

## **SELECTION OF MATERIALS AND TECHNOLOGY FOR FORMING THE LAYERS RESISTANT TO ABRASIVE WEAR**

Silvia REVESOVÁ, Pavel BLÁŠKOVITŠ

### **Abstract**

*This article deals with the selection of materials for forming wear resistant layers within agricultural machine parts wear. We can achieve required hardness, wear resistance and life extension of agricultural machine parts and tools by the selection of a suitable material and surfacing technology.*

### **Key words**

*tribology, abrasive wear resistance, electric arc surfacing, filler material for abrasive wear*

### **Introduction**

Studying wear is characterised by many different aspects and it is mostly influenced by the complexity of materials interaction on a functional surface as well as by operation conditions. In machine elements, there is a gradual wear in the result of friction. This is considered to be an undesirable effect in most cases. Therefore, we have to search for the possibilities to prevent it thus extending the technical life of a component. Surfacing presents one of these possibilities. Searching for the possibility of cutting the costs of changing the worn or damaged machine elements has led to the development of a wide range of surfacing technologies. Increasing the safety and extending the technical life of machines and devices are important requirements of modern technology. We can also add the requirement for simple maintenance, as well as simple and less time-consuming repairs in solving the random failures or operation accidents.

Wear is the (permanent) change of shape, size or features of material layers that usually form the surface of solids. It occurs as a result of friction and out of technologically required shaping or required change of material characteristics [3].

Slovak technical standard 01 5050 classifies wear as follows: adhesive, abrasive, erosive, fatigue, cavitation and vibration wear. Wear can have many forms that depend on the surface topography, contact conditions and environment.

### **Abrasive wear**

Abrasive wear belongs to such wear types that can occur most frequently in machine elements of industrial installations and it presents up-to 80% of overall volume [4]. It can also originate from other wear types in the course of which the free particles are being formed. These particles are becoming stiffer than the parent material. This happens under the influence of either intensive plastic deformation, or air oxygen oxidation. Abrasive wear rate can be reduced by:

- load reduction – particles will not be imprinted so deeply into the material surface and the ripples will be shallower
- hardening – with the same effect as it is in previous possibility [6]

Abrasive wear consists in separation of surface parts by undulation of another surface or particles that are situated between the friction areas. It mainly depends on load, slide-way length and hardness. The influence of number, size and shape of the particles is also very important [5]. Ripples belong to typical surface damages in abrasive wear.

In abrasive wear, it is necessary to distinguish between two critical phases, namely the process of imprinting the abradant into the surface where the imprint hardness and destruction process are the limiting factors. Interatomic bond force and the composition strength between structural components reciprocally at the borders of grains play a decisive role [4].

### ***Experimental programme***

Subject of this experimental programme presented the choice and evaluation of surfacing (Fig. No. 1, Fig. No. 2, Fig. No. 3) made out using the technology of hand arc surfacing with using of filler materials by Welco Company (Welco electrodes 1702 S, 1707 S, 1709) for surfacing layer resistant to abrasive wear. On the parent material S 355J0 (constructional steel according to Slovak Technical Standard 11523), we welded the filler materials to three layers. We were searching for such sample that would be hard enough, resistant to abrasive wear and contain minimum amount of chrome at the same time, so it would not burden the welder's health and the environment. Chemical composition of the filler material is presented in the table No. 1.



**Fig. 1** The surfaced sample No. 1

**Fig. 2** The surfaced sample No. 2

**Fig. 3** The surfaced sample No. 3

#### CHEMICAL COMPOSITION OF APPLIED FILLER MATERIALS

Table 1

Parent material 11523	Chemical composition (%)										
Electrode	C	Mn	Si	S	P	Cr	Ni	Mo	V	W	Fe
No. 1 – 1702 S	0,75	11.7	0.15	0.002	0.02	4.2	3.1	0.35	-	-	79.728
No. 2 – 1707 S	0.4	0.3	0.8	-	-	8	-	1	0.6	-	88.9
No. 3 – 1709	0.6	0.5	0.4	-	-	4	-	8	1.1	1.7	83.6

