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VEHICLE AS A COMPLEX TRIBO–MECHANICAL SYSTEM

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Abstract

The vehicles fall into a complex products group and involve several hundreds of tribo-mechanical couples. These couples operate under the conditions of elevated temperatures, high loadings and in the presence of abrasives and dust. From a tribological point of view, an engine comprises a great number of heavy loaded tribo-mechanical couples. This for the reasons that an engine during a vehicle lifetime of 100.000 km has to make over 300 mn revolutions. Therefore, it is very important to use appropriate oils in order to slow down tribological processes of vehicle elements loaded in this way. The same may be applied to the transmission elements, etc.

Key words*: vehicle, tribo-mechanical couples, oil.*

1. INTRODUCTION

Around 800 mn vehicles are currently registered in the world. Almost 60 mn of new vehicles are annually produced, while a part of end-of-life vehicle fleet is continuously withdrawn from the service. The European manufacturers are obliged to recycle at least 75% of the vehicle mass. The recycling costs are considerable, so that the government often grants subventions to be used for environmental protection. Taking into account that an average mass of passenger car amounts to over 1000 kg, being several times greater as for trucks and buses, it may be concluded that more than 50 bn kg of various materials are to be annually recycled and partially disposed.

Under the conditions of heavy competition among the world vehicle producers, the customers are increasingly offered to buy the cars being designed to pass 200.000 km, or even a million as for the trucks. This results in an increase of vehicle price and the vehicle belongs to a group of very complex products.

An increase of vehicle use lifetime calls for a scientific- technological advancements to be made in the fields of new technologies and materials for vehicle manufacture. A long vehicle service life also assumes an appropriate vehicle care and maintenance during its entire lifetime.

Basically, the vehicle failures may occure for the following reasons:

- breakdown of vehicle element due to overloading or default,
- extensive wearing out of vehicle elements due to presence of tribological factors,
- corrosion of vehicle elements because of longtime atmospheric effects or poor anticorrosion protection.

Maintenance of vehicles is carried out by replacing damaged elements by new ones or by repairing damaged parts. It is economically justified if single cases are concerned within a longer time period. When a vehicle approaches its lifetime end, most elements are subject to mass failures, thus meaning that it is a real moment to replace the old vehicle by the new one.

The influence of tribological factors on the failure of some tribo- mechanical couples [1] is very expressive in the vehicle. It is in correlation with the intensity of acting and with the time of exposure to friction and wearing under the

conditions in which a vehicle operates in a real environment. Conditions of vehicle usage are not constant during a year. A vehicle operates under the following conditions: high outside temperature differences; presence of dust and abrasives on contact surfaces of movable and turnable elements; presence of chemicals and harmful gases; various loading ranges and periodical overloading of vehicle elements, etc.

Based on reseaches it appears that all above stated affecting factors have to be taken into account yet in the conception stage of vehicle design and later on in the stages of construction, testing and validation of project before starting up the batch production. Clearly defined instructions have also to be given for vehicle maintenance and care during a vehicle lifetime.

A vehicle maintenance is very important during a vehicle usage, where a recommended oil change in due time by appropriate oil represents one of the basic aspects of vehicle protection from excessive wear and heating. Cooling and lubricating agent (CL), as a third element of numerous vehicle tribo- mechanical systems, is key factor for slowing down the development of tribological processes on contact surfaces.

The vehicle designers have available feedback information about functioning of the elements during the vehicle usage lifetime and these are the input data for designing the next vehicle model or for restoring default through recall of already launched vehicle. Therefore, each designer pays a great attention to data such as: element lifetime, reliability of its operation, failure-free operation, frequency of failures, etc. Namely, a designer is in dilemma whether to continue to further increase the element reliability and raise the vehicle price, or to leave a part of costs to be borne by the vehicle owner during the vehicle use. A third option relates to the possibility of leaving such costs to be charged by his company if failures occur in warranty period. If stated dilemma is supposed to be solved on the owner's damage, it is likely to be very risky strategy under the conditions of harsh competition in the market made up with numerous offers of world leading producers. One of the biggest world carmakers, Mercedes, confirmed the existence of such dilemma, namely, Mercedes was obliged to recall around a million vehicles. The same happened to the other world famous producers.

The process of transferring plants for producing some elements – outsourcing – into the regions with lower production costs contains a hidden danger that a certain achieved savings in providing some elements from that region may be paid at a great cost later on in the vehicle use, along with the quality drop and deterioration of company image. Therefore, the vehicle producers must constantly take care of a higher reliability, operation stability and general safety, along with acceptable production costs, selling price and warranty costs covered by vehicle producers,as well as tolerant out- of – warranty costs paid by the vehicle owner.

