	Weight/kg:	13,8	Duration/sec:	104	Body posture	6	Working conditions	3
	Weight/kg:	13,8							
	Duration/sec:	104							
	Body posture	6							
Working conditions	3								
Technical aspects: e.g. lifting device									
Organizational aspects: e.g. working with two people in order to lift heavy things									
Personal aspects: e.g. make sure that worker has an appropriate/physiological body posture (if possible!)									
Check & Eval.	Actual Measures: Potential in order to reduce the risk Technical: Reduction of the posture, weight and time indicators organizational: Reduce critical parameter by half with another worker personal: not possible in this case								
	New assessment with the KoBRA tool [≥5kg]								
	☒								
	☐								

4. Discussion

The assessment of working conditions in the production compared to the service department is often simpler, because there are many repetitive procedures, which can be optimized with economical advantages. However, the one-sidedness and the combined monotony are often established as disadvantages of synchronized work. In the service section the work activities show a high variety. Although the postures are often very unfavourable, the worker takes often "almost automatically" the corresponding compensation posture, which is favored by physiotherapy to reduce possible risks by one-sided loads.

When applying the risk assessment by use of the multiple loads tool, it is implicitly assumed that a bad attitude in load handling (like holding a distal load of high posture rating points), which must always be taken recurrently, is synonymous to different but always unfavorable body postures (e.g. overstretching the backward bending, lateral twisting of the spine in bad accessible sections or deep bending when removing heavy parts). This assumption, however, is at least questionable, because a general, physically different stressing activity cannot be compared to a one-sided and repetitive work. At least synchronization and frequent load changes can be respected like in then key indicator method (LMM) for assessment of manual activities (Steinberg, et al. 2012). However, this method should be used only at forces less than 50 N.

A particularly positive aspect of the project is that the workers were able to take part in the team meetings. In addition to the theoretical and metrological findings could thus be ensured that the findings of the investigation were reflected also in the subjective experience of the employees. Here, for example, an extreme posture, e.g. to reach a few cm more or to produce the necessary force to solve a corroded screw, which were already conspicuous in the objective analysis, is confirmed by the subjective perception of employees.

Literature

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