Influence of overlay layers on the abrasive wear

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Abstract: A problem of machine parts wear decrease and in this way of the economical effectiveness of rapid wearable parts interferes with majority of manufacturing processes. Service life and operating reliability of a great number of machine parts is largely influenced by friction and wear, which take a significant part in the power and material losses. Wear affects significantly the maintenance, repair and renewal costs of machine parts, too. Today we can use a row of overlay materials. They differ above all by chemical composition, which determinates the conditions of use. Next conditions are the solidification of the welded-on material and the diffusion ability of main alloying elements, which determine the resultant structure of an overlay. The paper intents on multilayer overlays problem and on the number of overlay layers influence on abrasive wear.

Keywords: abrasive wear; abrasive particle; overlay materials; functional surfaces; abrasive cloth

According to ČSN 01 5050 (1968) we classify the wear in 6 basic types, namely: adhesive, abrasive, erosive, cavitation, fatigue and fretting. In practice we meet most often combination of some types of wear (ČSN 01 5050 1968). More complicated cases occur, when the wear of one type evokes the wear of another type, which subsequently dominates. (Pošta *et al.* 1991).

Wear is a complicated process, which is influenced by a number of factors and effects. The basic method of the wear analysis is the systematic and complex evaluation of the examined case. Circumstances which the analysis must respect, are:

Outside conditions
- environment of the machine work (temperature, moisture content, chemical action, dust nuisance),
- operating medium (flow velocity, content of particles, their hardness, form, number, weight),
- dynamic load of the surfaces.

Internal conditions
- machine suitability of the presupposed work,
- suitability of the material choice,
- correct technology of the parts and machine production,
- incidence of defects which affect the correct parts function.

Operating conditions
- comparison of real operating conditions with the specified conditions,
- systematic or accidental overrange of operating conditions, operator error (Blaškovič *et al.* 1990).

Most of cases of machines or parts defects do not end by a breakdown, but it ends by an excessive wear, which must be removed by suitable maintenance, changing or renovation.

In the machine design, production, maintenance and renovation some methods are suitable to be used, which can systematically act against friction and wear unfavourable effects (Herák 2005).

In order to limit the wear resistance the surfacing of functional surfaces using a suitable overlay material is one of the effective provisions. The used overlay materials have different properties. At their choice we must respect the stress mode and the composition of the basic metal. Other overlay materials are suitable for work with sand and ravel, other ones for tools for soil cultivation (Vocel & Dufek 1976; Svanson 1993).

At high stressed parts, where we wish the highest possible long service life, we must choose the better material than the basic metal is. To this purpose we have various alloy steels at disposal, alloys containing high percentage of carbide generating elements, hard nonferrous alloys on the cobalt or nickel basis, and overlay with wolfram carbides (Ptáček 2001).

Surfacing is used not only for renovation but for new machine parts production, too. It may bring a significant effect in saving of material, costs and time. Surfacing is a relatively fast process for the wear resistance increase, what is its advantage.

Though the aim of surfacing is quite different than of welding, mostly used weld materials are different; nevertheless a great deal of both technological processes is common. It concerns some metallurgical aspect, influence of basic material, internal stress and used welding equipments with connected technology. Therefore arc welding as well as surfacing by the flame, electric arc with coated electrode, submerged arc, shielding atmosphere etc. are used (Avient *et al.* 1960).

For the practice the characteristic values of used materials must be determined. Then designers and engineers can choose suitable materials for given abrasive wear conditions. For the abrasive wear calculation the values of relative wear Ψ are used. This value can be found in tables of pertinent literature. The Ψ makes possible to compare the chosen materials wear with etalons (Suchánek *et al.* 1999).

MATERIALS AND METHODS

One of standard test methods is test an the abrasive cloth. Most often the machines with the rotating disk with abrasive cloth wound on the cylinder or in the form of endless belt are used. During the test as the samples as the abrasive cloth change their properties. In this way the test results are influenced. Therefore the sample surface ought to come in contact with the unused abrasive cloth. But most testing machines do not fulfill this demand for many reasons and a part of the sample comes in contact with the used cloth. Therefore so called overlapping coefficient is to be supervised:

Table 1. Nominal chemical composition

Electrode	C	Si	Cr	Mn	Mo	Nb	W	V	Fe
600	0.5	2.3	9	0.4	×	×	×	×	rest
65	4.4	×	23.5	×	6.5	5.5	2.2	1.5	rest

$$\alpha = \frac{So}{S_S}$$

where:

S_0 – the new abrasive cloth surface which is needed for the test realization (mm^2),

S_S – the really exposed surface of the abrasive cloth (mm^2).

