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THE USE OF METALLOGRAPHIC ANALYSIS OF FRICTION LININGS IN THE BRAKING SYSTEM TO DETERMINE THE PROCESSES OF TRIBOLOGICAL WEAR

WYKORZYSTANIE ANALIZY METALOGRAFICZNEJ OKŁADZINY CIERNEJ W UKŁADZIE HAMULCOWYM DO WYZNACZENIA PROCESÓW ZUŻYWANIA TRIBOLOGICZNEGO

Key words: wear process, friction pair, brake lining.

Abstract The work presents metallographic examinations of worn brake linings under various operating conditions. The main purpose of this work is to determine the types of friction pair wear of braking systems under specific operating conditions. This is important for car service employees and appraisers who, based on quantitative and qualitative analysis, will determine the dominant mechanisms of wear. This is very important due to the possibility of determining the operating conditions, and thus the assessment of the use not only of the friction pair, but also the entire technical object, which is a motor vehicle. On the basis of the quantitative metallographic analysis of the research, individual wear mechanisms were presented, taking into account the determined diagnostic criteria during the measurement.

Słowa kluczowe: proces zużywania, para cierna, okładzina hamulcowa.

Streszczenie W pracy przedstawiono badania metalograficzne zużytych okładzin hamulcowych w różnych warunkach eksploatacji. Głównym celem niniejszej pracy jest określenie rodzajów zużycia par ciernych układów hamulcowych w określonych warunkach eksploatacji. Ma to istotne znaczenie dla pracowników serwisów samochodowych i rzeczoznawców, którzy na podstawie ilościowej i jakościowej analizy wyznaczą dominujące mechanizmy zużywania. Jest to bardzo istotne ze względu na możliwość określenia warunków eksploatacji, a tym samym oceny użytkowania nie tylko pary ciernej, ale także całego obiektu technicznego, jakim jest pojazd samochodowy. Na podstawie ilościowej analizy metalograficznej badań ukazano poszczególne mechanizmy zużywania z uwzględnieniem wyznaczonych kryteriów diagnostycznych podczas pomiaru.

INTRODUCTION

The operating conditions of the friction pair depend on many operational factors. The main factors include braking frequency, rotational speed of the brake disc and environmental conditions (appearance of water in the friction area).

Paper **[L. 1]** presents the effect of different grain sizes of sand on their deposition on the friction lining of the brake pad and the focus was on showing abrasive wear. The most common abrasive wear occurs when the metal element is abraded by loose dry or wet mineral particles with a much higher hardness than the abraded element. The authors at work **[L. 2]** determined the size and intensity of wear of friction linings and characterized wear products and their impact on the natural environment. The contact model of the friction lining of the brake pad with the brake disc made it possible to determine the actual contact area (about 80%) **[L. 3, 4]**. In this work, by means of quantitative metallographic

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analysis, areas on the friction surface were determined which do not take part in the wear process. To sum up, the purpose of the conducted research was to determine the types of wear based on quantitative metallographic and profilographometric analysis, which include numerically the share of individual types of wear occurring on the friction surface of the friction pair.

MATERIAL, DEVICES AND CONDITIONS OF TESTS

The study used a stereoscopic microscope with a significant depth of field, which allowed observation of the surface and the possibility of using it not only in laboratory conditions, but also by people who do not experience everyday wear problems. In order to determine the chemical elements present on the surface of the friction lining, the SEM microscope was used. For quantitative metallographic examinations, the Met_Ilo program was used to determine stereological features, which greatly facilitates the measurement of characteristic areas analyzed. The profilografometric studies used state-of-the-art white light interferometry (WLI) to measure surface profiles and roughness down to 0.05 μm. Frictional lining was used as the friction material, most often used by manufacturers of brake linings after the operation process under strictly defined conditions, i.e. with known history. These were linings operated in conditions of frequent braking and with different strength as is the case in urban driving conditions. Next, a group of brake linings was distinguished, operating in fast highway driving conditions, where there are not very frequent braking, however with a lot of force, which favors the occurrence of significant temperatures at the point of contact. A separate group of linings was selected based on a significant share in the process of mineral compounds (sand) exploitation, as is the case, for example, at construction sites or off-road driving. Oxidation wear is characteristic of frequent stoppages of the operation process when the driver does not use the means of transport. This process is more intense when the friction pair is exposed to moisture **[L. 5, 6]**.

