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TYPICAL FAILURES IN THE DAMAGED ROLLING ELEMENTS MADE OF DIFFERENT MATERIALS IN THE MOST IMPORTANT VEHICLE UNITS

TYPOWE AWARIE WYNIKAJĄCE Z USZKODZEŃ ELEMENTÓW TOCZNYCH WAŻNIEJSZYCH ZESPOŁÓW POJAZDÓW WYKONANYCH Z RÓŻNYCH MATERIAŁÓW

Bearings are widely used in motor vehicles. The operations of natural causes wear on the bearing components. However, the rolling bearing wear often results in damage to other elements or components throughout the vehicle. The paper presents examples of typical and untypical consequence damage bearings used in vehicles. Damage are described in elements made ??of different materials.

Keywords: bearings, operation, damage, motor vehicle

Łożyska toczne znajdują szerokie zastosowanie w pojazdach samochodowych. W wyniku eksploatacji następuje naturalne zużycie elementów składowych łożysk. Jednak zużycie łożysk tocznych powoduje często uszkodzenie innych elementów lub całych podzespołów pojazdu. W artykule przedstawiono typowe i nietypowe przykłady konsekwencji uszkodzenia łożysk tocznych stosowanych w pojazdach samochodowych. Opisywane uszkodzenia występują w elementach wykonanych z różnych materiałów konstrukcyjnych.

1. Introduction

Motorization engineering is one of the fastest growing industry. Changes in the safety traffic and the protection of the environment regulations causes modern, industrial development of production even of the cheapest vehicles. It is vitally important that consumers are becoming very demanding for vehicles of high quality. They want to travel faster, effectively and comfortably. The new materials applied in vehicles and new technologies used both in vehicles building and their reparation have being arising very quickly. Modern welding technologies as for example micro-jet welding technology are being used in automotive industry [1-4, 8-11].

Author of the paper has gained the long-term, practical experience and additionally he has been collecting statistical data on the failures in vehicles. On the basis of his knowledge and experience, he has come to conclusion that the more advanced construction of the vehicles, the more problems resulted from their operation. In the article are presented the selected elements of vehicles, especially these in which a malfunction of bearing was diagnosed. Author of article has a great interest in such researches [12, 13, 15, 16, 17].

A maintenance of the bearing depends on material of which individual element is made [7]. Traditional materials used to produce bearings are: tin bronze, lead tin bronze, aluminum bronze, zinc-base alloys, tin and lead alloy, aluminum-tin alloy, sintered (porous) bronze and multilayer materials [6].

Actually, there is an increasing tendency for the different kinds of service action, that are announced by the vehicle manufacturers. Between 2010–2011 years one of the leading manufacturer of premium vehicles, announced such a service action several times. It concerned the combined front hub and wedge belt stretcher used to power transmission of engine fittings. It shows that the problem is really very important and applies used cars and quite new vehicles. The problem appears when the vehicle is no longer protected by a guarantee. In this case the vehicle is not repaired in the authorized service or it is simply resold.

The main conclusion of this consideration is that diagnostic and constant control of technical condition of vehicle should be the obvious procedure. The development of diagnostic tools permits to modernize the present diagnostic procedures and specify the range of all activities during diagnostic processes. Such a diagnostic should be realized for example when the machine was operated during the time given for example a limited number of hours.

2. The examples of defects in vehicles

Many defects in vehicles have significant influence on a road safety. More information about it is given below. These

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examples are resulted from the practical author's experience in service workshop during last months.

Timing system and engine fittings

The bearing elements of timing gear such as tightening rolls, operating rolls or bearings of liquid coolant pump must reach rigorous technical standards. The exhaust valves in timing gear work in the most difficult conditions, and therefore they are made of one of the most expensive alloy such a nimonik. The other materials are steel Cr-Si, chromium steel Cromo 193, austenitic steel Cr-Si. Materials which are being applied to production of timing shaft, spherical cast iron (ignition engine), steel to carburetion (diesel engine), malleable cast iron and surface melted cast iron [5,6]. Working surface of timing shaft are hardened. To power transmission of auxiliary units are used the toothed wheel (made of low-carbon steel and having the carbureted, hardened and grinded teeth) which next are put on timing shaft. Gear transmission has wheels for example made of sintered steel metal [5, 6].

