

Evaluation of Wear Resistance of Deposited Alloyed Superficies Layer

R. Bendikienė*, S. Chodočinskas, N. Keršienė

Department of Metals Technology, Kaunas University of Technology, Kęstučio 27, LT-3004 Kaunas, Lithuania

Received 03 September 2002; accepted 20 October 2002

In the present work formation of welded layer by using powder of cheap elements was investigated. Chromium and ferrosilicon were chosen for this purpose. These elements dissolve in the ferrite and increase its strength and hardenability. Because of metal high heat conductivity the layer becomes hardened after welding. So full heat treatment isn't necessary, and for the stress relieving low annealing can be used. For minimising of wear, graphite powder was added to the deposit powder. Carbon with above mentioned elements makes up carbides. That's the reason why deposit layer become high wear resistant. Thickness of deposited layer 2 – 2.5 mm doesn't change the geometrical parameters of initial component or detail.

Keywords: wear resistance, deposit welding, strengthened layer.

1. INTRODUCTION

All carbides in the iron base alloys are multi component solid solutions. They are designated as M_2C , MC , M_7C_3 and have space lattices of Fe_3C , VC , Mo_2C , Cr_7C_3 and Fe_3W_3C carbides. Not only eutectoid carbides can present in the microstructure of tool steel, but also primary and secondary carbides [1]. Soluble carbides saturate solid solution with carbon and other alloying elements, not soluble carbides drag on growth of austenite grains during heating. Interstitial solid carbides, which have formed after final heat treatment, have great influence on hardness, strength, impact and wear resistance.

Alloyed tool steels have high wear resistance and minimal deformation after heat treatment. Therefore such steel is used for the production of precise tools and technological equipment. All authors, who investigated wear resistance and durability of tools suggested complex technologies of heat treatment or complex alloying [2]. But these technologies are very expensive and it is difficult to carry out complex alloying.

The technology of deposition, using electrodes with different quantities of carbon, chromium, nickel, tungsten, molybdenum are widely used in practise [3]. Hardness of deposited metal increases when relation of chromium and carbon decreases. A lot of retained austenite forms when chromium content is too high. Large content of carbon stimulates precipitation of structural free graphite [4].

Maximal content of retained austenite is obtained with minimal content of carbide phase [5, 6]. When retained austenite distributes evenly strength of component or part increases.

Formation of carbides in the Fe-C-Cr-B-Si system was investigated by X-ray and spectroscopy [7, 8]. Chemical content of this alloy 1.4 – 2.6 % C, 13 % Cr, 0.7 – 4.3 % B, 2.2 – 5.8 % Si. Such composition of alloy increases wear resistance and abrasion resistance.

The purpose of the present work was to form thin strengthened layer by using chemical elements, which

dissolve in the solid solution and have an ability to make a stable phases.

2. EXPERIMENTAL

2.1. Technology of layer formation

To produce an alloyed superficial layer in the present work the technology of CO_2 and AGA MIX shielded arc deposit welding using metal powder and welding wire of 0.8 mm thickness was used.

Chromium, ferrosilicon and graphite powder was used for making of strengthened layer. Such composition of powder allows estimate influence of all chemical elements.

Mechanical properties of specimens were tested on a Rockwell device. Vickers hardness of specimens was measured from the fusion zone to layer by 0.1 mm step.

Chemical composition of specimens was tested by microspectral analysis. We carried out quantitative and qualitative analysis of alloys in the comparatively small microvolume. Laser microspectral analysis was carried out using CARL-ZEISS-JENA analyser, and spectrogram was registered on a negative film using PGS 2 spectrograph. Sixteen laser beam shots was carried out for optimization of spectrogram intensity and for reliability of the results. Fotometric analysis was carried out using microdensitometer MD 100.

Steadiness of tools and components depends on its wear resistance, and on the other hand wear resistance depends on steel properties, microstructure and morphology of carbide phase. Wear resistance of deposited specimens were estimated. We used an original wear machine for this purpose.