Thus, the research used a rich material of worn linings of friction brake pads used in motor vehicles. Due to the appropriate statistics of the considered cases, an image of particular types of wear mechanisms most often found in the examined friction pair was obtained.

RESULTS

On the basis of chemical analysis and metallographic examinations, a quantitative metallographic analysis was carried out using a SEM microscope in areas of predominant wear (**Figure 1–8**). **Figures 1, 2, 3, 4** in frames show examples of analyzed areas of dominant tribological wear.

The following types of wear were taken into account in the analysis:

a) friction wear – areas of brighter color than the rest of the environment were most commonly used as friction wear, usually approaching their color to white. These areas were subjected to elemental analysis in which the presence of iron was found. This phenomenon occurs when in the friction areas of cooperating elements there are rested or loose particles of abrasive or protruding unevenness of hard material.

Fig. 1. The friction surface of the brake lining with marked areas with predominant friction wear
Rys. 1. Powierzchnia tarcia okładziny hamulcowej z zaznaczonymi obszarami o dominującym zużyciu ściernym

b) oxidation wear – characteristic brown areas were observed. This occurs when the intensity of surface destruction by abrasion is less than the intensity of formation of oxide layers. This process involves the gradual removal (destruction) and restoration of oxide films on the surface of metals.

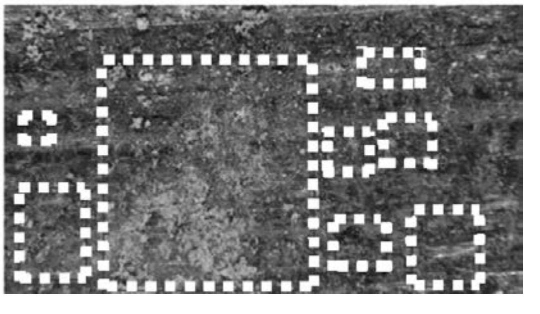

Fig. 2. The friction surface of the brake lining with marked areas with predominant oxidation wear
Rys. 2. Powierzchnia tarcia okładziny hamulcowej z zaznaczonymi obszarami o dominującym zużyciu przez utlenianie

c) adhesive or hydrogen wear – areas with obvious visible fault or chipping indicating the occurrence of grafting were qualified for this type of wear. Such areas appear in microscopic photographs with a very dark color (due to the existence of areas with a significant depth difference). In the case of hydrogen wear, destruction of the surface layer occurs due to adsorption of hydrogen on the friction coil and its diffusion into the material, which causes brittle cracking in the microbubbles of the surface layer and its decohesion under the influence of frictional forces.

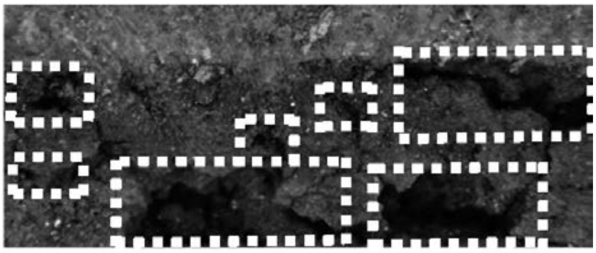

Fig. 3. The friction surface of the brake lining with marked areas with predominant adhesive wear

Rys. 3. Powierzchnia tarcia okładziny hamulcowej z zaznaczonymi obszarami o dominującym zużyciu adhezyjnym

d) abrasive wear – occurs due to the use of abrasive material (mud, sand, etc.) from the environment, which leads to extreme wear due to furrowing (**Fig. 10**).

