ANALYSIS OF THE SURFACE LAYER OF THE BRAKE DISK

ŠVÁBENSKÁ Eva[1], ROUPCOVÁ Pavla[1], PODSTRANSKÁ Ivana[1], PETR Martin[2], FILIP Jan[2], SCHNEEWEISS Oldřich[1,3]

[1]Institute of Physics of Materials AS CR, Brno, Czech Republic, EU
[2] Regional Centre of Advanced Technologies and Materials, Palacky University, Olomouc, Czech Republic, EU
[3] Central European Institute of Technology & Institute of Physics of Materials (CEITEC IPM), Academy of Sciences of the Czech Republic, Brno, Czech Republic, EU

Abstract

Our research is focused on the changes in thin surface layer of the brake disk due to the impact of severe plastic deformation and heating by friction process. The aim of this study is to compare structure, chemical and phase compositions of the surface layer in depth up to several hundreds of nanometers in the no affected central part of brake disk and the part which was in contact with brake pads by braking. The basic information on structure and phase composition was obtained by optical and scanning electron microscopy, X-Ray Powder Diffraction and Mössbauer Spectroscopy. The thin surface layer was studied using Conversion Electron Mössbauer Spectroscopy and X-ray Photoelectron Spectroscopy. We explain the observed changes with the knowledge on effects of plastic deformation and/or diffusion of alloying elements in the material of the brake disk.

Keywords: Grey cast iron, brake disk, microstructure analysis, surface layer

1. INTRODUCTION

In the few past decades, the novel materials for brake disk are development. Nowadays trends of vehicle weight reduction and improvement of material properties for brake disk and brake rotors open doors for this novel material or different type of innovation as co-cast disk (aluminum bell with steel braking strip). Titanium alloys, Aluminum matrix composite [1, 2] or metallic matrix composites and carbon composite [3] can give better material properties as tensile strength, hardness, thermal conductivity [4]. However, this material can find only occasionally in exclusive models of cars. Gray cast iron is still commonly used in automobile industry although some of their properties are worth then composite material, on the other hand is cheap and easily to produce.

Cast iron, especially gray cast iron is an iron-carbon cast alloys with contents other elements higher than in steel. The range of alloyed elements is much wider and can change useful properties of product.

Brake disk made from cast iron can be expose structural transformation as a result of working condition, where the materials are exposed to significant changes of temperature and friction. Structural transformations of materials and their surfaces have an effect on the whole system and functionality. Temperature commonly may reach up to 500 °C or higher and hydraulic pressure 2 ÷ 4 MPa by braking in automobiles [5]. Surface and near-surface temperatures can become high enough to cause changes in the structure and properties of the materials.

Friction stressing can change chemical composition and induce changes in phase composition of the surface layer due to oxidation and mechanical alloying [6].

The role of grey cast iron structures in wear course, frictional characteristic [7] and also change of temperature of brake disk during the fiction had been study [8, 9].

2. MATERIALS AND METHODS

As a sample was use saw up gray cast iron nonventilated worn with use brake disk from personal car 1.8l after ~60 000 km. One part of samples for microstructure examination were grinding and polishing. The friction surfaces of the samples were study without any preparation. Detailed studies of the surfaces of the disk part which was not exposed by strains and heat shocks by friction (surface N) and the friction exposed part (surface F) were carried out.

Surface layers of brake disc were investigated by optical microscope (Neophot 32 by Carl Zeiss Jena) and scanning electron microscope JEOL 6460 with Oxford Instruments analytical equipment INCA Energy (EDX).

The X-ray powder patterns were collected on X'Pert diffractometer and CoKα radiation with qualitative analysis by HighScore® software and the JCPDS PDF-4 database. For a quantitative analysis HighScore plus® with Rietveld structural models based on the ICSD database was applied.

The X-ray photoelectron spectroscopy (XPS) was use for analyses thin friction layer. The XPS measurements were carried out with the PHI 5000 VersaProbe II XPS system (Physical Electronics) with monochromatic Al-Kα source (15 kV, 50 W) and photon energy of 1486.7 eV. All the spectra were measured in the vacuum of 1.2 x 10-7 Pa and at the room temperature of 22 °C. The analyzed area on each sample was spot of 200 µm in diameter. The survey spectra was measured with pass energy of 187.850 eV and electronvolt step of 0.8 eV while for the high resolution spectra was used pass energy of 23.500 eV and electronvolt step of 0.2 eV. Dual beam charge compensation was used for all measurements. The spectra were evaluated with the MultiPak (Ulvac - PHI, Inc.) software. All binding energy (BE) values were referenced to the carbon peak C1s at 284.80 eV. For peaks identification NIST XPS data base [11] was used as well.