Figures 1 and 2 show seriously damaged water pomp in effect of blocking the rotor shaft. This situation was caused by lack of collinear as a result of connecting rotor to frame. This failure results from damage to bearing race way which was excessively radial loaded by shaft. The fitting errors, for example too high tension of timing belt or wrong reparation may cause such a failure. For example, according to repair technology there is need to replace the water pomp and timing belt. The new belt may cause more tension in timing system and thus the pump bearing (which is not in good condition) is not able to carry the increased radial loads.

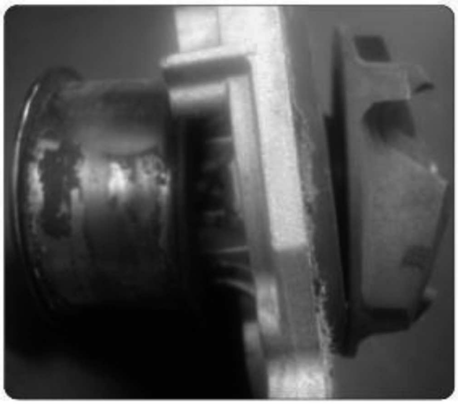

Fig. 1. Damaged water pump

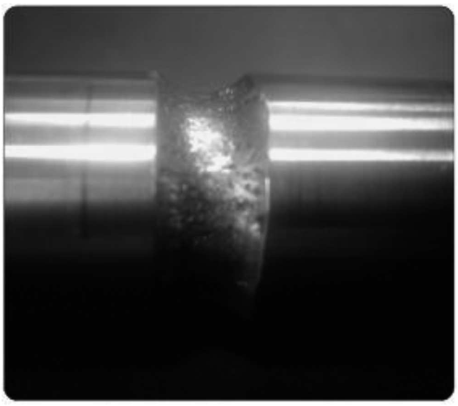

Fig. 2. Damaged roller of water pump

The next example is damage to tension shaft, which tighten the belt timing. A belt pulley of tension shaft was fused because of too high temperature (Fig. 3). A high temperature as a result of increasing the friction coefficient causes fusion of plastic on belt pulley. Defect of bearing seal and the same decrease in lubricant of tension shaft may causes fusion of shaft. It is because the higher coefficient of friction, the higher temperature. The cumulative effect of that situation is a seized up shaft, broken V-belt (wedge belt) and finally lack of power transmission of the basic auxiliary devices.

The bearings of auxiliary devices should be diagnosed in the same way. After a period of time, the rolling elements and race way of automotive alternator bearing are destructed. In effect, a casing may be broken, rotor or stator may be damaged. This kind of failure immobilizes practically all the vehicle. The same range of damages to the pump bearings of steering system may cause failure of pump rotor or shaft. The negative effect of it is a liquid waste from system and finally a pump is seizured.

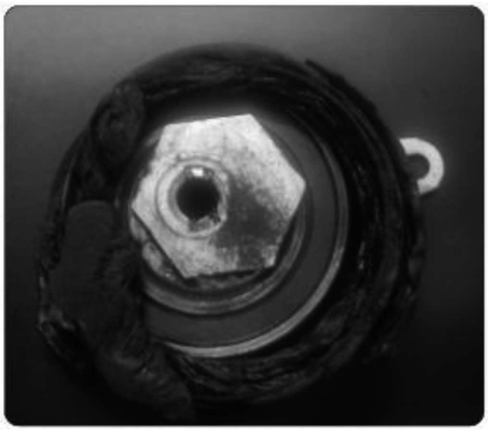

Fig. 3. Fused belt pulley of tension shaft

The examples of failures shown in figures above (1-3) consequently lead to serious damages to the elements of timing system. The kind of damages is presented in figures 4-6 below.

Fig. 4. Damage to belt and chain of timing system

In case of blocking any of timing system elements, some stresses may appear, which are unpredictable even by the constructors. In effect, a timing belt or chain is slid or broken. It may causes (especially if the engine is earlier damaged a serious and expensive damage to transmission unit, such as distortion of valves, damage to pistons (as a result of their collision) or damage to timing shaft, which may then leads to damage to car head. At present, after this kind of failure is impossible to repair the damaged engine, especially because of a distinct lack of repair technology (made professionally by a vehicle manufacturer) and consequently a lack of spare parts. Manufacturers of vehicles, guide rolls or toothed belts often gives divergent recommendations for periodically exchanging of elements in power transmission system of timing shaft.

Fig. 5. Distortion of valves

Fig. 6. Camshaft broken

Author proposes a possible solution to this situation. According to the author, a continuous monitoring of the technical condition or diagnosis those elements of which damage could lead to failure units as well as sub-units of vehicle.

Clutch kit

Cast iron of perlitic structure, often with addition of chromium, nickel and molybdenum alloys has good material properties and is used to manufacture flywheel and pressure disk. Fibrous material or sintered metal is used to produce abrasive lining [5, 6].

The next example (Fig. 7, 8) shows the damaged thrust bearing of clutch set. This kind of failure causes the noise when pressing on the accelerator pedal, for example in order to change gear. After pressing on pedal, thrust bearing works under pressure only when it is pushed axially to pressure disk. Bearing, which is damaged is able to generate the noise after pressing on pedal.

In Figure 9, the compressed material is marked by red rectangle. This material originate from damaged both elements

Fig. 7. Worn thrust bearing

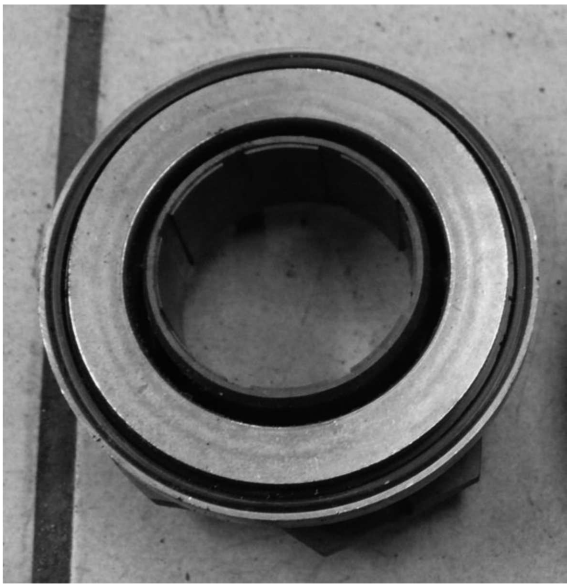

Fig. 8. New bearing

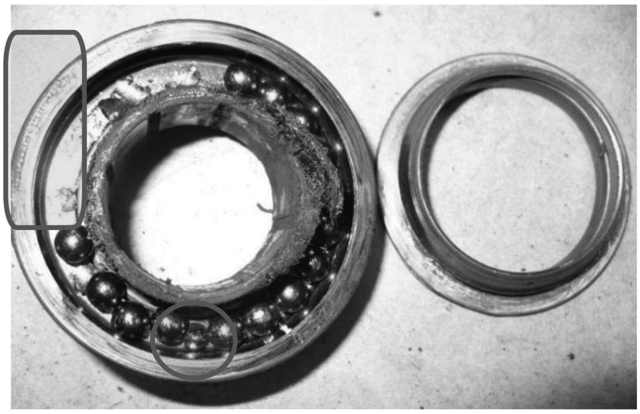

Fig. 9. Degradation of rolling elements of thrust bearing

and race way of bearing. This kind of failure is caused by inappropriate hardness of individual rolling elements. This leads to total degradation of the bearing elements. Rolling element marked by circle in the same picture changed completely it's dimension by being worn. It is seen by comparison it's diameter to the other rolling elements of bearing. Such a damage may cause appearance of the radial and axial clearances which significantly exceed design guidelines.

Gearbox

The materials used for production toothed wheels must be characterized as having good hardening capacity and the fine-grained structure because of high strength requirements.

The hardened surface of toothed wheels in the power transmission system is i.e. made of low-allow-steel for carboning or carbo-nitriding, low-alloy-steel for thermal improving, [5, 6].

The bearings worn in gearbox, give distinct acoustic signals, which indicate that gearbox doesn't work properly. The gearboxes in the current, modern vehicles should be automatic. However, it happens quite often, that users of relatively new vehicles, argue that gearbox during operation emits high level of noise. The worn rolling bearing on shaft coupling is a good example of it.

At the beginning of the destruction of bearings in gearbox, only the acoustic changes appear. It is associated with an operation it's elements and it manifests as artificial sound during stopover or slight acceleration of vehicle.

Destruction of rolling bearing elements causes it's damage and transmission shafts don't work according to design guidelines. The reason of it is a change of its axial positions. The negative effect of this process is destruction of toothed wheels. And finally, the damaged gearbox doesn't work properly.

Figures 10 and 11 show a damage of tapered roller bearing of main shaft in gearbox. In this case, gearbox emitted high sound while driving when the power transmission system was variably loaded, for example while engine was braking and next accelerating.

Figures 12 and 13 shown examples of worn main shaft of gearbox. In this case a pin, which is an integral part of the main shaft is destructed. Destruction relates to the surface of rolling elements and the pin surface. This example points to the conclusion that it is rather a manufacturing defect, because a vehicle had respectively low mileage. The reason for it could resulted from for example faulty heat treatment both the rolling elements and the pin itself. In effect, the bearing race way was defected, i.e. a nominal pin diameter decreased significantly as a result of loss of the material (wearing of surface).

Fig. 10. Main shaft of gearbox and damaged tapered roller bearing

Fig. 11. Damaged roller element

Fig. 12. Damage to main shaft bearing pin of gearbox

Fig. 13. Material wearing and change in diameter of pin

This kind of defect is manifested as an increased noise as a result of clearance on the shaft. In effect, the toothed wheels of gearbox don't mesh properly. This failure can't be repaired because there is no possibility of changing the rolling bearing because it's inside track is on shaft. It may be resolved only by buying new shaft which is very expensive in comparison to the price of the single rolling bearing. Also, regeneration padding is rather a short-term solution. A structural solution described above is very often apply by the many manufactures of different vehicles brand.

Advanced diagnosis and monitoring of bearing state should be done for purely economical reason, because the cost of any bearing element is very high in comparison to the price of bearing itself [14, 18].

The main transmission gear

The examples of defects in main transmission gear are presented in figures 14 and 15. ‘The totally damaged tooth of toothed wheel in main transmission gear are there shown. This kind of damage is caused by the rolling bearing (of main shaft) failure. In effect, toothed wheels of main gearbox don't mesh properly.

Fig. 14. Damaged bearing of main shaft

Fig. 15. Defected toothed wheels of main shaft

Figure 16 shows a totally damaged inside track of roller bearing that was located in driving axle of lorry. This severe structural damage indicates that a user of vehicle was not interested in the reason of specific voice that indicated improper work of main transmission gear. The scale of destruction indicates that a lorry was regularly overloaded, for example a maximum vehicle capacity was exceeded.

Fig. 16. Totally damaged inside track of roller bearing in lorry

Differential gear

Figure 17 shows the damaged toothed wheels of differential gear. That kind of damage is caused by destruction of the bearings race-way of main transmission that is shown in figure 16. The toothed wheels are seriously damaged because of a large deviation from the nominal geometric parameters of the axis position.

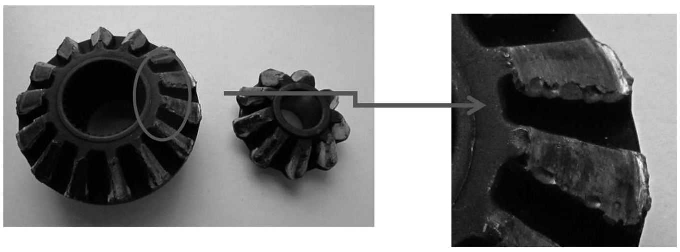

Fig. 17. Damaged elements of differential gear

Wheels of vehicle

The next example (Figure 18 and 19) shows destruction of wheel bearing pin. This kind of failure is caused by a very little bearing preload. As a result of it, an inside track is displaced relative to the pin. An operation in such adverse conditions caused loss of material of co-operated elements As a result of process of surface grinding, an operation in such adverse conditions caused loss of material of co-operated elements.

All the examples of damaged elements, given above pointed to the conclusion that these elements, without doubt should be exchanged. This example of failures for sure causes irregular distribution both stresses and surface pressure in the bearing elements. Finally, because of it the wheel may be blocked. This may then lead to the dangerous situations, considering the fact that at the present time vehicles are able to achieve high speed.