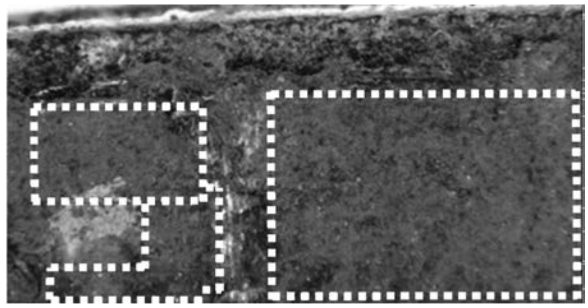

Fig. 4. The friction surface of the brake lining with marked areas with predominant abrasive wear

Rys. 4. Powierzchnia tarcia okładziny hamulcowej z zaznaczonymi obszarami o dominującym zużyciu abrazyjnym

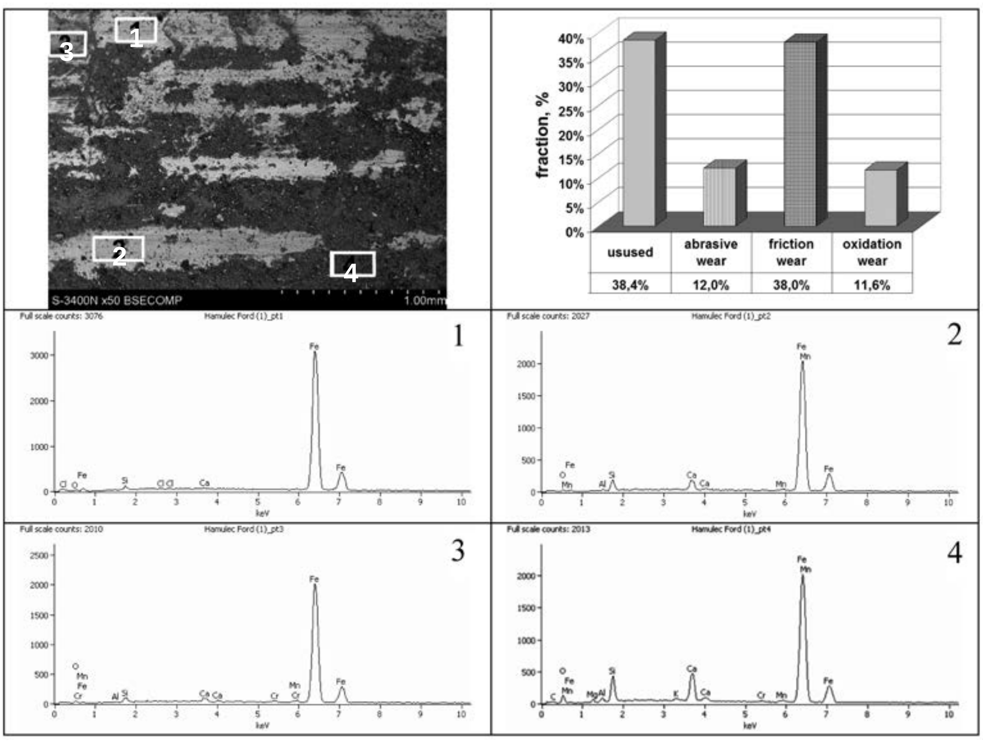

Fig. 5. Area of friction wear of brake lining and share of particular types of wear on the basis of quantitative metallographic analysis with elemental analysis

Rys. 5. Powierzchnia tarcia okładziny hamulcowej przy zużyciu ściernym oraz udział poszczególnych rodzajów zużycia na podstawie ilościowej analizy metalograficznej wraz z analizą pierwiastkową

On the friction surface in areas with a dominant wear and abrasion process, a significant proportion of iron was observed. Oxygen has been observed in addition to iron for oxidation wear. In the process of abrasive wear, the participation of silicon appeared. **Fig. 10** shows the effects of the brake pad cooperation with the brake disc, which results in numerous furrows appearing on the friction surface. Performed profilographometric tests of the exemplary friction surface of the brake pad lining, on which the dominant nature of adhesive wear was observed (**Figure 9**), confirm the results of metallographic metallographic tests by the dominant nature of wear by tacking (**Figure 7**).

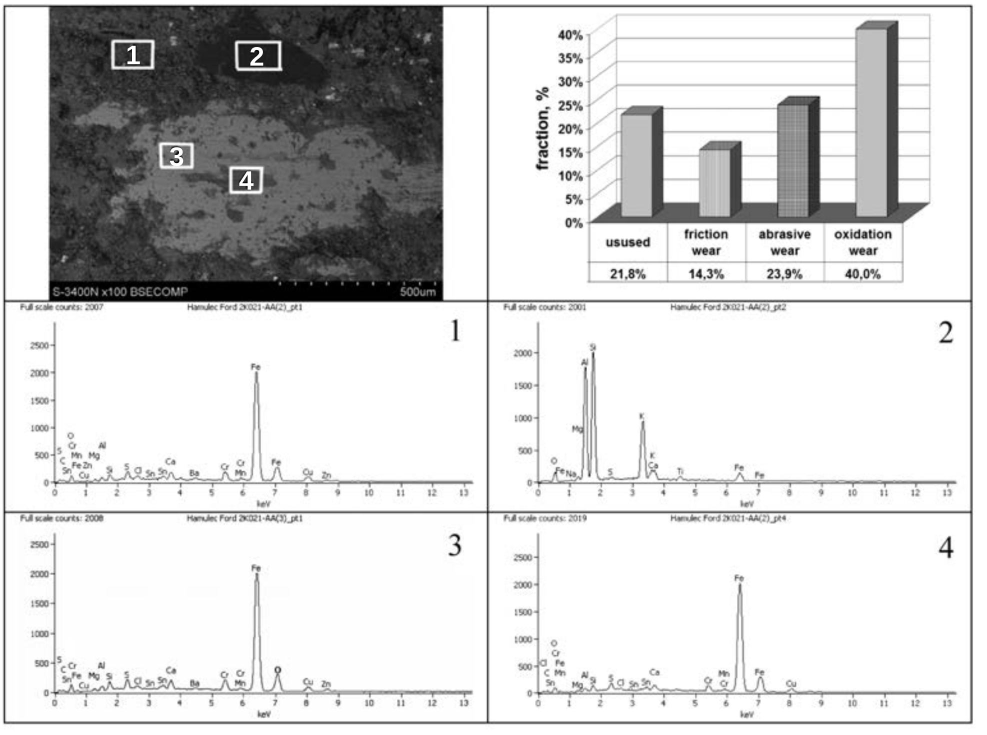

Fig. 6. The friction surface for oxidation wear of the brake lining and the share of particular wear types based on quantitative metallographic analysis together with the elemental analysis

Rys. 6. Powierzchnia tarcia okładziny hamulcowej przy zużyciu przez utlenianie oraz udział poszczególnych rodzajów zużycia na podstawie ilościowej analizy metalograficznej wraz z analizą pierwiastkową

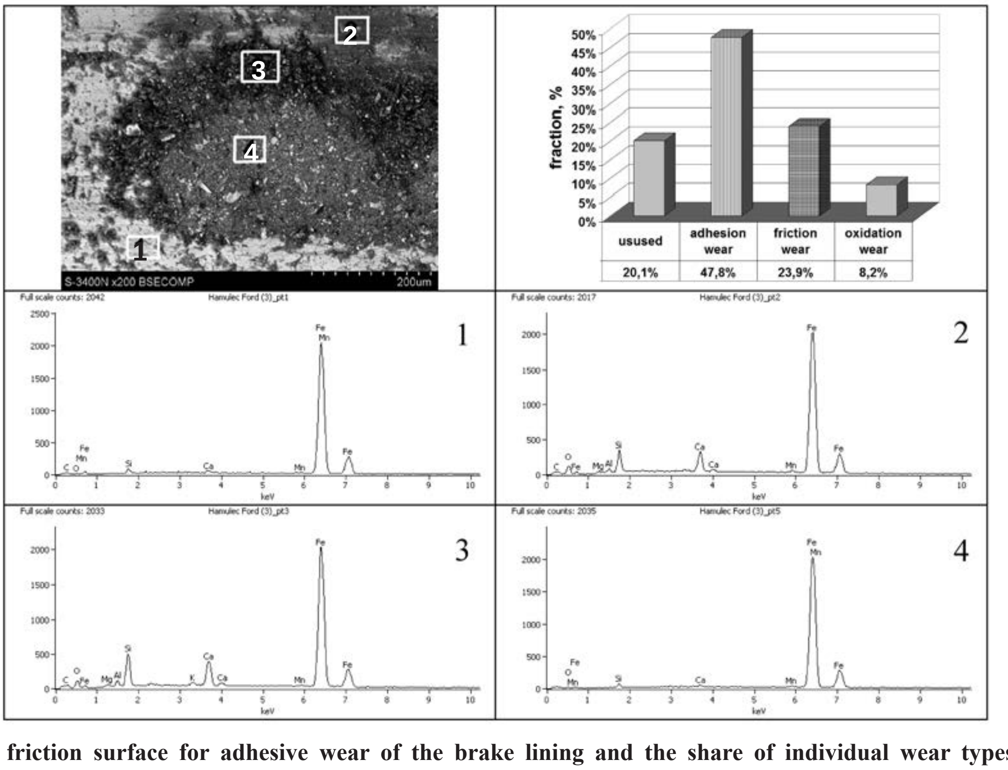

Fig. 7. The friction surface for adhesive wear of the brake lining and the share of individual wear types based on quantitative metallographic analysis together with the elemental analysis

Rys. 7. Powierzchnia tarcia okładziny hamulcowej przy zużyciu adhezyjnym oraz udział poszczególnych rodzajów zużycia na podstawie ilościowej analizy metalograficznej wraz z analizą pierwiastkową

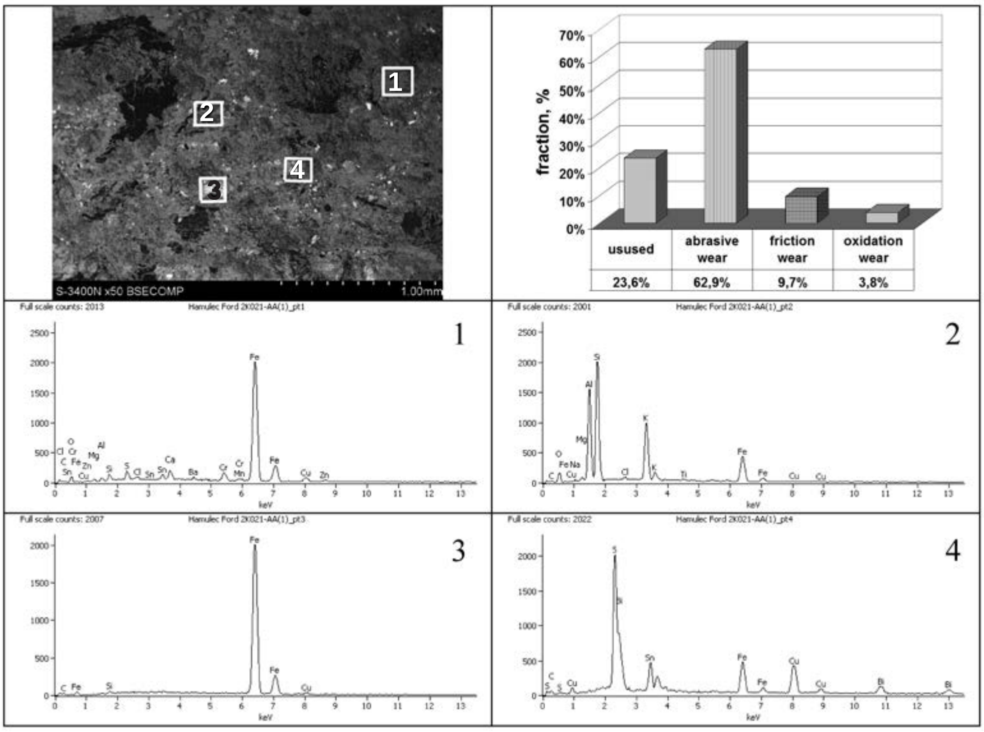

Fig. 8. The friction surface for abrasive wear of the brake lining and the share of individual wear types based on quantitative metallographic analysis together with the elemental analysis

Rys. 8. Powierzchnia tarcia okładziny hamulcowej przy zużyciu abrazyjnym oraz udział poszczególnych rodzajów zużycia na podstawie ilościowej analizy metalograficznej wraz z analizą pierwiastkową

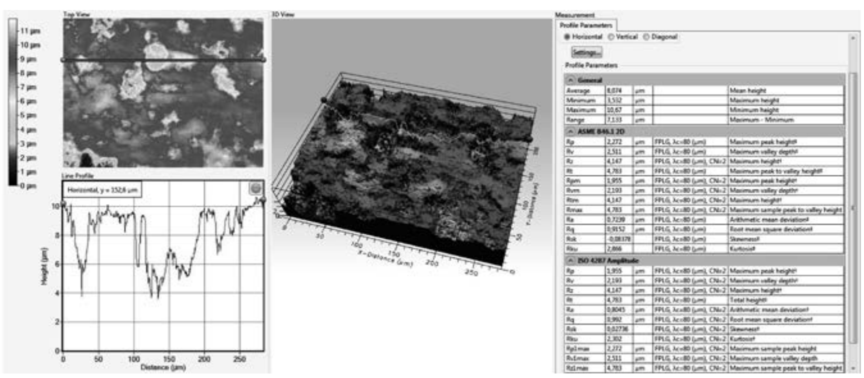

Fig. 9. The friction surface of the brake pad lining

Rys. 9. Powierzchnia tarcia okładziny hamulcowej klocka hamulcowego

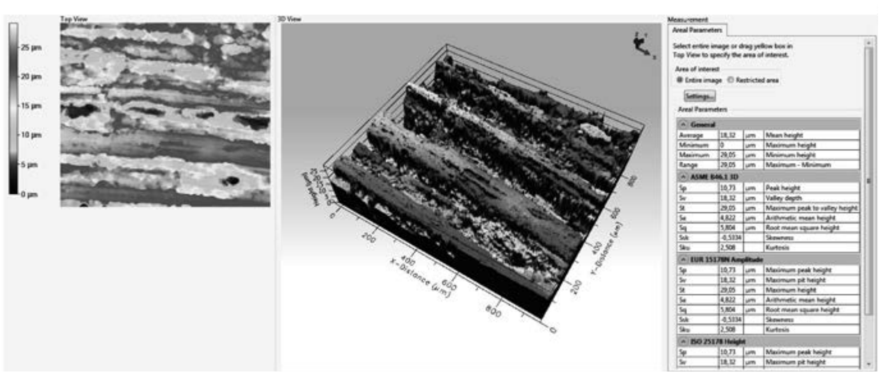

Fig. 10. The friction surface of the cast iron brake disk after wear with visible grooves

Rys. 10. Powierzchnia tarcia żeliwnej tarczy hamulcowej po zużyciu z widocznymi rowkami

CONCLUSIONS

The following final conclusions were formulated based on the results of metallographic and profilografometric tests:

- the most common types of wear of brake linings in braking systems are wear by oxidation and abrasive wear,
- in extreme conditions, adhesion (crumbling on the surface) or abrasive (sand, mud) may occur,
- the process of adhesive and hydrogen wear observed on the surface of the friction lining is very similar to each other, which results in emerging cracks and chippings on the friction surface,
- the decisive influence on the wear of both the brake pad and the brake disc has the operating conditions of the vehicle and the driver himself,
- presence of particles of sand or other dirt on the brake lining causes drawing of the friction surface of the brake disc excluding it from further exploitation,
- oxidized areas can cause degradation of the material and cause unpleasant sounds during braking,
- it is possible to determine the mechanism of wear on the basis of quantitative metallographic analysis provided that the set diagnostic criteria were adopted during the measurement.

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