Modern vehicles are equipped with a lot of electronics, which control some vehicle functions or indicate the parameters of the states. In order to repair such vehicles it is necessary to own On Board Diagnostic (OBD) systems [2], being a new technology for making a diagnose in the vehicle repairing. The fundamental conception of this technology is based on a linking system of sensors and pickups, thus processing the received signals and displaying the output data with a software backup, along with an assistance of the vehicle user. A wider application of mechatronics in new vehicles designing was aimed at an increase of reliability, safety, unification, flexibility and vehicle control intelligence level, along with the costs reduction and energy savings. Some new reseaches have shown that in some extent the introduction of electronics in vehicle functioning has gone too far and that electronics failures have greatly resulted in the vehicle stoppages. It is not possible to repair modern vehicles without having relatively expensive OBD systems. The repairs are mainly carried out in authorized services and rarely on the roads, as it was possible with a classically designed vehicles.

2. MAJOR VEHICLE TRIBO - - MECHANICAL COUPLES

As it is already stated, a vehicle as a complex technical system [3], being consisted of several thousands single elements, comprises several hundreds of tribo-mechanical couples abailable for functioning. Some of the couples are in a permanent contact when a vehicle is functional, but certain couples make contacts only if driver or automatics switch on some controls. Heavy loaded tribo-mechanical couples are in engine [4], gearbox, differential, braking elements, gearshift elements, wheel bearings, steering

mechanism elements, windscreen wipers, etc. Most of the couples are supplied with CL fluid, as a third element of tribo-mechanical system. Otherwise, many couples in contact with movable or rotable elements would have very short lifetime and frequent failures would occur in vehicle functioning.

Normally, brake lining elements, being in contact with the brake disk or drum, are running without CL fluid agent, because they use friction to complete their function. The same may be applied for the contact of clutch and engine flywheel, where the torque is transferred by means of contact surfaces friction to the gearbox, having initial slipping in changing gears or when a vehicle is going to move.

The lifetime of tribo-mechanical couples is mostly affected by the following factors:

- static and dinamic loads, temperature-induced loads with variable working conditions, mechanical impacts, sudden overloads, etc.,
- number of completed moving or turning cycles during lifetime, i.c., total working hours,
- quality of elements as for accuracy of sizes and shapes, surface quality, material quality, heat treatment, surface improvement quality, etc,
- proper selection and quality of CL fluid agent and its replacement according to recommendations,
- vehicle driver skillness and regularity as for vehicle maintenance,
- external surrounding factors, such as chemicals, abrasives, etc.

If it is supposed that a vehicle producer has built a vehicle and its elements in accordance with the quality standards and has issued necessary instructions for handling and maintenance during vehicle usage lifetime, than the wearing of tribo-mechanical couples would depend on number of cycles, i.e., total functioning time of elements.

If average driving conditions as for city drive, inter-city drive and motorway drive are taken into account, assuming an adequate speeds and number of revolutions of a gasoline engine, it appears that within a lifetime of 100.000 km, without an idle speed, an engine has to make over 300 mn revolutions. As for a predicted vehicle lifetime of 200.000 km, an engine has to make more than 600 mn revolutions. Such data clearly show the complexity of problems related to the engine elements from a tribological standpoint.

A situation is slightly more favourable for a gearbox elements, because of the lower temperatures. The same may be applied for vehicle differential.

Based on researches from several sources [5] it appears that some elements of tribo-mechanical couples were activated several thousand times within a projected vehicle lifetime.

For some elements, an average number of activations within a projected vehicle lifetime of 100.000 km is as follows:

- clutch	around	400.000
- I st gear elements	around	80.000
- II nd and III rd gear elements	around	100.000
- IV th and V th gear elements	around	50.000
- reverse	around	20.000
- vehicle braking	around	200.000

Number of cycles with regard to the door opening and closing, window regulators,etc.,is also considerable, but these elements are usually depreciated during depreciation period of the whole vehicle.

3. TRIBOLOGICAL CHARACTERISTICS OF SOME VEHICLE ELEMENTS

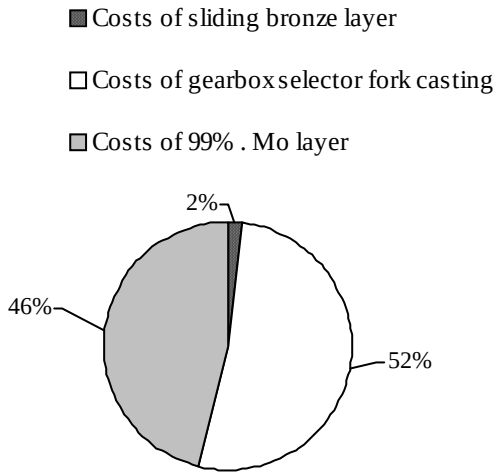
Normally, a worn out vehicle elements are to be replaced by new spare parts, produced and controlled according to stringent factory norms and international standards. In some cases, worn out and damaged elements are subject to reparation. If new technologies are applied for reparation, involving a process of contact surfaces improvement, than if compared with an original product, even longer lifetime may be achieved.