This type of surfacing belongs to plainer and nowadays also the most widespread ways of surfacing concerning the availability of devices and their undemandingness in handling. Heat needed for the parent material and electrode melting, including the cover, generates in the electric arc. Fusion metal can be alloyed through the electrode cover and corestock. In surfacing, it is necessary to keep the arc short, so it is possible to provide the protection of the metal pool against the air atmosphere and not to stove the alloying elements [1]. Surfacing is carried out by laying down weld beads using the longitudinal or transversal method and covering the beads by 1/4 up-to 1/3. Surfacing is rarely made on a vertical plane. Thickness of a surfacing layer is usually of 2 or more millimetres and it can be resistant not only to wear, but also to collision, pressure, corrosion etc. [2].

One of the important aspects in the surfacing process is the choice of the electrode. Correct choice of the electrode can improve the properties of a surfacing layer, increase hardness, toughness and stretch out the life of functional area.

#### *Sample preparation*

Three types of surfacing were selected for the experimental testing. Sample No. 1 surfaced by 1702 S electrode without pre-heating, sample No. 2 surfaced by 1707 S electrode and No. 3 surfaced by 1709 electrode with pre-heating up- to 200 °C following the producer's recommendation.

#### Surfacing parameters:

Welding current intensity:  $I = 120 \text{ A}$  (all samples)

Welding voltage:  $U = 22 \text{ V}$  (all samples)

Direct current of reversed polarity was used.

Diameter of electrodes: 3.2 mm

Electrodes were dried at  $300 \text{ }^{\circ}\text{C}$  for 2 hours before use.

#### *Testing methodology*

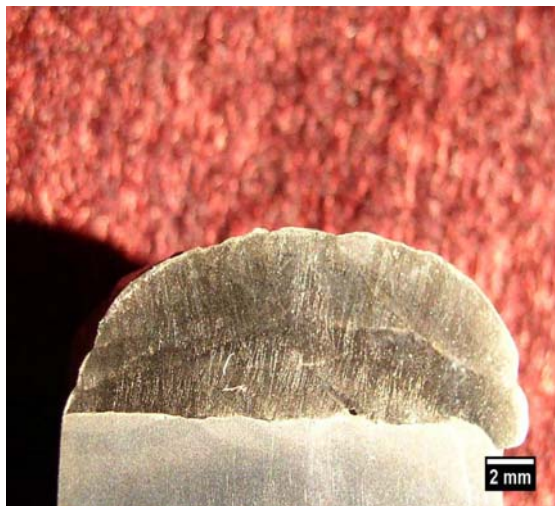
Aim of this testing was to determine the most suitable surfacing layer resistant to abrasive wear. We selected three basic tests for evaluation:

1. metallographic testing (macroscopic and microscopic);
2. hardness testing (microhardness measuring – microhardness attests mainly to the character of the structure and its homogeneity. At the layer-underlayer interface, it attests to the character of the weld and the amount of mixing the filler and parent material);
3. testing of the abrasive wear resistance according to Slovak technical standard 01 5084.

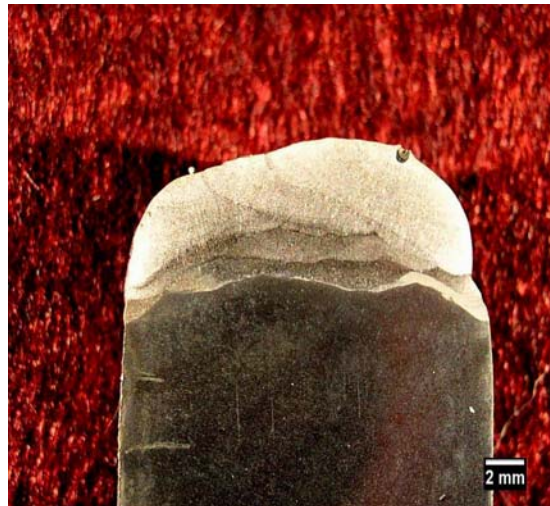
#### *Experimental programme evaluation*