2.2. Chemical composition of deposited layer

Properties of deposited layer depend on layer chemical composition. Changing chemical composition and heat treatment conditions, it is possible to adjust mechanical and service properties of the layer.

Chemical compositions of all deposited layers are given in Table 1.

*Corresponding author. Tel.: + 370-37-323875; fax.: + 370-37-456472.
E-mail address: regita.bendikiene@mf.ktu.lt (R. Bendikiene)

Table 1. Chemical composition of layer

Alloy	Chemical composition, %		Alloy	Chemical composition, %	
	Cr	Si		Cr	Si
A1	1.0	0.35	B1	-	0.35
A2	1.7	0.35	B2	-	0.39
A3	2.4	0.35	B3	-	0.48
A4	2.9	0.35	B4	-	0.55
A5	3.5	0.35	B5	-	0.68

Alloy	Chemical composition, %		Alloy	Chemical composition, %	
	Cr	Si		Cr	Si
C1	2.8	0.7	D1	1.3	0.7
C2	2.8	0.8	D2	2.8	0.7
C3	2.8	0.9	D3	3.4	0.7
C4	2.8	1.0	D4	4.3	0.7
C5	2.8	1.5	D5	5.0	0.7

Fused low carbon steel wire minimizes content of alloying elements in the superficial layer. So, for formation of the layer minimal volume of steel wire was used.

In the present work, four groups alloys A, B, C, D were investigated. In the A group alloys chromium content grows from 1.0 % up to 3.5 % (Fig. 1). Silicon content in this group was constant.

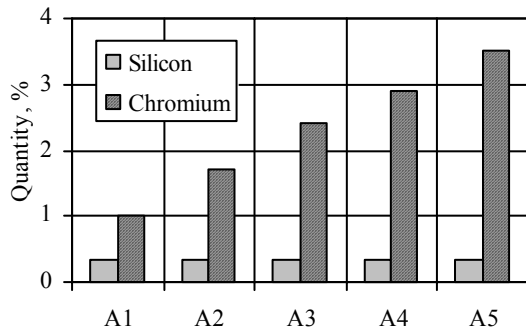


Fig. 1. Chemical content of A group alloys

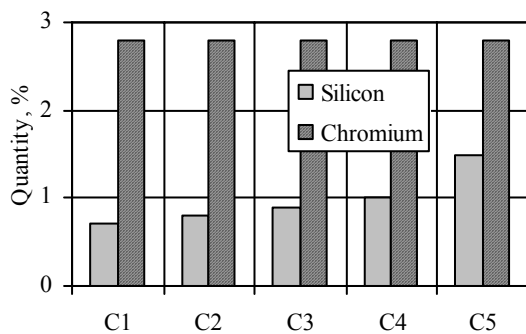


Fig. 2. Chemical content of C group alloys

Ferrosilicon, chromium and graphite powder mixture was used for the formation of C group alloys. Graphite and chromium relation was constant, but quantity of ferrosilicon was superseded. Chromium content obtained in the deposit layer 2.8 % while silicon quantity varied from 0.7 % up to 1.5 % (Fig. 2).

Relation of graphite and ferrosilicon powder content was constant in the D group alloys, when chromium content was changed. Silicon content in the layer was constant (0.7 %) and chromium content varies from 1.3 % up to 5.0 % (Fig. 3).

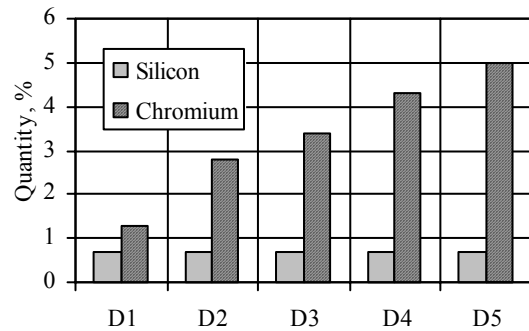


Fig. 3. Chemical content of D group alloys

Ferrosilicon and graphite powder mixture was used for the formation of B group alloys. Silicon content in the deposit layer was enlarged by silicon content from the ferrosilicon powder. Therefore obtained content of silicon in the deposited layer – (0.35 – 0.68) %.

