Electron Beam Surfacing of Wear-Resistant Coatings on the Base of Chromic White Iron Alloyed by Vanadium

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Abstract – Influence of alloying by vanadium of surfacing material on the base of chromic white iron PGS27 on structure and properties of surfaced coatings is investigated. During surfacing process vanadium are formed vanadium carbides V_2C. Microhardness and wear-resistant is increased due to additional matrix reinforcing by carbides V_2C.

Thermal treatment (normalizing annealing) of surfaced coatings noticeably increased their micro-hardness and wear-resistant due to precipitation strengthening.

1. Introduction

Increase of lifetime of machine details in mining and process industry in Far North conditions is actual problem. Intensive abrasive wear of heavy-loaded machine details is main factor of small lifetime. The deposition of wear-resistant coatings on work surface of heavy-loaded details is one of the effective techniques of increasing of wear resistance.

Vacuum electron beam surfacing is one of the progressive technologies of deposition of wear-resistant coatings. Producing of coatings for various working condition from powders of various chemical elements and compounds is advantage of electron-beam surfacing technology. Using of thermoreacted chemical element (such as V, Zr, Ti, Nb) and high-carbon surfacing material enable to forming of coatings reinforced by carbides.

Chromic white iron PGS27 alloyed by vanadium (up to 6% wt) was chosen as high-carbon surfacing material. Vanadium has high reactivity and formed carbides in molten metal. Vanadium carbides are very stable to coagulation at high temperature. Hardness of vanadium carbides VC ($H_V \sim 3000$ [1]) is higher in comparison with base carbides (Cr, Fe)$_7$C$_3$ ($H_V \sim 1550$ [1]) of chromic white iron. Vanadium reacts with carbon of chromic white iron formed vanadium carbides V_2C. Using surfacing powder mixture on the base PGS27 with vanadium practically formed carbidosteel coatings.

The object of paper is investigation of structure and properties of composite coatings PGS27-V obtained by electron-beam surfacing in vacuum.

2. Materials and experimentation methods

Coating obtained by electron beam surfacing in vacuum. Substrate material is steel 45 (120×25×4 mm). Coating thickness is 2 mm. Surfacing powder material is chromic white iron PGS27 with vanadium (Table 1).

Table 1. Chemistry of surfacing powder materials, % wt

No.	V	Cr	C	Si	Ni	Mn	Fe
1	0	26.70	4.30	1.00	1.60	1.20	base
2	2	26.17	4.21	0.98	1.57	1.18	base
3	4	25.63	4.13	0.96	1.54	1.15	base
4	6	25.10	4.04	0.94	1.50	1.13	base

Powder dispersivity is 100–450 μm. Structural analysis is obtained by using of microscope "AXIOVERT 25 CA", X-ray spectrum analysis – "KOMEBAX MICROBEAM" and DRON-3. Hardness of coatings is measured by using TR 5006 (HRC) and microhardness (H_μ, GPa) – PMT-3. Comparative abrasive wear is measured by using wearing machine GOST 23.208-79 "Friction with no stringently fixed abrasive" (quartz sand). Comparative standard is steel 45.

3. Results and discussion

Structure of chromic white iron coatings is characterized by presence of initial hexahedral carbides (Cr, Fe)$_7$C$_3$ and dispersed eutectic carbides (Cr, Fe)$_7$C$_3$ (Fig. 1). Additional alloying of deposited material PGS27 by vanadium (up to 6% wt) results to formation of vanadium carbides V_2C in surfacing process. According to investigation [2] vanadium first of all are formed carbides in molten metal. Substantial part of vanadium carbides is nucleus of center for initial hexahedral carbides (Cr, Fe)$_7$C$_3$. The other part of vanadium carbides is located in matrix (0.7% wt according to the X-ray spectrum analysis). These carbides are not revealed by an optical method because of their ultradispersiveness and are detected by X-ray method only.

Measurement of hardness, microhardness and abrasive wear resistance of coatings showed increase of values of these parameters in coatings containing up to 4% wt V and decrease in coatings containing 6% wt V and above (Fig. 2). Maximum parameters has coating PGS27 + 4% wt V: $H_\mu = (7.33 \pm 0.29)$ GPa, (60.2 ± 0.15) HRC and $K_w = 21.03 \pm 0.64$.

It is necessary to assume that increase of hardness and wear resistance of coatings alloyed by vanadium (up to 4% wt) is caused by disperse reinforcement of matrix by vanadium carbides V_2C. Decrease of hardness and wear resistance of coatings alloyed by vanadium (from 6% wt and above) is caused by significant transition of carbon from matrix to vanadium carbides.