##### *Metallographic testing*

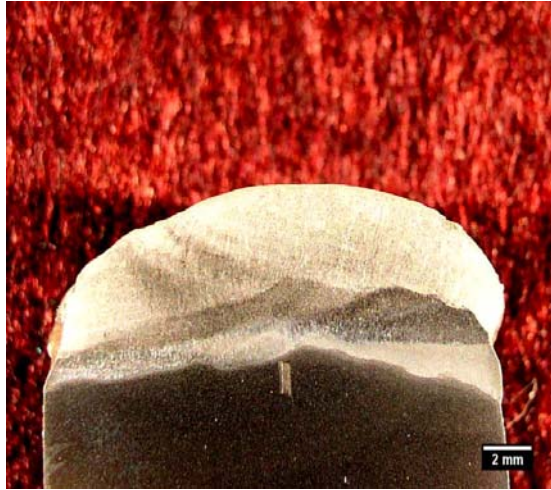
- a) Macrostructural analysis results – macroscopic observation was carried out with naked eye and a magnifying glass. We were observing different damages of the welded-on material surface as well as the equality and thickness of the surfaced layer. At the meltdown border line in sample No. 1 (Fig. 4) we observed a slag. In sample No. 2 (Fig. 5) in the third surfacing, it is possible to observe disintegrity of the size 0.5 mm. Heat affected zone is indistinctive. In sample No. 3 (Fig. 6), there was no disintegrity compared by sight such as lack of inter-run fusion, cavities or pores.