The photoemission measurements were complemented by ^{57}Fe Mössbauer spectroscopy in scattering geometry with detection of 14.4 keV gamma radiation (MS) and conversion electrons (CEMS). The spectra were measured at room temperature and calibrated against α-Fe. The computer processing of the spectra was done using CONFIT program package [12].

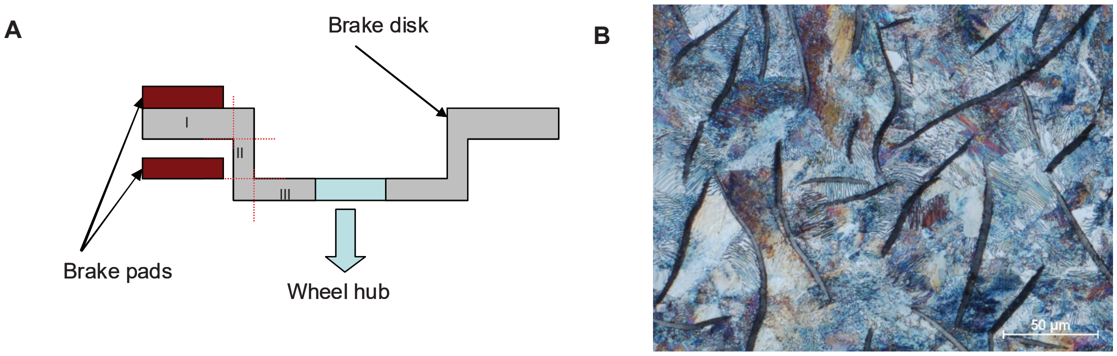

Fig. 1 Place of sampling and number of sample (A) and pearlitic structure of gray cast iron. Etched with 2% Nital

3. RESULTS AND DISCUSSION

3.1. Structure and phase identification

Gray cast iron disc have pearlitic metallic matrix with the typical structure. (**Fig. 1B**) The pearlite had a lamellar structure with characteristic spacing of ferrite-cementite plates. Study of phase structure by X-ray diffraction provides similar information, where only a small contribute of other iron phase was observe.

The examination of the as-polished specimen before etching with a light optical microscope was the first step for phase identification and morphology especially for examine the graphite phase. Graphite was occurred in the form flake in a relatively uniform distribution and as a rosette (**Fig. 2**). The size and position of graphite flakes depends on the parameters of casting and cooling.

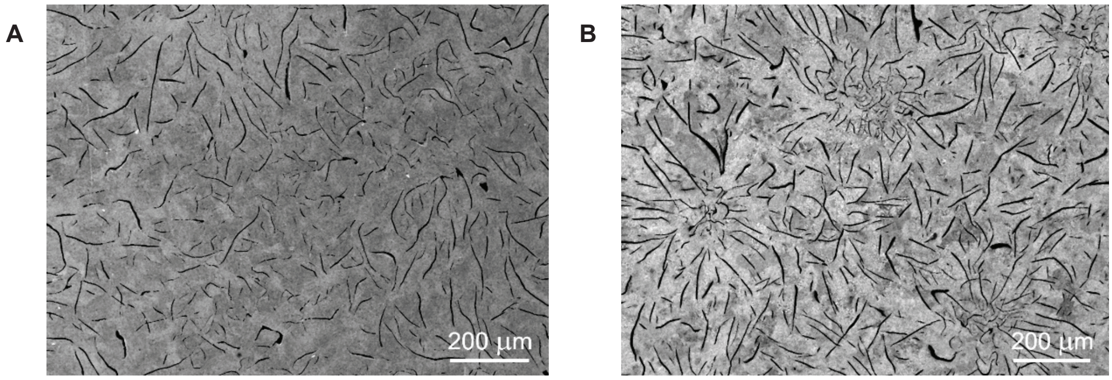

Fig. 2 SEM image (100 x) of variation graphite flake structure observed at different part of brake disk. Image A was made near the brake part of disk (sample I), image B was observe at sample III

Quite similar situation was observed by scanning electron microscopy. Energy dispersive X-ray gave general knowledge about chemical composition of sample and identification of inclusion. In sample III were find more various inclusions then in sample I and II. Inclusions were probably formed from MnS, FeS, SiO_2, AL_4C_4, and CaC_2. In some other elements as titanium, vanadium, niobium, phosphorus and chromium were also discovered. Part of this elements and elements contained in inclusion are common ingredients of gray cast iron and other can change material characteristic as increasing resistance of wear, hardness and other.

