Properties of martensitic overlays

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Abstract: The abrasive wear resistance of martensitic overlays is the function of many variables. The hardness is one of the variables. This fact is raised by the possibility of carbidic phases separating from the austenite in the course the overlay layer cooling and by the possibility of the further martensite disintegration and carbidic phases precipitation. The paper is engaged in the hardness and abrasive wear resistance problems of one-layer martensitic overlays.

Keywords: welding; overlay material; abrasive wear

For repairing using surfacing or for preventive surfacing such procedures are sought so that the best wear resistance would be gained. The wear resistance depends on the overlay hardness and on the structure. The overlay hardness is affected by many factors. The chemical composition of the weld deposit belongs to these factors and it affects the temperatures of the austenite transformation starts (Hertzberg 1989). The alloyed elements content influences the hardenability and the trough-hardenability. Using the martensitic overlays we have to secure the martensite start conditions in the whole overlay volume (Hertzberg 1989; Hrabě & Chotěborský 2006).

The conditions of the martensite start can be modified by the quenching rate of the weld deposit, too. The next factor which affects the resultant weld deposit hardness is the mixing of the basic molted down material and the overlay material (Brožek 2001). The rate of the melting down and then the rate of the overlay material thinning can be affected by the surfacing conditions (the voltage and current rate). In the top of it the surfacing conditions affect the zone influenced by heat, which properties are different from the properties of the basic material and of the weld deposit (Brožek 1995; Garbar 1997). Using multilayer deposits the next factor accedes, namely the tempering resistance of the surfaced overlay material. At low tempering resistance the expressive variation in hardness and in wear resistance of single overlay zones occurs. The limitless tempering resistance of the overlay material is the ideal state (Badisch & Mittener 2003; Chatterjee 2006).

The properties of martensitic overlays depend on the tempering temperature. The tempering processes affect expressively the hardness. It is caused by the martensite tempering and by the transformation of the retained austenite in the deposit. At the same time carbides can arise, which owing to their size will take part in the abrasive wear mechanism (Kato 1997; Gahr 1998; Colaco & Vilar 2003).

MATERIALS AND METHODS

Properties of martensitic overlays depend on the structure (Garbar 1997). The structure containing martensite and retained austenite is the resultant structure of martensitic one-layer overlays. The content of martensite and retained austenite depends on the cooling conditions. It is evident that the structure deeper under the surface will have other properties than the structure of the overlay surface. This depends
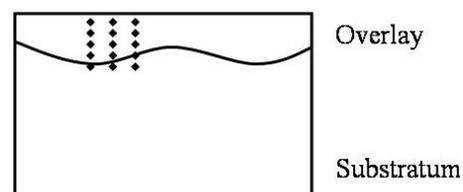

Figure 1. Diagram of the specimen

Table 1. Chemical composition of electrodes and of basic material

	C	Si	Mn	Cr	Mo	V	Nb	W
Substratum	0.047	–	0.24	0.076	–	–	–	–
Electrode 1	0.5	2.3	0.4	9	–	–	–	–
Electrode 2	0.5	0.8	1.3	7	1.3	–	0.5	–
Electrode 3	0.4	1.0	1.0	9.5	0.6	1.5	–	–
Electrode 4	0.9	0.8	0.5	4.5	–	1.2	–	2.0

on the kinetics of the primary austenite transformation and on the resultant structures origin.

The martensitic overlay properties were determined using the overlay material of nominal chemical composition presented in Table 1.

The overlay was surfaced by hand arc welding on the plate of dimensions 60 × 60 × 20 mm from the material ČSN EN S235J0 (1996). After surfacing the specimens of dimensions 25 × 25 × 20 mm were cut from the plate. Using these specimens the microhardness was measured from the surface to the basic material (Figure 1).

Further the content of martensite and of the retained austenite was metallographicaly examined. The primary austenite grain size was judged according to the martensitic phase. The retained austenite occurred always on the boundaries of primary austenitic grains.

Next the abrasive wear resistance of the specimens was tested according to ČSN 01 5084 (1973). The wear resistance was tested in various overly zones as far as the limit stage was reached. The limit stage accused at the time when the tested surface contained less than 90% of the overlay material.