The wear was determined using the pin-on-disk machine with abrasive cloth according to ČSN 01 5084 (1973) (Figure 1). The machine consists of the uniform rotating horizontal disk whereon the abrasive cloth is fixed. The test specimen is fixed in the holder and pressed against the abrasive cloth by the weight of 2.35 kg. The main motion acts the disk with the abrasive cloth, the feed motion acts the screw, which moves the holder with the specimen. During the test the specimen moves from the centre to the outer edge of the abrasive cloth (or on the contrary) and a part of its surface comes in contact with the unused abrasive cloth.

Facing the ČSN 01 5084 (1973) the test was accommodated. The holder is adapted for the specimens of 25 × 25 × 17 mm sizes. This adaptation is necessary

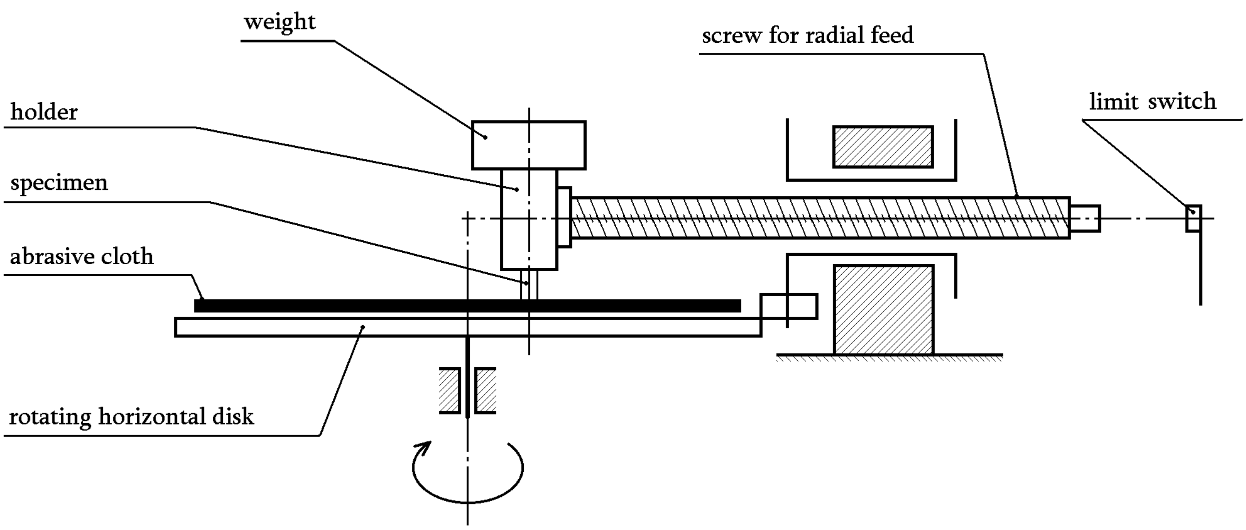

Figure 1. Schematic representation of the pin-on-disk testing machine

Figure 2. One layer deposit using the UTP DUR 600 electrode

Figure 3. Two layers deposit using the UTP DUR 600 electrode

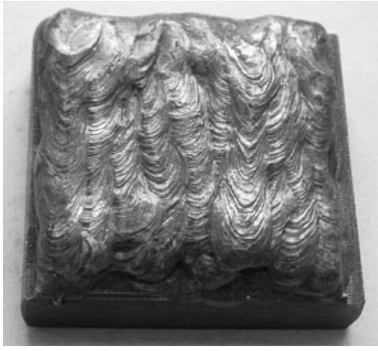

Figure 4. Three layers deposit using the UTP DUR 600 electrode

Figure 5. One layer deposit using the UTP LEDURIT 65 electrode

Figure 6. Two layers deposit using the UTP LEDURIT 65 electrode

Figure 7. Three layers deposit using the UTP LEDURIT 65 electrode

for the overlay materials testing, because the surfacing on the specimen of 6 or 10 mm in diameter is not possible (Brožek 2001).

In the renovation practice many overlay alloys of different properties are used. For the tests the hardfacing electrodes UTP DUR 600 and UTP LEDURIT 65 (BÖHLER THYSSEN) were used. Their chemical composition is presented in Table 1. UTP DUR 600 is universally applicable for cladding on parts of steel, cast steel and high Mn-steel subjected to abrasion, compression and impact. Typical application fields are the earth moving and stone treatment industry, e.g. excavator teeth, crusher jaws and cones, mill hammers etc. UTP LEDURIT 65 is suited to highly abrasion resistant claddings on parts subjected to extremely high abrasion wear also at elevated temperatures up to 500°C. The extremely high abrasion resistance is reached by the very high content of special carbides of Mo, V, W, Nb. Main application fields are surfacings on earth moving equipment, worn parts in the cement and brick industry for crushers and agglomeration grates.

Chemical composition was measured using the GD-OES (Glow Discharge Optical Emission Spectroscopy) (Vnouček 2001).

The overlay material was surfaced on the plates in one layer (Figures 2 and 5), two layers (Figures 3 and 6) and in three layers (Figures 4 and 7). From these plates four specimens were made of sizes 25 × 25 × 17 mm.

For single deposits the relative abrasive wear value ψ_h, chemical composition of single layers and metal-

Table 2. Chemical composition of surfaced layers (by weight %)

Electrode	Layer	C	Si	Cr	Mn	Mo	Nb	W	V	Fe
	1	0.45	1.68	6.98	0.38	0	0	0	0.02	90.80
UTP DUR 600	2	0.48	1.89	7.89	0.40	0	0	0	0.03	89.44
	3	0.49	1.88	8.43	0.40	0	0	0	0.04	88.45
	1	4.60	1.13	19.00	0.28	4.44	4.92	0.75	1.35	63.56
UTP LEDURIT 65	2	4.43	1.16	21.51	0.24	4.65	5.56	0.95	1.52	59.77
	3	4.26	1.09	21.69	0.21	4.63	5.92	1.00	1.55	54.72

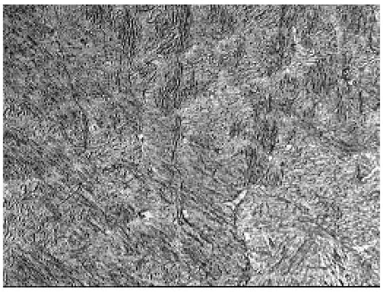

Figure 8. One layer deposit using the UTP DUR 600 (martensitic structure)

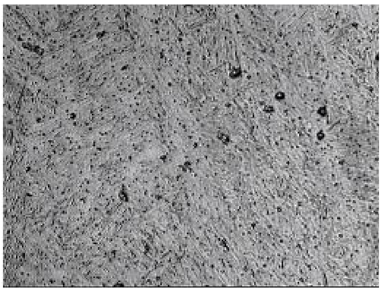

Figure 9. Two layers deposit using the UTP DUR 600 (tempered martensite)

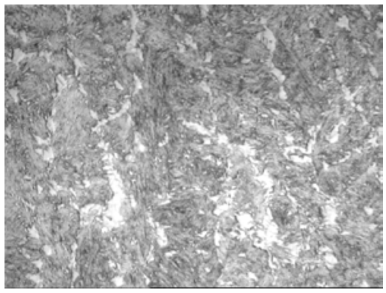

Figure 10. Three layers deposit using the UTP DUR 600 (martensite and retained austenite)

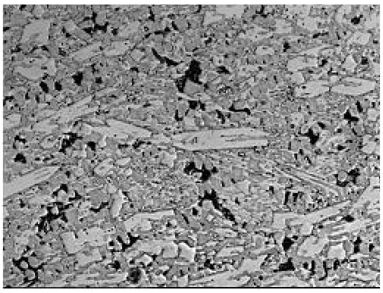

Figure 11. One layer deposit using the UTP LEDURIT 65 (fine-grained martensite with Cr, V, W, Nb carbides)

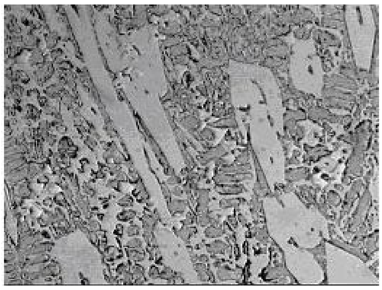

Figure 12. Two layers deposit using the UTP LEDURIT 65 (in size and form different precipitated carbide crystals)

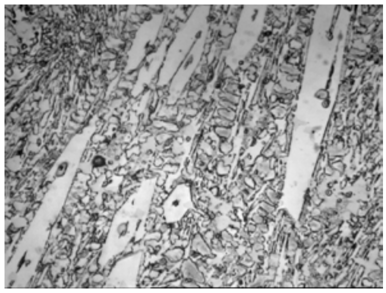

Figure 13. Three layers deposit using the UTP LEDURIT 65 (fine marten site + austenite with Cr, V, W, Nb carbides)

lography were determined (Hrabě & Chotěborský 2004).

RESULTS

Chemical composition of single deposit layers changes as shown in Table 2. The table shows that with the increased number of layers the chemical composition by weight of alloy elements increases.

When surfacing the mixing of surfaced metal and basic material liquid mass occurs. After solidification the diffusion of single elements can come. Diffusion of elements depends above all on the thermodynamical temperature and on the concentration difference of the overlay and of the basic material. In addition the diffusion of elements depends on the diffusivity, which changes with the drop in temperature which is different for each element and depends on the type of crystal lattice.

With a change of chemical composition the resultant structure of claddings changed, too (Figure 8–13 magnification 500×).

Figures 14 and 15 present measured values of relative abrasive wear of single layers.

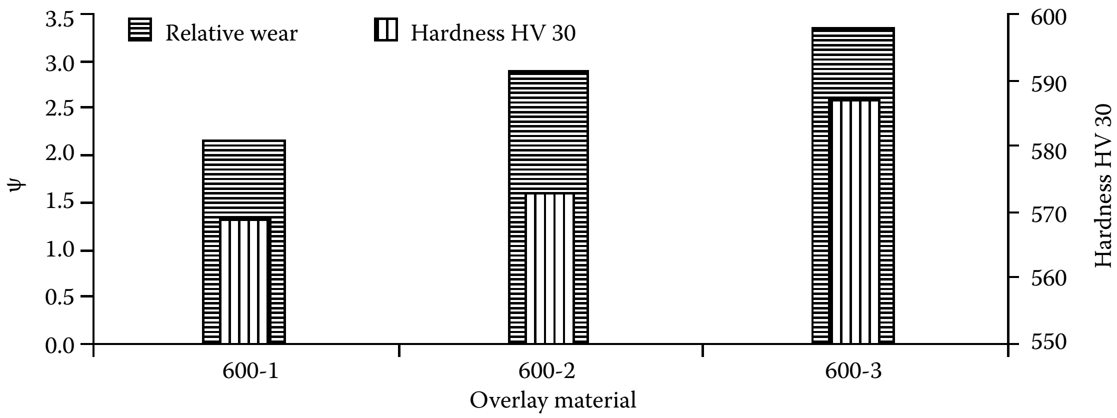

Figure 14. Relative wear and hardness of one, two and three layers overlay using UTP DUR 600

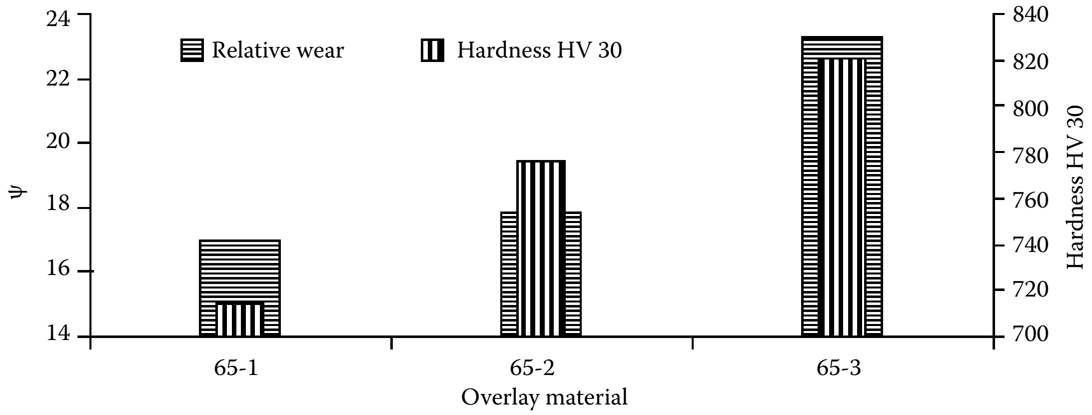

Figure 15. Relative wear and hardness of one, two and three layers overlay using UTP LEDURIT 65

Table 3. Surface roughness of 1, 2 and 3 layers overlay

Sample	Point	Surface roughness		Sample	Point	Surface roughness	
		Ra	Rt			Ra	Rt
600-1	A	1.08	8.53	65-1	A	1.12	14.60
	B	1.06	10.50		B	0.60	5.20
	C	0.48	4.67		C	0.60	6.07
600-2	A	0.90	8.70	65-2	A	0.73	9.00
	B	0.92	7.30		B	0.57	4.90
	C	0.63	6.23		C	0.45	8.13
600-3	A	0.79	9.10	65-3	A	0.78	6.83
	B	0.97	8.13		B	0.62	9.00
	C	0.72	5.43		C	0.43	4.80

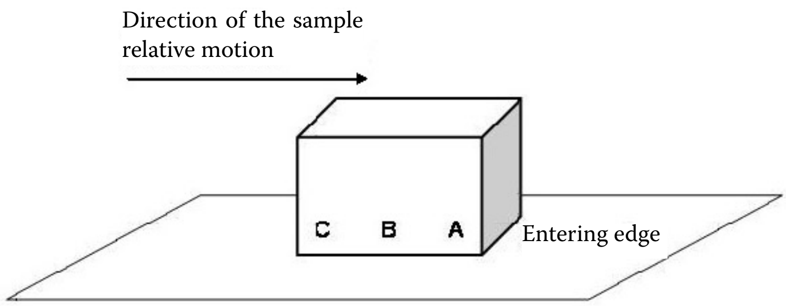

Figure 16. Points of measurement of the surface roughness

Next the surface roughness after wear was determined. It is connected with the hardness of single layers and consequently with the microchip (Table 3).

From the measured values it is evident that the maximum surface roughness is on the entering edge and to the leaving edge it decreases (Figure 17 to 22).

CONCLUSION

From chemical composition and metallography of single surfaced layers it is unambiguous to say that the overlay material UTP DUR 600 is of martensitic type and overlay material UTP LEDURIT 65 of ledeburitic type. Using martensitic materials hardening or other heat treatment are made only exceptionally.

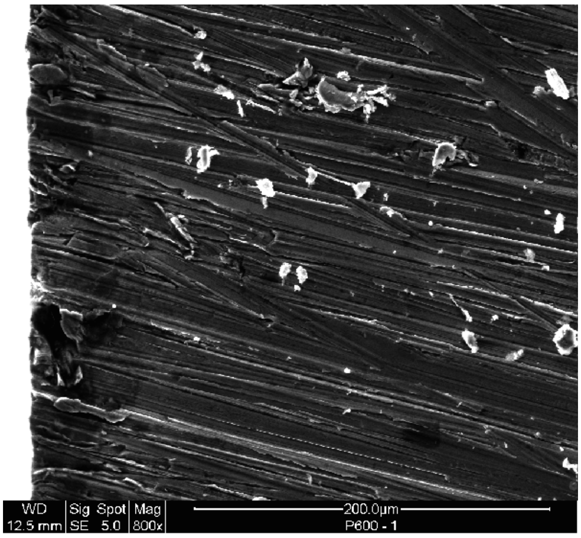

Figure 17. Morphology at entering edge of one layer overlay using UTP DUR 600

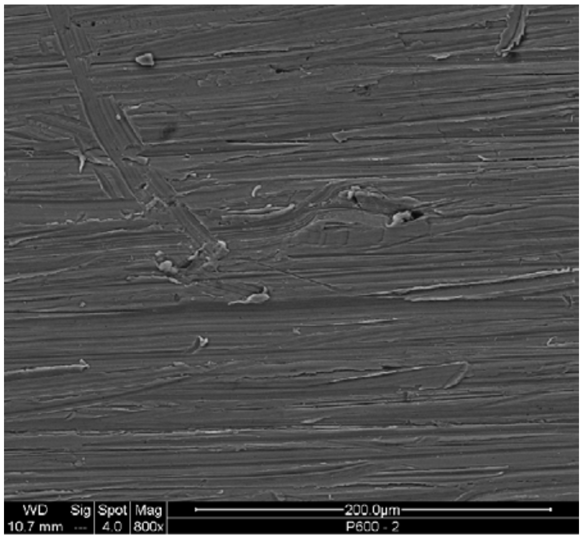

Figure 18. Morphology of surface in plane B

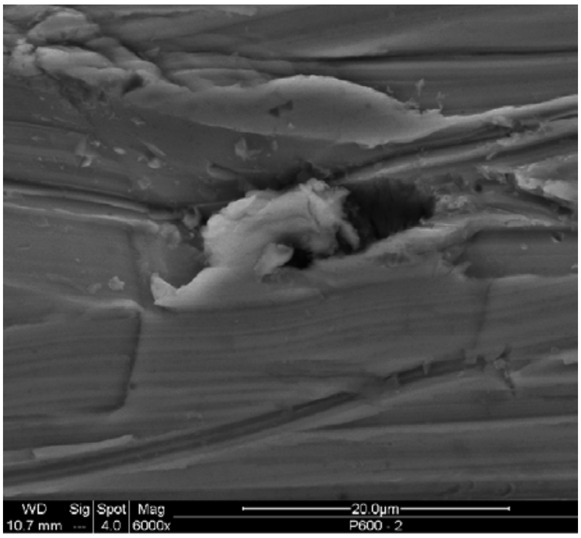

Figure 19. Local view of Figure 18; abrupted abrasive particle of Al_2O_3 in the sample surface

