Exploitation wearing and car element malfunctions

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Summary
This article presents the issues connected with various types of exploitation wearing and malfunctions of vehicle parts and components in a practical approach – from the perspective of assessments and the opinions of car specialists. The work is illustrated by well-matched illustrations and examples from the expert’s practice. Malfunctions and engine damage have been presented, as well as malfunctions and damage of gear shifts, transfer cases, truck frames and other equipment types. This is accompanied by an assessment of the causes of their occurrence. Everything is supplemented by numerous schemes and figures directly connected with the topic with this subject.

Introduction
In the case of making a technical assessment/opinion [12,15,18,26,31] coming from exploitation, very often after a malfunction it is vital for the car expert (at best with the customer or his representative) to be present during the dismantling of the damaged component, subassembly or vehicle and be able to very carefully observe and analyze such a process, as after it is finished the initial state cannot be restored. Because of his fact, before one starts to dismantle the subassembly/unit/vehicle, one should consider the actual scale of the damage, what the possible causes of the malfunctions can be, i.e. it is always advisable to work out the so-called initial mind model for the assessment/opinion by the expert.

This is a very difficult task and it requires from the expert much professional experience in order to form an objective and clear final conclusion in the technical opinion.

Experience points that the circumstances when the malfunction/damage occurred that are given by the participants are not too credible. This particularly refers to the given time span or the mileage between the symptoms of incorrect working of a subassembly/unit or a vehicle in the moment when the malfunction occurred and exploitation was made impossible. Similar difficulties in identifying the cause of malfunctions arise after repairs done in a workshop/service or sometimes after repairs done by the user himself.

It is also important problems of transport [21-23,25,27-31] and storage [24] of the equipment.

1. Exploitation usage of mechanical vehicle parts
Usage [1, 2, 6, 14, 15] is a process of gradual destroying of parts under the influence of physical-chemical factors having impact on the parts throughout the whole period of their exploitation.

Usage of mechanical vehicle parts occurs during the process of normal (correct) exploitation and is an unavoidable phenomenon. It happens during transport, storage [9,10] and using mechanical vehicles. Exploitation usage gradually increases with the intensiveness depending on the type of usage, the factors causing wearing out and the type and intensiveness of the forcing.

The scale of part wearing out is dependent on the time of exploitation or the vehicle mileage. The intensiveness of wearing out in various periods of exploitation is not the same. The Lorentz curve graphically illustrates the scheme of exploitation wearing – fig. 1 [1].

Fig. 1. The curve of part exploitation wearing

The scale of part Z wearing is shown on the axis of ordinates and the work time (exploitation mileage) is shown on the abscissa axis. In order to make this somewhat simpler, the analysis had been done only on one part. The wearing of the second combination, e.g. the kinematical assembly or the cooperating pair may be similar in character. Exploitation Z might be measured in various units (e.g. linear exploitation, mass exploitation, volume exploitation, neutral increase etc.).

Analyzing the exploitation curve we can note that the particular segments differ in the intensity of wearing out. The OP segment shows the curve of wearing for parts in the initial period of exploitation. This is the period of running-in of cooperating parts, in which wearing increases with a gradually decreasing intensity. In point P, the intensity of wearing out takes on a constant value, which informs about the end of the running-in process. In this period, the assembly
neutral caused by parts wearing out takes on the scale of the neutral, in which the conditions of part cooperation are optimal. In the analyzed figure, α represents the time of part running-in, as a result of which the wearing out of the Zₜ part occurred.

The PR segment is a straight segment of the wearing period and the linear mileage of wearing testifies to its constant intensity. This segment presents wearing during the period of normal exploitation. The total value of wearing gradually increases, which is identical with the gradual increasing of the L neutral in the combination. After reaching the boundary wearing value Zₚ, part wearing out starts to rapidly accelerate.

The RA segment characterizes the accelerated wearing of parts, which occurs after surpassing the boundary Zₚ value. Further combination exploitation causes its accelerated wearing out, which in turn can lead to damaging the part, or even the entire unit.

The time, in which the intensity of wearing out (tgα) is constant until the point when the wearing out reaches the boundary Zₚ value, is called the inter-reparation/inter-renovation mileage τₑ.

\[
{T_e} = \frac{Z_{gr} - Z_d}{\alpha}
\]  

(1)

As formula (1) informs, in order to prolong the inter-reparation mileage, one should aim to decrease τₑ, i.e. to decreasing the intensity of part wearing out.

This can be achieved through proper exploitation and punctually and correctly conducting technical services. The counter in formula 1 indicates the reparation activities, that is the possibility of restoring the exploitation usefulness of parts through regeneration. Using more perfect methods of cooperating parts running-in, the Zₚ value can be decreased, at the same time prolonging the inter-reparation mileage.

The OPR'B curve in figure 1 can be conventionally taken as the curve indicating normal part wearing out, occurring in certain exploitation conditions with τₑ a intensity. However, the wearing out intensity can increase for various reasons and it can reach the tgα value – in this case we are dealing with accelerated wearing, occurring in accordance with the OPR'B curve.

The reason of accelerated part wearing may be different conditions of exploitation (e.g. road, terrain and climatic conditions, as well as the type of the work greases etc.) However, for a certain number of vehicles used in different conditions, by using correct technical services, the mileage of part wearing – in accordance with the OPR'B curve can be treated as wearing out normal for the respective exploitation conditions [3,4,5, 8, 10, 17, 19]. This is where the relativity of the terms normal and accelerated wearing out comes from.

The most frequently used classification of wearing out processes is as follows [2]:

- grinding wearing (in sliding movement without the grinding layer, through the loose center, with the grinding layer and in the stream of the loose center),
- adhesive wearing out (with shallow and deep extraction),
- fatigue wearing (classic, spalling, fretting and pitting),
- wearing due to oxidation,
- corrosive wearing (chemical and electro-chemical corrosion),
- erosive-frictional wearing (fretting-corrosion),
- erosive wearing,
- cavitational wearing out,
- thermal wearing (with intensive oxidation of the upper layer and local layer melting).

The following general classification of factors causing part wearing out can be sufficiently used for the analysis of results and causes of part wearing out:

- mutual mechanical interaction between cooperating surfaces,
- molecular interaction between cooperating surfaces, mechanical interaction with constant foreign matter,
- mechanical grease (liquid) interaction,
- chemical grease interaction,
- environmental chemical interaction,
- the influence of high temperatures.

2. Part cavitational exploitation

Cavitation [1, 11,16] is the processes of creating and dissipating of steam-filled bubbles in liquids with increases and falls of pressure.

The phenomenon of cavitation occurs in the areas where the sum of hydrodynamic and hydrostatic liquid pressure has the value which is lower than the pressure of the liquid steams. Cavitation can arise when high liquid flow speeds occur or as a result of high frequency liquid vibration, e.g. in engine cooling units.

A typical course of cavitational wearing looks as follows – in the moment of liquid transition (the liquid having gas bubbles) to the areas of high pressure (wire narrowing, oil wedge in the bearing, narrowing of space in cooling units), steam condensation or dissolution in the liquid of the gasses contained within the bubbles. The liquid fills the bubbles with high speed and energy, which causes percussive influence on the part surface.

The percussive influence of liquid causes destruction of the surface which leads to metal deformation in the outer layer and the occurrence of micro-cracks. Mainly soft alloy phases undergo the devastating influence of cavitation, e.g. in steel parts the ferrite grains are destroyed, and in bearing alloys, the soft structure gets damaged.

The proneness of a unit to cavitation is characterized by the degree of cavitation described by the dependence [1]:

\[
{X} = \frac{K}{\gamma \cdot V_{0}} = \frac{v \cdot V_{0}}{2 \cdot g \cdot (p_{0} - p_{s})}
\]  

(2)

where: Xₚ – degree of cavitation, K – cavitation counter, V₀ – liquid flow speed, γ - liquid consistency, g – the g force, p₀ – static liquid pressure, pₛ - liquid steam pressure at a certain temperature.

Figure 2 [20] shows the cavitational wearing out of an engine cylinder sleeve (type S-359) [11], with enlarged cavity occurring as a result of cavitational influence of the cooling liquid. Figure 3 [20] shows the cavitational-mechanical wearing out of a steering lever peg after 15 000 km mileage with visible traces of water influence from the surface bed and road surface aided by friction in the bar-peg combination.
3. Part damage

Part damage [1, 7, 8, 12, 18, 19] differs from wearing out in a way that in the case of damage the part completely uses its usefulness for further exploitation. Damage occurs suddenly, most often as a result of the influence of mechanical factors. The causes of part damage may be diametrically opposite, however they can be divided into the following groups:

- Exploitation damage, after-accident damage, construction faults,
- Technological faults.