**Fig. 4** Macrostructure of the sample No. 1  
(1702 S)

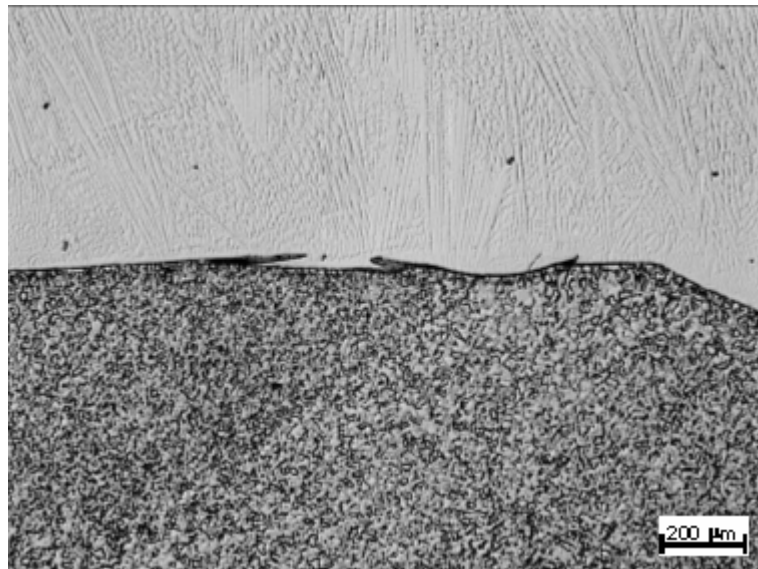


**Fig. 5** Macrostructure of the sample No. 2  
(1707 S)



**Fig. 6** Macrostructure of the sample No. 3 (1709)

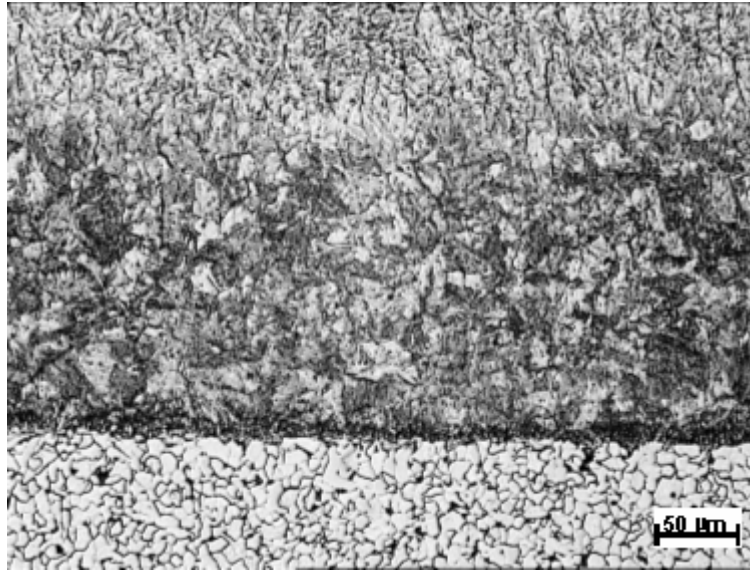
- b) Microstructural analysis results – we used light microscopy for prepared cross-sections, according to the sample preparation procedure for metallographic testing. Selection of the corrosive depended on the chemical composition of analysed sample. Sample No. 1 surfaced by 1702 S electrode was corroded by 3 % of natal, and samples No. 2 and 3 surfaced by 1707 S and 1709 electrodes were corroded by 10 % of  $\text{CrO}_3$ . Analysis was focused on the evaluation of the surfacing integrity, buttering microstructural analysis, and heat affected zone of the base material. In Figure No. 7, we can see the parent material – surfacing transfer. The surfacing layer is of a cast character and the parent material is of ferritic - pearlitic structure and polyendric morphology. Bainitic structure occurs here and it causes the fact that the melted parent material is alloyed from the filler material of the electrode and carbidic particles originate consequently. At the interface, there is formation of a fine-grained structure in the result of recrystallization process within the surfacing of another layer.



**Fig. 7** Microstructure of a transition zone, parent material – surfacing of a sample no. 1 (1702 S)

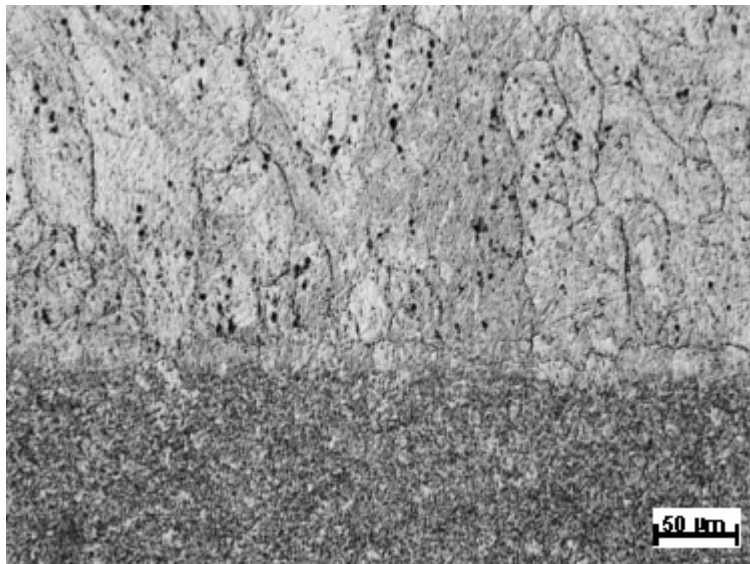


Transition zone (Fig. 8) consists of a dendrite mixed with the parent material. We assume high density of precipitates and carbides within the alloying elements (Cr, Mo). Heat affected zone, which is now indistinctive, has grain that has not coarsened and it comprises polyhedric morphology of ferrite and secreted pearlite along the borders of ferritic grains.