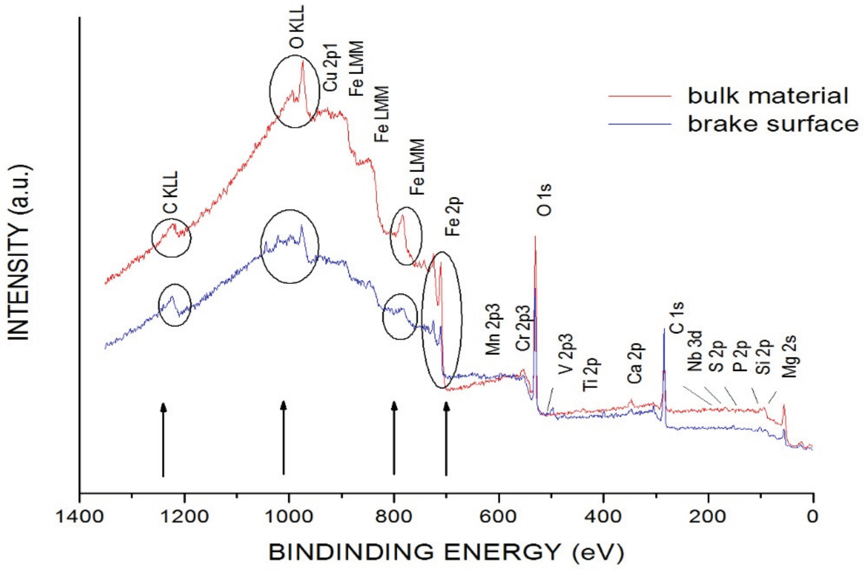

Fig. 3 XPS survey scan spectra of the polished bulk surface (blue line) and F surface (red line). The ellipses label the peaks with important differences in intensities between the surfaces of the samples

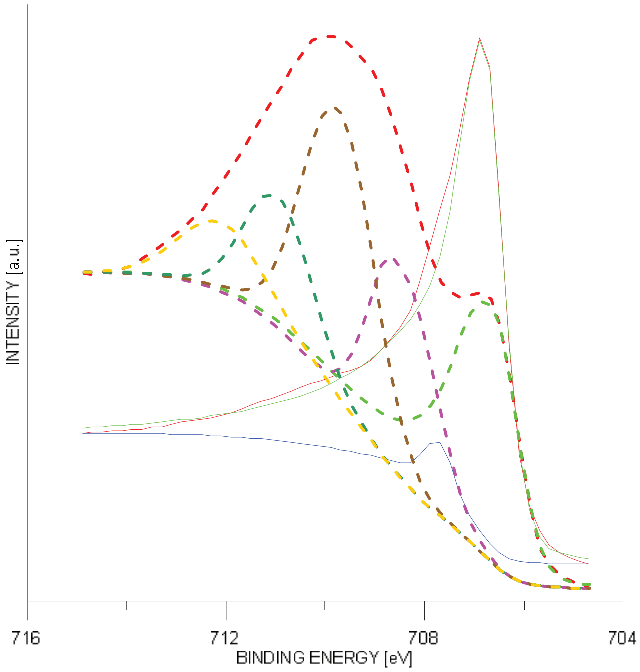

Fig. 4 XPS iron Fe2p peaks with fitted components of the polished bulk surface (solid lines) and F surface (dashed lines)

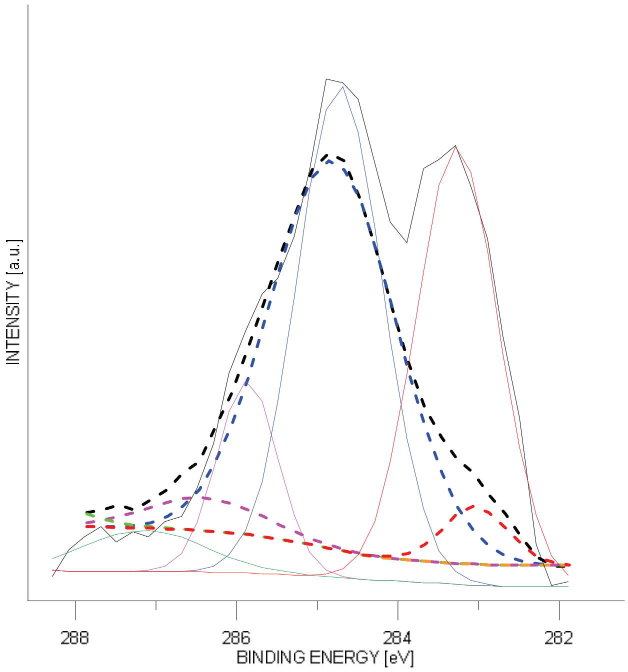

Fig. 5 XPS carbon C1s peaks with fitted components of the polished bulk surface (solid lines) and F surface (dashed lines)

3.2. Surface layer of brake disk

The main area of our interesting was working zone of brake disk. Thin surface layer of brake disk were investigated by XPS and CEMS Mössbauer spectroscopy. It should be noted that XPS spectra yield information from the surface about 1 nm in depth and CEMS spectrum corresponds to the surface thickness about 0.2 micrometer.