Exploitation damage occurs in the case of improper using of a vehicle [2, 5, 6, 13], incorrect service or wrong storage [9]. The following damage can be given as typical examples:

- Connecting rod snapping as a result of not securing the connecting rod head or after an improper user’s reaction after the occurrence of — mostly hearable in the first phase — so-called bumping, knocking — the result of such an emergency is presented in figure 4 and 5. In figure 4 [20] there is a clear fatigue fissure on the connecting rod bolt, on which there is a crack, and the lack of a reaction from the user which caused the damage of the engine block and consequently nearly its total destruction. On the other hand, figure 5 [20] illustrates the scope of damage of the engine mentioned above, e.g. crankshaft seizure and damaged block.

- Part seizure as a result of overloading, overheating or lack of grease, i.e. failing to fulfill the liquid friction conditions.
Figure 6 [20] presents the emergency wearing, the so-called scraping of the main diesel engine pans for the engine type 4 CT90 of the Tarpan Honker vehicle exploited in difficult terrain conditions – the abrasive wearing of the half-pan, the total wiping of its soft composition and its tearing off [15,18].

Figure 7 [20] presents the view of the crankshaft peg of the same engine being a cinematic pair, on which one can see the signs of wiping in the form of peripheral furrows and scratches [15,18].

- cooler, body or engine head as a result of e.g. cooling liquid leaks or its freezing, figures 8 and 9 [20].

These figures present the damage of a carburetor S-47 type engine fan, caused by sudden damage done to the under-head seal and cooling liquid leak. A result of this was damage to the engine block, sleeve cracks, damage to 3 pistons, damage to the head – in this emergency, there occurred a combination of mechanical-thermal damage, additionally combined with strong corrosion [11].

4. Superchargers

For an engine (regardless of the vehicle type) [3,10,11,16] to immediately obtain appropriate elasticity and power, the most often chosen constructional solution is to boost it with exhaust fumes. In this case, a supercharger is added to the engine unit – fig. 10 [20].

A supercharger’s lifespan is determined by its construction for the entire exploitation period of a given vehicle. However, foreign bodies, contaminated oil, incorrect greasing or too high fume temperature often cause damage and therefore it is necessary to repair or even replace the device.

Damaging the supercharger’s casing or turbine may cause an oil leak – fig. 11 [20] which can e.g. due to the high collector temperature, may ignite and cause an engine fire and other damage influencing the engine’s work and its durability.

Due to the very high rotation rate of the turbine and supercharger wheels, even the smallest foreign bodies behave as bullets. Therefore, during maintenance, it is necessary to replace the air filter and it is also very important to thoroughly clean the fume and air suction system on the section leading to and from the air cooler and to remove all foreign bodies from the exhaust pipe/collector.

All wires connected to the supercharger have to be tight so that the flow of oil, air, fumes, and – depending on the model – of the refrigerant goes smoothly, without losses, and is stable.
If a repair is to be professional and dependable, companies offer specially adjusted assembly sets for each supercharger model. They are equipped with a set of assembly elements compliant with the guidelines of factory manufacturers, such as: gaskets, sealing rings, nuts, stays and the oil for the first filling of a given supercharger.

Replacing a supercharger should be accompanied by replacing the oil and the oil filter. This will ensure that potential foreign bodies which were in the previous oil circulation will be removed and will not damage the new supercharger (the old supercharger most often gets damaged by foreign bodies or by particles which have entered the circulation).

5. Frames and support sets
Wearing and working causing permanent exploitation deformations often occur on their own due to several years of arm’s vehicle exploitation in changing exploitation conditions [4,8,15, 27, 31].

6. The power train
A frequently occurring unit, in which there are various degrees of wearing, are transfer cases [18,19]. Here, mainly due to a certain mileage, too big clearance can occur e.g. in bearing holes, fig. 14 [20]. Also the wearing of cogs in a cogged wheel appears together with their peeling and cracking – fig. 15 [20]. The authors have chosen the transfer case of a personnel-terrain vehicle Tarpan Honker as an example. The cause of the transfer case disassembly was the more and more loud working in terrain conditions and creaking during operation. The verification was done after inspection on a current maintenance (OB) point.

7. Conclusions
The article presents an outline of the basic problems concerning the wearing out of vehicle elements which are encountered by an expert, during giving opinions and technical assessments, e.g. the causes of emergencies and damage – everything in a typically practical approach.

The authors characterized the typical causes and types of malfunctions and damage of components and units of various types of vehicles depending on their exploitation, degree of wearing, quality of repairs, influence of other factors (very often human factors), which sometimes are extremely difficult to settle whilst forming a technical opinion.

Such a form and outline of the article is mainly to direct and point to the methodology of dealing with the issue both by the expert and by the vehicle user.

Supplementary to the article are numerous figures and Picture directly connected with the presented topic.