**Fig. 8** *Microstructure of a transition zone, parent material  
– surfacing of a sample No. 2 (1707 S)*

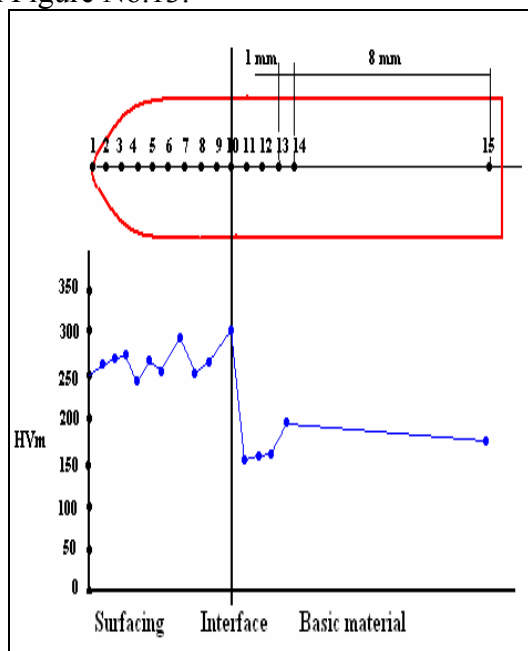
Figure No. 9 shows a detail of the surfacing microstructure. The surfacing microstructure is characterized by similar dendrite morphology in all samples. The surfacing microstructure character around the heat affected zone – dendrite morphology is not distinctive, borders of columnar grains are markedly corroded, and this can be caused by precipitation of secondary phases. On the basis of the surfacing chemical composition, we assume that these are the carbides of alloying elements.



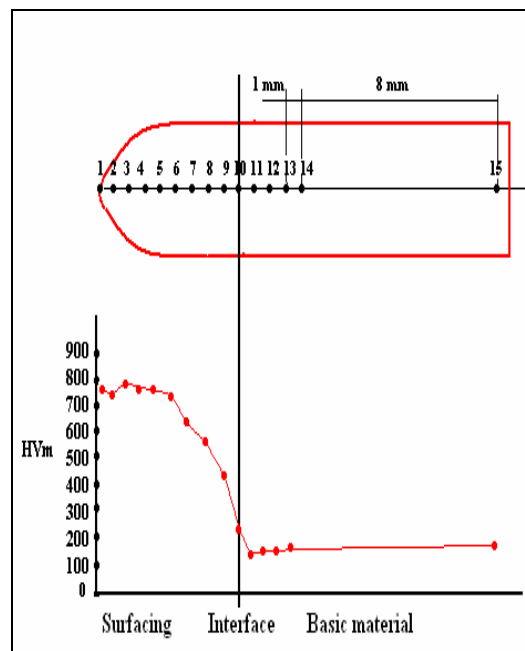
**Fig. 9** *Microstructure of a transition zone, parent material  
– surfacing of a sample No. 3 (1709)*

### Microhardness measurement

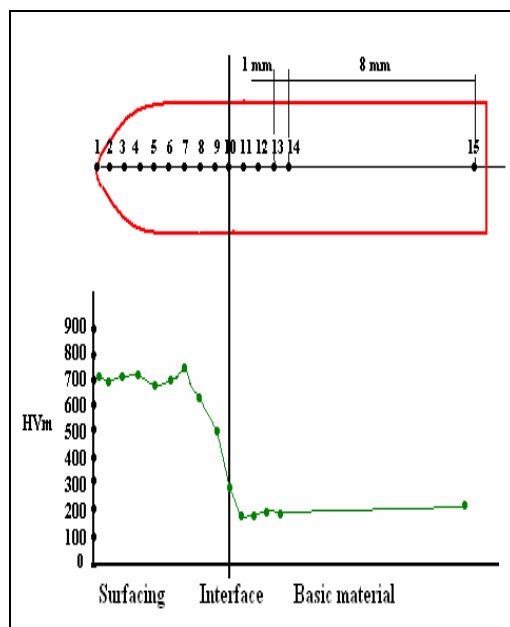
Microhardness of individual samples made out by a hand arc-drop surfacing technology was measured in 15 places of sample cross-section. In sample No. 1 (Fig. 10), the lowest average value of microhardness was measured and this was probably caused by the chemical composition of parent material (1702 S). The surfacing hardness in samples No. 2 (Fig. 11) and No. 3 (Fig. 12) changes from 262 to 762 HV<sub>0,01</sub> (Tab. 2). In these locations, the concentration of chrome probably rises. The measured surfacing microhardness is presented in Figure No.13.