2.3. Microstructure of deposited layer

The most important part of deposited layer is fusion zone. The investigation of microstructure was carried out in the parent metal and in the fusion zone.

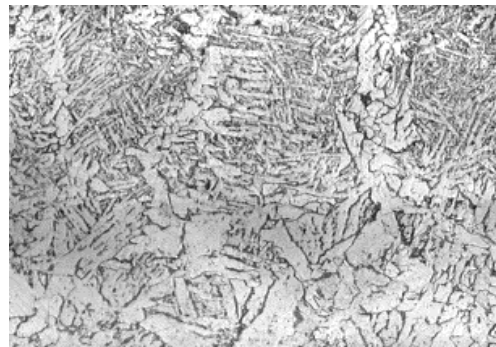


Fig. 4. Microstructure of fusion zone of A1 alloy (×150)



Fig. 5. Microstructure of layer of A2 alloy (×150)

There is no distinct transition in the microstructure of A group alloys crossing area of fusion zone (Fig. 4). Ferrite – pearlite structure can be observed in the bound of parent and deposited metal [7]. Widmannstaetten structure exposed in the layer microstructure of A group alloys.

With increasing of carbon content, the formation of widmannstatten structure decreases. With increasing of chromium content, the quantity of ferritic constituent decreases and small carbides begin to form. Big pearlite grains form in the A1 and A2 alloys, martensite forms in the A3 – A5 alloys. A carbide net can be observed.

Widmannstatten structure can be observed in the microstructure of B group alloys (Fig. 6, Fig. 7). Retained austenite and martensite predominate in the layer microstructure.

Fusion zone of C group alloys shows clear transition from the parent metal to fusion zone. The clear carbide phase can be observed in the layer and quantity of this phase increases when increases quantity of ferrosilicon powder.



Fig. 6. Microstructure of fusion zone of B2 alloy (x150)

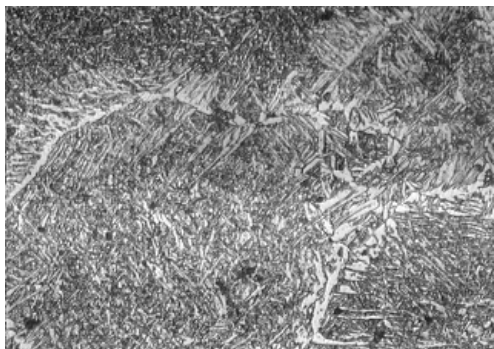


Fig. 7. Microstructure of layer of B2 alloy (x150)

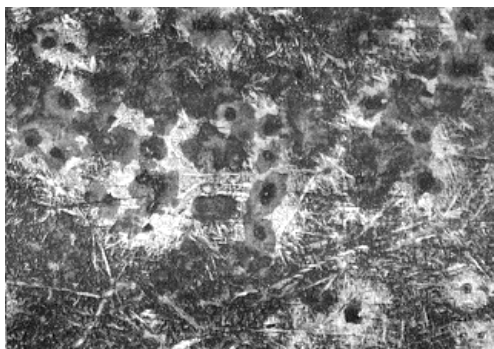


Fig. 8. Microstructure of layer of C5 alloy (x150)

Silicon releases carbon which present in the solid solution, so more carbides form [8]. Graphite concentrates in some areas when silicon content increases (Fig. 8).

Small carbides present in the microstructure of D group alloy layer microstructure. With increasing carbon

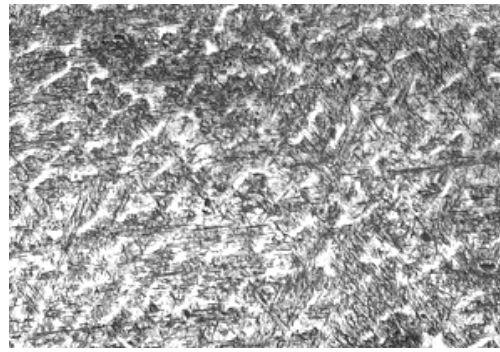


Fig. 9. Microstructure of layer of D5 alloy (x150)

content, zones of ledeburitic eutectic begin to form (Fig. 9). Such a matrix of ledeburite should be result of high wear resistance.