RESULTS

In the case of the one-layer overlay the mixing of the tested overlay material with the basic material occurs. It is presented in Table 2. The chemical
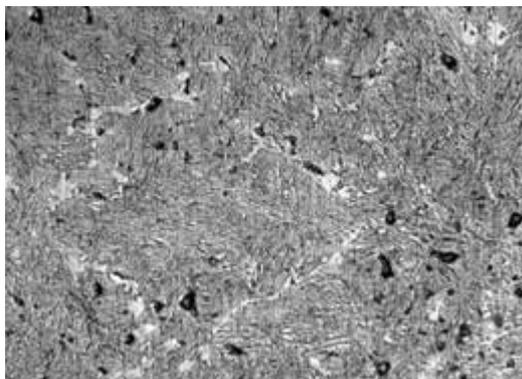

Figure 2. Electrode 1 – martensite and fine austenite grains, nital 500×
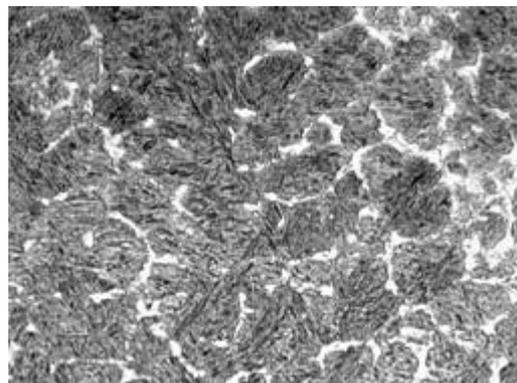

Figure 3. Electrode 2 – martensite and fine retained austenite on the boundaries of grains, Villela-Bain 500×
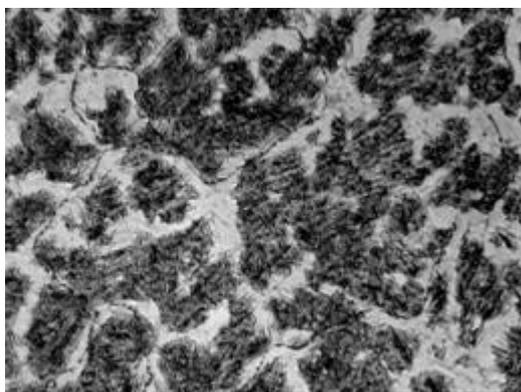

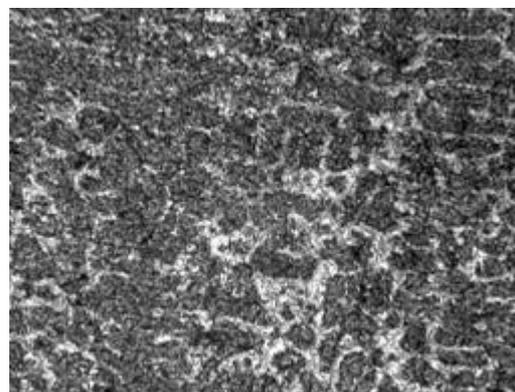Figure 4. Electrode 3 – martensite and retained austenite on the boundaries of grains, Villela-Bain 500×

Figure 5. Electrode 4 – martensite and fine austenite on the boundaries of grains, Villela-Bain 500×

Table 2. Chemical composition of one-layer overlay (weight percentage)

	C	Si	Mn	Cr	Mo	V	Nb	W
Electrode 1	0.45	1.68	0.38	6.98	–	–	–	–
Electrode 2	0.29	0.68	1.10	5.29	1.07	–	0.41	–
Electrode 3	0.27	0.60	0.37	6.55	0.37	0.76	–	–
Electrode 4	0.89	0.66	0.31	3.56	–	0.98	–	1.13

composition was determined on the overlay surface of the specimen using GDOES (Vnouček 2001). Table 3 presents the weight percentage of single elements with regard to their content in the electrode (100%).

The structures of tested overlay materials are shown in Figures 2–5.

Figure 6 shows the relation between the microhardness and the distance measured from the surface to the basic material. The determined hardness values were interlined by a straight line $y = k \times x + c$. Equations of these straight lines and the determination index are presented in Table 4.

Figure 7 presents the relation between the wear rate and the distance from the overlay surface measured from the surface to the basic material. The hardness values were interlined by the polynomial of the second degree. Equations of these curves and determination indexes are presented in Table 5.

DISCUSSION

For the comparison of the one-layer overlays we must know the total covered distance when the whole overlay runs out. The total covered distance we can calculate using the equation

$$s = \frac{1}{2} \times m \times \int_0^x \Psi_m(x)^{-1} \times dx \tag{1}$$

where:

m – overlay weight,

$\Psi_m(x)$ – equation of the wear rate related to the distance from the surface (Table 5),

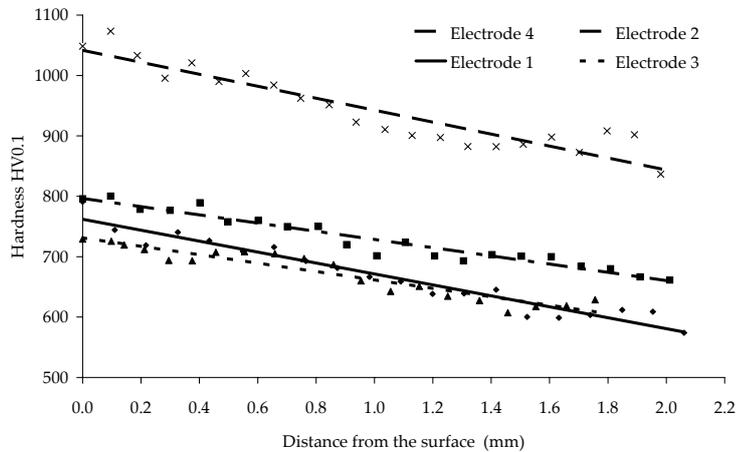x – zone distance from the surface.

Figure 6. Overlay hardness related to the distance from the overlay surface
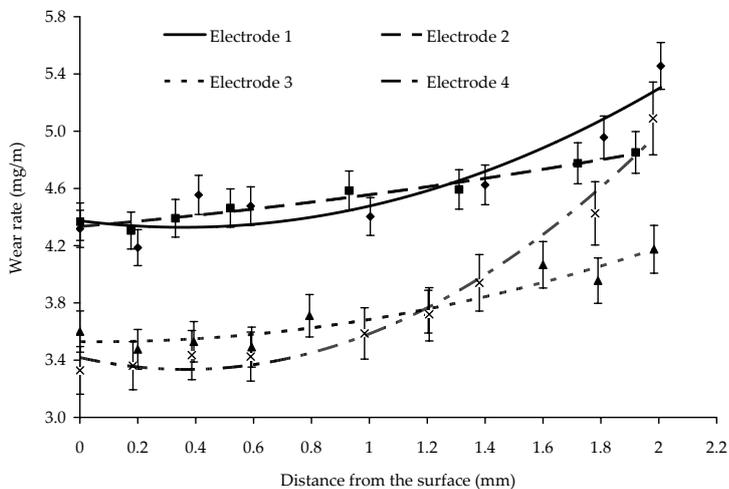

Figure 7. Wear rate related to the distance from the surface

Table 3. Change in chemical composition of the layer with regard to the electrode (100%)

	C	Si	Mn	Cr	Mo	V	Nb	W
Electrode 1	90	73	95	78	–	–	–	–
Electrode 2	58	85	85	76	82	–	82	–
Electrode 3	68	60	37	69	62	51	–	–
Electrode 4	99	83	62	79	–	82	–	57

Overlay weight

$$m = S \times x \times \rho \qquad (2)$$

where:

S – functional surface of the specimen,

ρ – density of overlay material.

The total covered distances of tested martensitic overlays are:

Electrode 1 = 2129 m

Electrode 2 = 2135 m

Electrode 3 = 2613 m

Electrode 4 = 2622 m

At certain simplified conditions, at the knowledge of the straight line gradient (Table 4) and at the interlay of the wear rates by the straight line $\Psi_m(x) = K \times x + C$ the behavior of martensitic overlays can be predicted. In this way we obtain the relation $K(k)$. According to the by tests determined values we obtained the equation $K(k) = 0.0038 \times k$.

Then we can write

$$\Psi_m = K(k) \times x + C \qquad (3)$$

Table 4. Equations of the overlay hardness related to the distance from the surface

	Equation of linear regression	Determination index
Electrode 1	$-90.648x + 762.01$	0.9435
Electrode 2	$-68.365x + 796.86$	0.9422
Electrode 3	$-70.040x + 731.41$	0.9032
Electrode 4	$-99.569x + 1042.3$	0.8721

The deviation of the predicted and the measured relation for the electrode 1 is presented in Figure 8. The covered distance deviation is 58.01 m.

Deviations of the covered distances measured as the difference between the measured (Table 4) and the calculated (Table 5) were as follows:

Electrode 1 = 58.01 m (2.7%)

Electrode 2 = 9.95 m (0.46%)

Electrode 3 = 39.3 m (1.5%)

Electrode 4 = 13.1 m (0.5%)

CONCLUSION

The resultant hardness of the tested overlays single zones was decreasing. This decrease is possible to be expressed by a linear equation. In single zones of the overlay the contents of martensite and austenite were determined. On the basis of this measuring the decreased part of retained austenite in the direction to the basic material was determined. The decreasing character of the overlay hardness can be explained by
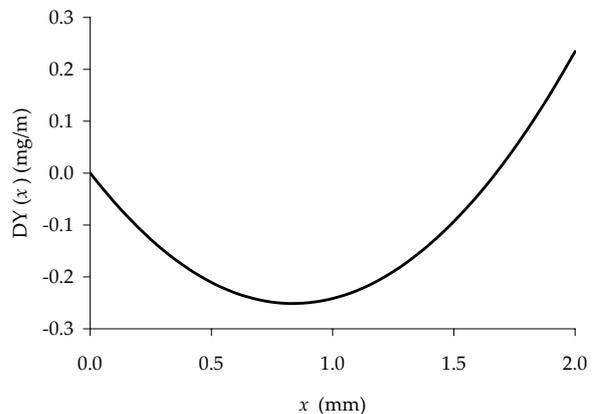

Figure 8. Deviation of the predicted and measured relation

Table 5. Equations of the wear rate related to the distance from the surface

	Equation	Determination index
Electrode 1	$0.359x^2 - 0.2562x + 4.3741$	0.8735
Electrode 2	$0.0466x^2 + 0.1753x + 4.3341$	0.9616
Electrode 3	$0.173x^2 - 0.0179x + 3.5292$	0.9097
Electrode 4	$0.4307x^2 - 0.188x + 3.3738$	0.9762

the different rate of cooling of single layer zones and also by the different chemical composition. Owing to the mixing of liquid mass and basic material the dilution of the overlay material occurs. At the cooling the diffusion of elements in the solid solution occurs in correspondence with the laws of diffusion. On the basis of these premises it is possible to say that the course of chemical composition will be in correspondence with the resultant hardness, it means that in direction to the basic material the main alloys content of the overlay material will decrease.

The wear resistance of tested martensitic overlays depends exponentially on the overlay hardness. But it is not possible to claim that the harder the more abrasive resistant the overlay is. The wear resistance is of more complex character and the hardness is one of the variables. Excepting the martensitic matrix hardness the wear resistance depends on the size and distribution of precipitated phases. These phases are mostly of carbidic type. In tested overlay materials the carbides of chromium, vanadium, tungsten and molybdenum occur.

The abrasive wear rate course of tested overlay materials depends on the slope of the hardness course. The bigger the slope of the hardness course the bigger the abrasive wear rate is. The application of the Eq. (3) is confined to martensitic overlays without big carbides and to specimen sizes mentioned in the part Materials and Methods.

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Abstrakt

Chotěborský R., Hrabě P., Müller M. (2007): **Vlastnosti martenzitických návarů**. Res. Agr. Eng., **53**: 116–120.

Abrazivita martenzitických návarů je funkcí mnoha proměnných. Jednou z těchto proměnných je tvrdost martenzitického návaru. Tento fakt je umocněn možností vylučování karbidické fáze z austenitu při chladnutí návarové vrstvy a možností dalšího rozpadu martenzitu a precipitací karbidických fází. Článek se zabývá problematikou tvrdosti a abrazivity jednovrstvých martenzitických návarů.

Klíčová slova: svařování; návarové materiály; abrazívní opotřebení

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