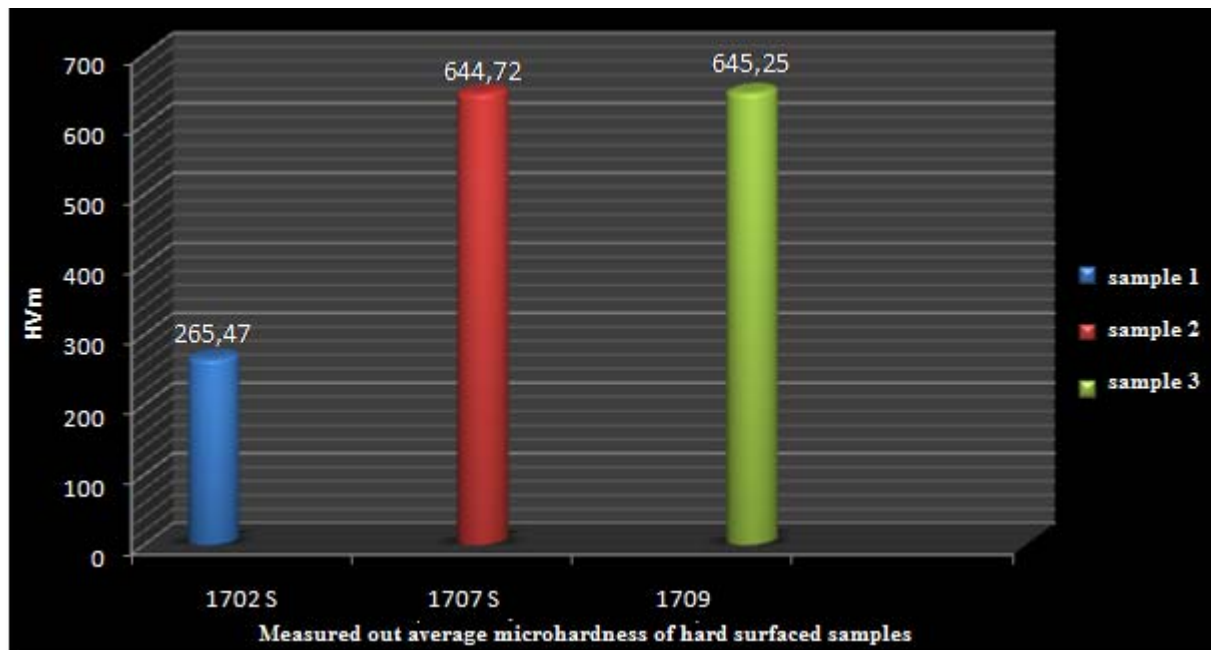
**Fig. 10** Measuring the microhardness on the sample No. 1 – 1702 S



**Fig. 11** Measuring the microhardness on the sample No. 2 – 1707 S



**Fig. 12** Measuring the microhardness on the sample No. 3 - 1709



**Fig. 13** Measured out average microhardness of hard surfaced samples

#### *Test of resistance to abrasive wear according to the Slovak technical standard 01 5084*

Before measuring the wear resistance, we weighed the samples individually on the electronic weighing machine with an accuracy of  $10^{-3}$  g. After weighing, we tightened the sample into the holder of the tester and loaded by compressive force of 0.25 N. The sample was moving radially from the edge to the middle where it automatically stopped. Thereafter, we picked it and cleaned it. Abrasive cloth was replaced and we put on another sample. Reference indicator  $W_{opz} = 0,35715$  g was obtained after the abrasive wear of the sample from the material 12 014.20 in such way that is specified in the Slovak technical standard 41 2014. After testing, we weighed the samples again and, using the measured values, we figured out the weight reduction and relative resistance to abrasive wear.