2.4. Wear resistance of deposited layer

Great number of metal components and tools work at the hard condition of the intensive wear. So urgent problem is minimise wear of components [5]. In the present work alloys of A, B, C and D group are suggested for strengthening of superficies layer. Deposit welding technology was made and chemical composition, which ensures formation of carbide phase, non-stable austenite and martensite, was selected.

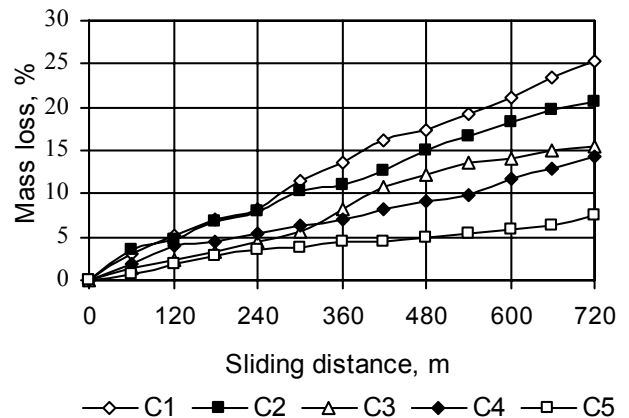


Fig. 10. Wear resistance of C group alloys

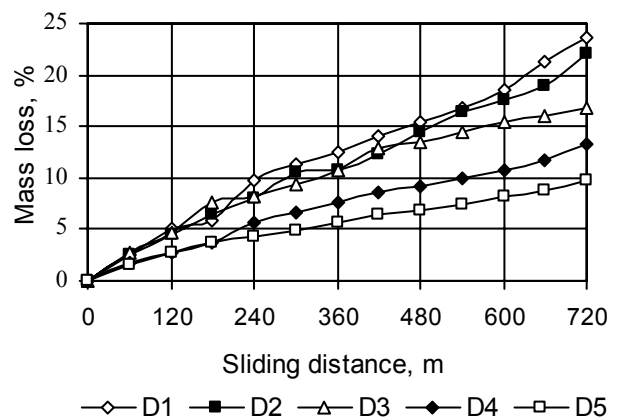


Fig. 11. Wear resistance of D group alloys

When using powder mixture of high chromium steel X12M and graphite powder, minimal wear of A group

Table 2. Wear resistance of A and B alloys

Alloy	Mass loss, mg											
	Sliding distance, m											
	60	120	180	240	300	360	420	480	540	600	660	720
A1	5.60	13.35	20.60	32.85	39.90	49.35	54.65	66.35	74.35	86.95	91.00	101.60
A2	7.50	14.45	20.05	25.40	30.10	34.00	38.00	48.10	52.05	56.40	60.55	65.10
A3	5.60	10.05	13.65	15.60	18.00	22.80	33.90	37.60	41.25	46.10	48.05	54.15
A4	3.60	8.65	11.65	14.30	16.55	19.10	23.70	25.80	27.50	29.80	31.60	33.20
A5	2.95	4.30	8.95	11.80	14.85	17.55	20.25	21.75	24.30	28.15	36.05	40.95
B1	9.30	16.50	23.15	30.05	35.25	39.45	49.00	54.45	61.75	67.30	74.60	80.20
B2	4.05	9.75	13.10	18.10	22.85	27.45	33.30	39.40	48.50	52.45	64.05	68.20
B3	6.75	12.05	17.00	22.90	28.60	33.15	36.30	38.80	40.50	43.20	46.30	48.80
B4	5.50	11.05	16.00	22.00	32.95	40.90	44.60	50.30	55.95	62.30	67.40	73.85
B5	3.50	7.40	12.15	15.50	18.50	23.55	27.75	31.85	37.00	41.50	45.75	50.65

alloys after 720 m sliding distance was 33.20 mg mass loss. In the chemical composition of mentioned alloy chromium content reaches 3.5 % and silicon – 0.35 %.