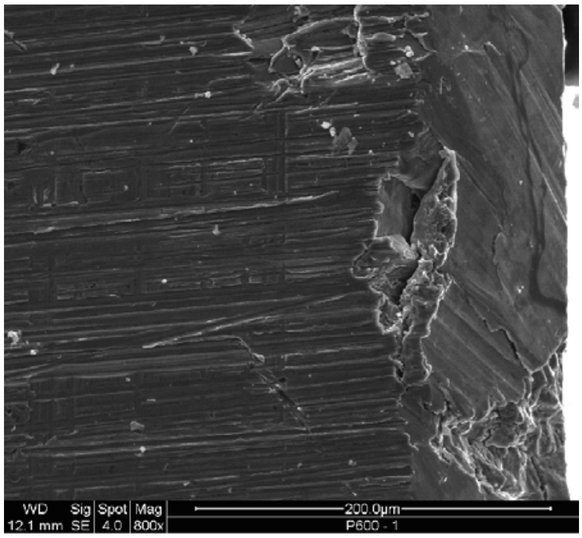

Figure 20. Morphology at leaving edge of 1 layer overlay using UTP DUR 600

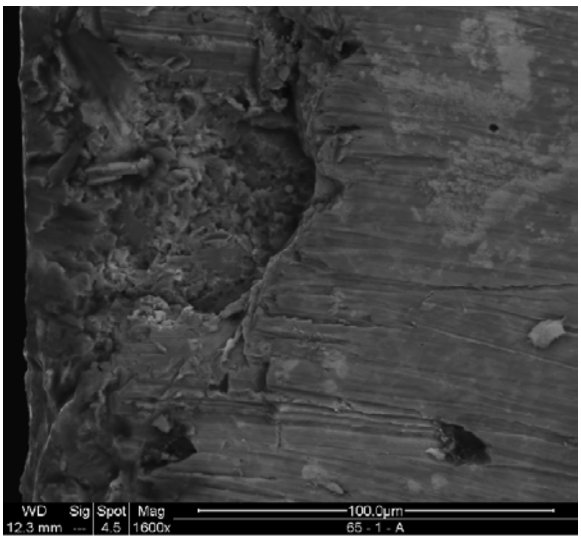

Figure 21. Entering edge of 1 layer overlay UTP LEDURIT 65

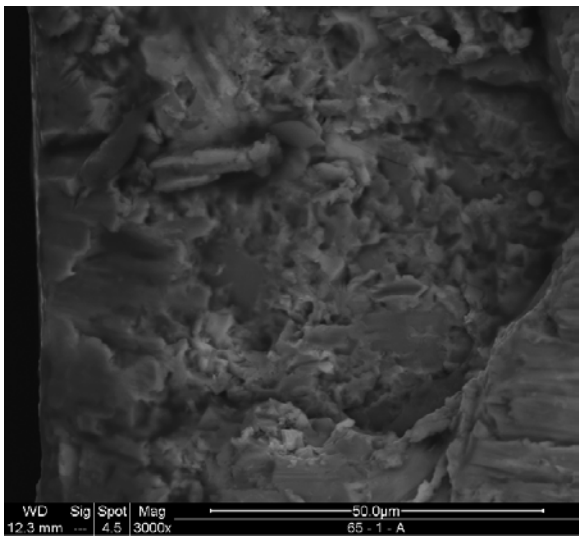

Figure 22. Local view of Figure 21; entering edge of 1 layer overlay UTP LEDURIT 65

Therefore hardness reached by free cooling by a heat removal into the basic material is for martensitic overlays important, so-called natural hardness of an overlay. The attainable maximum hardness of heat treated martensitic material depends above all on the carbon content. It is evident that the rates of cooling depend above all on the basic material mass and the natural hardness is only an orientation information.

Abrasive wear resistance of ledeburitic overlay materials is much better than of martensitic materials (see Figures 15 and 16). The typical properties are a high natural hardness and owing to this abrasive wear resistance, too. The cause is the heterogenity of structural constituents which make an island effect. Especially the hypereutectic cast irons, which contain long thin needles carbidics of in though eutectic, are very suitable for hard conditions of wear by mineral abrasive. Partly cheaper white cast irons are used, which differ only by the higher Cr content (2 to 5%), partly high alloyed cast irons, which contain 20 to 35% Cr. Higher resistance at elevated temperatures is reached by a tungsten addition, higher corrosion and chemical effect resistance by a nickel addition. These alloys have mostly a high natural hardness, which does not vary using various surfacing methods. Their use is very wide, e.g. for part surfacings of machines for earth moving industry. But at the same time these overlays are relatively brittle and therefore the hard brittle overlay layers must be backed by tough materials.

From the measured results it is evident that the relative abrasive wear of the overlay materials UTP DUR 600 and UTP LEDURIT 65 is proportional to the chemical composition charge in single layers, or, let us say to the carbide generating elements content in the layer. The overlay material UTP LEDURIT 65 was wear resistant in the first layer 16.9 × compared with the etalon and the material UTP DUR 600 was wear resistant only 2.16×. In the third layer the wear resistance of UTP LEDURIT 65 was 23.25× and UTP DUR 600 3.34× compared with the etalon. From Figures 15 and 16 it is evident that with increased number of layers the surface hardness increases. The hardness is proportional to the relative wear resistance.

From the surface morphology examination of martensitic overlay above all the fragmentation of abrasive particles from the entering edge is perceptible. Then the microchips begin to form. The entering edge is not plastically deformed and the microchip is formed continually. When the fragmentation of abrasive particle occurs during the microchip formation, it occurs on hard particles (carbidic particles dissipated in the matrix).

At the surface morphology examination it was determined that on the entering edge the overlay material braking out occurs by the dynamic effect. On the entering edge the overlay material fails semibrittlly by transcrystalline cleveage fracture, as it is shown in Figures 21 and 22. After the tip breaking off of the bonded abrasive the microchip can from.

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Abstrakt

Hrabě P., Chotěborský R., Medlín R. (2006): **Vliv počtu návarových vrstev na abrazivní opotřebení**. Res. Agr. Eng., **52**: 115–122.

Problematika snížení opotřebení strojních součástí a tím i zlepšení ekonomické efektivnosti rychle opotřebitelných částí, zasahuje do většiny výrobních procesů. Životnost a spolehlivost řady strojních částí je v rozhodující míře ovlivněna třením a opotřebením, které se významně podílí na ztrátách energie a materiálu. Má též významný vliv i na náklady spojené s údržbou, opravami a renovací strojních součástí. V současné době můžeme využít řadu návarových materiálů, které se liší především chemickým složením, jenž určuje podmínky užití v praxi. Další veličinou jsou podmínky tuhnutí návarového kovu a schopnost difúze hlavních legujících prvků, které určují výslednou strukturu návaru. Článek je zaměřen na problematiku vícevrstvých návarů a vliv počtu návarových vrstev na abrazivní opotřebení.

Klíčová slova: abrazivní opotřebení; abrazivní částice; návarový materiál; funkční povrch; brusné plátno

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