For that purpose, there are some technologies to be used, such as surfacing, hard chromium plating, plasma spraying, plasma wire burning technology, etc. The reparation is acceptable from a techno-economic standpoint if the basic material and machining of some vehicle elements are expensive and when worn out material volume is small in comparison with the volume of the new element.

A gearbox selector fork may be used as an example showing how some world producers are improving the contact surfaces by applying antiwear layer-coating by means of plasma

technology. The two layers are usually applied, the first being a binding- bearing layer to the fork basic material and the second layer is antiwearing and decreases the gearbox noice level. Expensive materials are usually used for a binding layer, such as nickel-aluminium alloy or pure molybdenum. The costs of applying 99% molybdenum layer are sometimes closing to the material costs of the whole element made of casting, forging or sintered materials. The costs of sliding antiwear bronze layer are considerably lower, as illustrated in Figure1 for one of the possible processing versions.

The high costs of a bearing molybdenum layer, which prevents intensive fork wear as the sliding layer is worn out, may be only justified by the high wear resistance, thus avoiding a



gearbox disassembly and repairs during usage lifetime, as mostly happen in the practice.

Figure 1: *Costs structure of casting and metallized layers of gearbox selector fork*

How resistant is a molybdenum layer to wearing is best shown by reseaches conducted with a truck gearbox selector fork, where a molybdenum layer was only applied without sliding layer.

As for specific vehicle elements, where it is not possible to use CL fluids, such as for example disc brake pressure plates, it is necessary to provide a required friction coefficient in order to apply a vehicle braking. In addition to an effective braking, it is necerssary to ensure a long lifetime of pressure plates and wear resistance. In practice, the pressure plates usually wear to several millimetars, depending on the brake design.

A wearing curve is given for a real case of testing the wearing intensity of disc brake pressure plates, depending on a travelled way "X" and under braking conditions as shown in Figure 2.

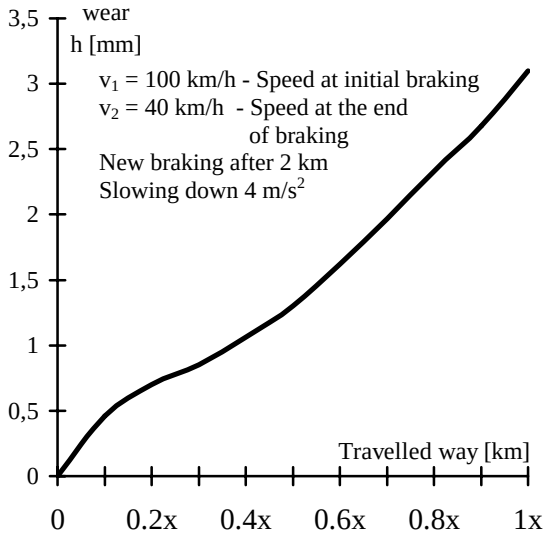


Figure 2: *Wearing curve of disc brake pressure plate in a function of travelled way -X*

Testing was carried out up to 3mm wear, although some pressure plates models may be worn out to a greater extent. A pressure plate lifetime is often tested on appropriate test benches, according to methodology which has to provide test conditions similar to those prevailing in vehicle use in a real environment. A travelled way of 40.000 km is considered as being satisfactory for a pressure plate lifetime from an aspect of wearing and without noticeable other damages.

As for the vital engine elements it is important to use an appropriate motor oil. A motor oil change interval is today moved to over 30.000 km, owing to continuous researches in this field.

The additives, being the secret of their producers, are used to form a metal coatings with a steady micro film, which extensively reduces wearing and friction, and enables protection in engine cold start. The other benefits of additives are following:

- considerable engine lifetime increase,
- steady compression and fuel consumption,
- uniform engine operation,
- decrease of harmful exhaust gases emissions,
- lower oil consumption, etc.

The other vehicle tribo-mechanical couples have their specific requirements. Their wearing problems have to be solved by taking adequate measures and by applying new materials, new technologies and, if possible, appropriate CL fluids.

4. CONCLUSION

In order to keep the company image and due to a strong competition, the manufacturers of vehicles and their elements are obliged to make continuous improvements as for a higher reliability and reduction of costs associated with a vehicle usage.

Since there are several hundreds of tribo-mechanical couples, the vehicle designers are obliged to apply appropriate design solutions, thus slowing down a wearing process and preventing elements from failures. During a vehicle lifetime, some worn out elements have to be changed several times by the new spare parts. This relates to clutches, universal joints, couplings, brake plates and pads, tyres, etc.

From a tribological point of view, a vehicle is very complex product if we take into account several millions of engine revolutions, which have to be made during a vehicle lifetime in order to start the vehicle, as well as a great number of switching-on and switching-off of some elements. Since a vehicle is also an expensive product, a slowing down of tribological processes is imposed as a priority goal aimed at reduction of costs during a vehicle use.

5. LITERATURE

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