Wear resistant and hardness of this group comparing with other alloys were the smallest (Table 2).

Wear resistance of B group alloys are higher. These alloys are obtained using ferrolsilicon and graphite powder mixture. Wear resistance of this group was from 80.20 mg to 48.80 mg mass loss (Table 2).

Retained austenite transforms into martensite during wear, increasing wear resistance of B group alloys.

Alloys of C and D groups were made using chromium, ferrolsilicon and graphite powder. Wear resistance of these alloys is much higher.

Minimal wear resistance of C group alloys after whole distance was 7.60 mg mass loss. Wear resistance of this group 5 times higher than wear resistance of A group alloys, and approximately 7 – 10 times higher than alloys of B group. With increasing the quantity of chromium powder (from 20 – 55 %) mass loss was 9.75 mg. Like in the C group, silicon stops second transformation of martensite, so hardness of these alloys remain constant (60 HRC) up to 250 – 260 °C.

Wear resistance of C and D group alloys was the highest, because mixture of retained austenite and martensite presented in their microstructure.

3. CONCLUSIONS

1. Strengthened layer of 2.5 mm thickness was obtained by using powder of inexpensive elements – high chromium tool steel X12M, chromium ferrosilicon and graphite. This alloying doesn't change mechanical properties of parent metal.
2. Due to thermal conductivity after deposit welding, alloyed superficies layer hardens. So there is no reason to heat treat after welding.
3. Mechanical and service properties of the layer ensure minimal wear of the layer. It is suggested to use

complex alloying with chromium, ferrosilicon and graphite powder mixture, changing relation of powder. Using such mixtures, hardness of obtained layers reaches 60 HRC. These layers have the highest wear resistant due to their microstructure with non-stable austenite and carbide phase.

4. There is no lines in the carbide arrangement. So mechanical properties of alloys in all directions are the same.
5. These layers could be used for renovation of machine elements or for strengthening of superficies layers.

REFERENCES

1. **Jordovic, B., Kakas, D.** The Influence of Plasma Nitriding on the Structural Changes on the Surface of High Speed Steel *Acta Stereol* 11 1992: pp. 483 – 488.
2. **Janovec, J., Vyrostkova, A., Svoboda, M.** Influence of Tempering Temperature on Stability of Carbide Phase in 2.6 Cr – 0.7 Mo – 0.3 V Steel with Various Carbon Content *Met. And Mater. Trans. A2* 1994: pp. 267 – 275.
3. Cryogenic Processing of Tools and Dies *Metallurgia* 10 1995: p. 371.
4. **Ambroza, P. A.** Using of Steel and Alloying Elements Powder for Deposit Welding *Journal of Mechanics ISSN 1392-1207* 3/18 1997: pp. 56 – 59.
5. **Tokarev, A. O.** Treatment of Wear Resistant Metal Coating by Using High Concentrated Energy *Journal of Metal Science and Heat Treatment* 2 2001: pp. 18 – 21.
6. **Karpov, L. P.** Difusion Annealing of Chromium Galvanic Coating *Journal of Metal Science and Heat Treatment* 7 2001: pp. 21 – 22.
7. **Schastlivcev, V. M., Tabatchikova, T. I., Makarov, A. V., Jegorova, L. J., Jakovleva, I. L.** Wear Resistance of Carbon Steel with Fine Lamella Pearlitic Structure *Journal of Metal Science and Heat Treatment* 1 2001: pp. 27 – 31.
8. **Mitejev, A. A., Volchok, I. P.** Questions about Silicocarbide Phase in the Wear Resistance Alloys *Journal of Metal Science and Heat Treatment* 10 2001: pp. 24 – 27.