Fig. 18. Hub with bearing pin

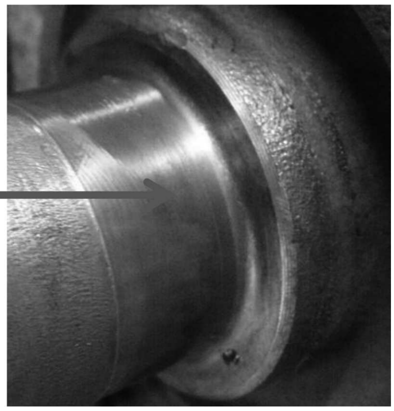

Fig. 19. Worn surface of pin in hub

Figure 20 shows damaged wheel bearing. In that case both bearing races were destructive because of operating. The condition of race was estimated to be completely destroyed. This means that exploitation of vehicle in such bad condition would be highly dangerous for its users.

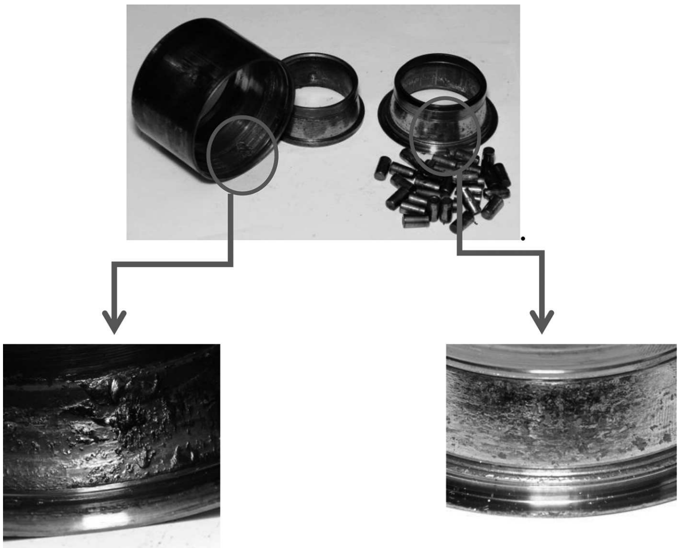

Fig. 20. Damaged race of wheel

The bearing seal damage, loss of lubricant or pollution of joined hub of wheel may cause a clearance on the wheel, destruction of wheel and additionally, the brake assist or driver control systems may indicate a wrong value of rotational speed. Finally, the wheel may be blocked or „torn off".

Damage of wheel bearings during operation or the same damage because of design errors may lead even to tearing off wheel while driving or to its sudden blockading. It is a high risk for a road safety. There are the well-known examples of serious road traffic collisions, caused by described damages, it relates especially to delivery vans and lorries.

3. Conclusion

All examples given above show that development of diagnosis of bearings in vehicles is a very important issue.

Prevention of the units and sub-units damages by suitably and early examination the rolling bearings closely has a significant influence on road safety, driving comfort and also ensure the safety of drivers and effectively prologues a time of failure-free and cost-effective operation of vehicles.

Accurate diagnostic of vehicle bearings is very specific and difficult process. It results from a large number of set and systems co-operated with each other at the same time and additionally they are located on the small surface. On the other hand it is very difficult to apply standard diagnostic procedures, for example such as the organoleptic analyses, mainly because of high-energy acoustic vibrations which interfere with measurements. Taking some factors into consideration, such as for example very big mileage of vehicles, the influence of bearing mounting on maintenance, repairing cost and the key factor i.e. a road safety, accurate diagnosis and a steady monitoring of the condition of bearings seems to be one of the most important vehicle operational problems.

The diagnostic process used for discovering what is wrong with vibro-acoustic methods must base upon well-designed algorithm of conducting this process. The reason for it is that it is absolutely necessary to apply different methods both of measurements and processing of signals obtained.

Thanks to such a procedure, there is a possibility of detecting an interesting signal component, and next by proper analyzing all results, the damage is diagnosed.

The vibro-acoustic methods of detection give quite new possibilities for designing and developing technical equipment.

It is possible to prevent from possible damage before putting given element into operation. A good example of it is development of new methods for measuring vibration of rotating systems. This allows for much more accurate balance rotors in turbocharger with high rotation.

Currently manufactured devices for production of turbochargers shafts allow a significant narrowing of the tolerance used by compressor manufacturers pre-installed.

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