Comparison of XPS survey scan spectra (**Fig. 3**) of the polished bulk surface and F surface indicates some differences in intensities of the peaks. Detailed analysis of iron Fe2p peaks (**Fig. 4**) shows that in the surface of the polished sample of bulk material from centre of the brake disk dominates pure Fe (0), which is represented by component with binding energy around 706.8 eV [11]. In the spectrum of F surface the component of binding energy about 709 eV is the most intensive and it can be ascribed to iron oxides: FeO (709.4 eV and 709.6 eV) or Fe_3O_4 (709.2 eV) [11]. The carbon C1s spectra (**Fig. 5**) also differ substantially. Two main components can be clearly identified there: (i) the component with binding energy ~ 283 eV which represents carbon in cementite (Fe_3C) and (ii) the component ~285 eV belongs to elementary carbon/graphite [11, 13]. In the spectrum of polished bulk surface both peaks can be observed approximately in the same intensity. In the spectrum of F surface an important decrease in the intensity of the ~ 283 eV can be observed in comparison with the component of a elementary carbon/graphite (285 eV). Besides these two components more intensive peak at ~ 286 eV appears which can be ascribed to bonds carbon and oxygen atoms [11]. Similar substances can be formed during friction processes of the brakes. These results are in a good agreement with the data published in [14].

Mössbauer spectra (MS) of the surface N and F are shown in **Fig. 6**. Phase analysis derived from the spectra indicates that by braking decreases content of cementite Fe_3C and oxide phase with Fe^{3+}.

In the **Fig. 7** CEMS spectrum of the surface F is compared with MS of the surface N. CEMS spectrum corresponds to the surface thickness about 0.2 micrometer. An important increase in the content of oxide phase can be observed there in CEMS spectrum. Cementite Fe_3C was not detected may be due to lower quality of the spectrum.

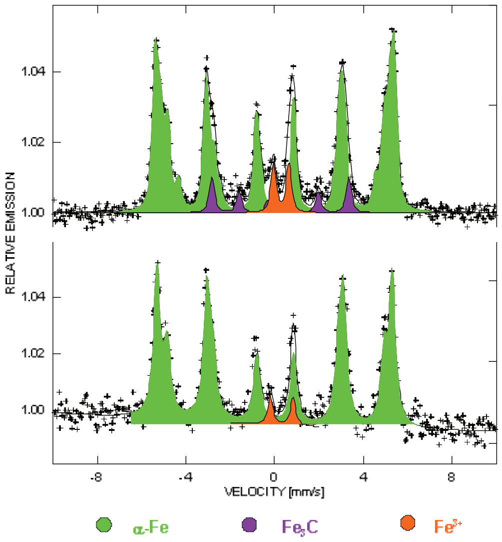

Fig. 6 Mössbauer spectra (MS) of the of the N surface (above) and the friction exposed surface F

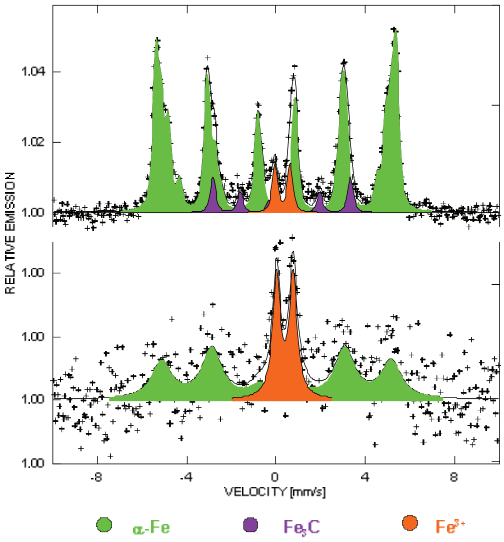

Fig. 7 Mössbauer spectrum (MS) of the N surface (above) and CEMS spectrum of the F surface.

4. CONCLUSION

In this work, different methods were used to study changes in thin surface layer of the brake disk by friction process. The experiment result shows that heat change during the friction can change structure of the surface layer on brake disk. The XPS results show differences in iron and carbon substances in the surfaces of the sample prepared by polishing of bulk without friction and the surface with friction by braking. The graphite and Fe_3C are smeared in iron oxide and substances with carbon-oxygen bonds. The formation of iron oxides and disappearing of Fe_3C were confirmed by phase analysis of CEMS results.

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