In the compared surfacing types, the relative resistance to abrasive wear is different. In order to find out which surfacing is the most resistant to abrasive wear, we calculated the average relative resistance for each sample.

- for surfacing 1702 S..... $\bar{\Psi}_{abr} = 1,8183$
- for surfacing 1707 S..... $\bar{\Psi}_{abr} = 2,4600$
- for surfacing 1709 ..... $\bar{\Psi}_{abr} = 2,6955$

The best resistance to abrasive wear was again reached by the sample No.3. It is suitable for cutting tools of all types. Surfacing is characterized by high resistance to abrasive wear but it also has the advantage in terms of economic availability and mainly in terms of chrome content which was the lowest, especially in this sample. Thanks to the Cr content reduction in the layer, Cr content in welding fumes reduces and simultaneously it does not pose a burden to the environment and the welder's health.



## Discussion on the results

Applied filler materials were selected on the ground of chemical composition and the recommendation according to the company catalogue. Chrome content in the filler material increases toughness, oxidative resistance of the weld, transit temperature of notch toughness and notch sensitivity. Chrome and carbon form chromium carbides that are characterised by high wear resistance, but even small amounts of these elements unfavourably influence the man's health and the environment. The advantageous combination to chrome is molybdenum. Their content increases hardenability of steel and hardness at higher temperatures, which was also proved in the sample No. 3 hardfaced by 1709 electrode. Despite the lowest content of chrome and the highest content of molybdenum, it reached the best results (the highest level of microhardness and abrasive wear resistance). During the macrostructure observation, we did not notice any lack of inter-run fusion, cavities or pores. Sample No. 2 also reached high level of hardness and abrasive wear resistance. However, the content of chrome was at the highest level in this sample. Weld beads forming after surfacing is regular. In sample No. 1, we recommend to change the surfacing parameters, because it reached the lowest level of hardness, and abrasive wear resistance. By visual control, we found some surfacing defects. These were probably caused by the low molybdenum content in the surfacing material.

## Conclusion

Present spurt technical development imposes increasing requirements on the quality of manufactured machine components. The requirements comprise particularly the operational reliability, component life, but also the requirements for precise parameters and quality, adequate toughness, corrosion resistance, resistance to individual types of wear such as collision, pressure etc.

All these requirements imposed on machine components cannot be, in most cases, secured by only one kind of material. Also by this reason, individual layers are coated onto the parent material of a component by surfacing technology. These layers mainly function as a protection, but they are also resistant to corrosion, pressure, collision and other individual wear types. The component is renovated in this way, or a new component is then hardfaced.

Following this knowledge, the development of new filler materials is very important. These materials should reduce chrome content in the surfacing so that their ability to reduce the resistance to given wear types does not decrease.

## References:

- [1] BLAŠKOVITŠ, P., ČOMAJ, M. *Renovation of the surfacing and thermal spraying*. Bratislava, 2006. 204 p.
- [2] BALLA, J., *Tribology and tribotechnology*. Nitra: VŠP, 1987. 129 p.
- [3] Dostupné na internete: <http://www.strojarstvo.sk/docwww/SK/284/284.pdf> [cit. 2008-04-28]
- [4] Dostupné na internete: [http://www.stifner.sk/skola/doc/afm/texty\\_AFM\\_2004.doc](http://www.stifner.sk/skola/doc/afm/texty_AFM_2004.doc) [cit. 2009-11-12]
- [5] Dostupné na internete: <http://www.mtfda.szm.sk/subory/opotrebenie.pdf> [cit. 2009-04-28]

**Reviewers:**

Jozef Balla, Professor, PhD. – Slovak University of Agriculture in Nitra

Pavel Kovačócy, Assoc. Professor, PhD. - Department of Welding, Institute of Production Technologies, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava