REUSE OF WEAR DEBRIS IN AUTOMOTIVE DISC BRAKES

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ABSTRACT
Paper presents an idea of wear debris reuse in the automotive disc brakes. According to this idea, worn material is used as a material building up third body. Application of this idea leads to diminishing of brake discs and brake pads wear.

INTRODUCTION
A number of the research works concern phenomena called third body formation. This phenomena also occur in automotive disc brakes and is a matter of interest [1,2,3,4,5]. By governing of the processes connected with third body formation it is possible to reduce the wear.

MATERIALS AND METHODS
Research was conducted for the typical brake friction pairs, which are: grey cast iron brake discs and non-asbestos organic friction material. Pin-on-disc and brake disc-brake pad test stands were used in the research. There were also performed in-field tests with vehicle equipped with disc brakes and ABS system. Investigations of surface layers included: optical microscopy, scanning electron microscopy, surface roughness measurements, geometrical measurements and chemical analysis.

RESULTS AND DISCUSSION
Brake disc and brake pad differ significantly both by material and by functions. So, their role in third body formation differs also. Both, brake disc and brake pad exhibit wear and in the automotive brakes, brake pads are the elements, which wear more intensively.

There were defined two conditions, which have to be fulfilled to diminish wear of disc brake. First - storage of wear debris on the brake disc or brake pad, and second - creation of wear particles in the size allowing for this storage.

Disc brake as a source of material
Basic constituents of typical material for disc (grey cast iron) are: iron (Fe) and carbon (C). The rest are alloy additives. In some cases during wear, wear particles could have bigger sizes that are necessary for material storage. This is unfavourable, because big particle will probably leave the friction zone and could damage third body structures. Strong influence of the presence of wear particles on the stability of friction coefficient was stated. In the presence of loose particles in the friction zone, value of friction coefficient fluctuates. Wear resulting in big sizes of wear particles, usually occurs in the zone of borders between metallic structures and graphite flakes-figure 1.

Brake pad as a source of material
Non-asbestos organic friction material could be build from up to twenty components. Size and distribution of friction material components differ depending on supplier. Similar to the brake disc, big size wear debris could be created during operation. This is especially valid for the structural elements of friction material - usually different kinds of fibers. Those fibers can be pulled out of friction material matrix, increasing both local and general wear. Local wear, in this case means removal of fiber and surrounding material and general wear means wear caused by big particle moving across friction path.

Some of the constituents of brake pad - especially organic ones, can not be a source of material for the friction zone in some operating conditions. It is connected with relatively low temperatures of melting and evaporation, which causes fast transformation to the liquid or gaseous state.

Environment as a source of material
Due to "open" design of automotive disc brake, environmental factors have access to the friction zone and additional material could be delivered. Environment is a source of: particles coming from air and road dust, active components of air (especially oxygen) and water.

Particles coming from air and road dust usually are hard and their acting could be unfavourable. Operation of car in dusty environment usually takes effect of characteristic wear pattern of brake disc.
Oxygen causes corrosive processes and grey cast iron is not corrosive - resistant. As a result of friction processes iron oxides are formed on the surface of brake disc and on the metallic constituents of friction material.

During wet braking two cases are possible. First one, when water separate elements of the friction pair, and causes radical drop of generated friction force - until removal of water. Second, in the case when volume of water is insufficient for the separation of the brake disc and brake pad water removal depends on the temperature and rotational speed of the brake disc. Those mentioned parameters, influence water removal by evaporation and acting of centrifugal force. Removal of water supports the removal of wear particles.

Storage functions of disc brake

In relation to the brake pad, disc is rather smooth, but both parts have directional characteristic of surface roughness. Lower values of roughness parameters are achieved in the direction of sliding speed. In order to accumulate products of wear, there is need of storage capacity. Low roughness excludes storage of material, but surface of brake disc consist of three basic areas: metallic structures, graphite flakes and pits [1]. Pits are able to collect wear debris. Those pits originate from process of graphite removal or as a result of corrosion.

The role of storage capacity was examined by special test run, where wear track was divided into three different operating distances. The last one performed, to obtain typical operating surface. Preparation of brake disc were also different - instead of grinding rough machining were used in order to obtain high values of surface roughness and thus storage capacity. After the tests, wear tracks were compared using scanning electron microscopy in BSE mode in order to distinguish different groups of material. Three zones were distinguished on the SEM images: Bright-Metallic, Medium-Wear debris, Dark-Graphite-figure 2.

Storage capacity of brake pads is larger then discs. This can be observed for instance, during the operation of corroded discs. Products of disc corrosion are removed from its surface and compacted on the pad –figure 4. This process seems to be bad from the operation point of view. However, thanks to accumulation, products of corrosion are not worn out, but stay on the elements of brake pair and are in further operation of brakes. Iron oxides created by corrosion became part of the third body. Wearing out of those oxides leads to increase of wear rate. It should be pointed out, that actual operating zones of brake pad are almost free from corrosive products - they are accumulated in the hollows.

CONCLUSIONS

The idea of reuse of wear debris in the processes of third body formation gives possibility of wear reduction and thus, lower emission to environment.

Tribological processes should be used in order to obtain third body ensuring stable value of friction coefficient, lower wear rate and comfort operation of brakes.

The majority of material should be accumulated on the brake pad.

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