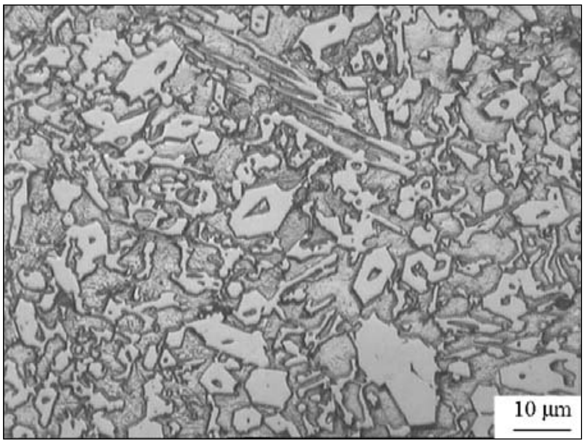

Fig. 1. Microstructure of coating PGS27 + 4% wt V

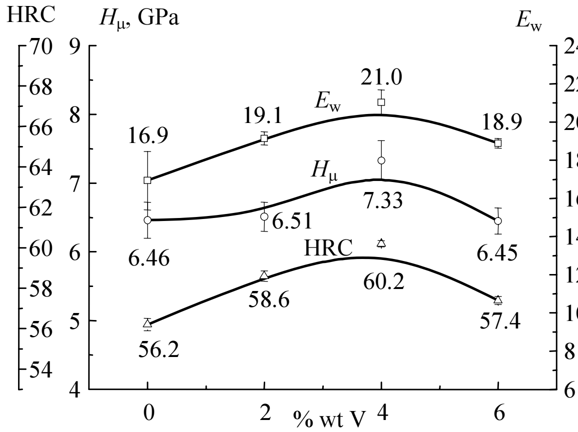

Fig. 2. Hardness (HRC) microhardness (H_μ) wear-resistance (K_w) of coatings depending on content vanadium in PGS27

Rapid crystallization of coatings during surfacing process result to non-equilibrium structural state. In this connection was realized thermal treatment (normalizing annealing) at $T = 1100$ °C during 60 min.

Structural investigation after additional thermal treatment is showed considerable emanation of superdispersed carbides (Fig. 3). Normalizing annealing result to equilibrium structural state, solution of carbides $(Cr, Fe)_7C_3$ and emanation of superdispersed vanadium carbides VC and chromium carbides. It is necessary to note that annealing result to diffusion transition from V_2C to VC [2].

Measurement of hardness, microhardness and abrasive wear resistance of coatings showed increase of values of these parameters after normalizing annealing (Fig. 4). Maximum parameters has coating PGS27 + 4% wt V: $H_\mu = (10.92 \pm 0.23)$ GPa, $K_w = 27.15 \pm 0.03$.

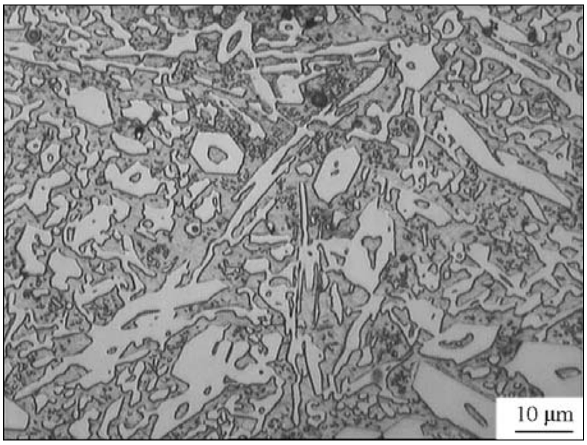

Fig. 3. Microstructure of coating PGS27 + 4% wt V after normalizing annealing

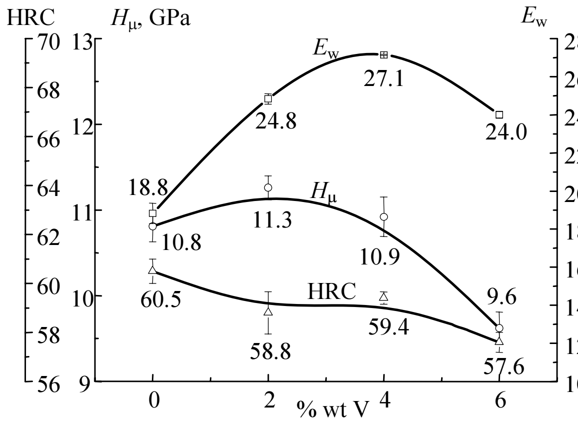

Fig. 4. Hardness (HRC) microhardness (H_μ) wear-resistance (K_w) of coatings depending on content vanadium in PGS27 after normalizing annealing

4. Conclusions

1. Vanadium carbides V_2C-VC during electron-beam surfacing of powder material PGS27-V are formed.

2. Increasing of vanadium content in PGS27 (to 4% wt) result to increasing of microhardness and wear-resistance.

2. Additional thermal treatment of coatings result to significant increasing of microhardness and wear-resistance due to precipitation strengthening by superdispersed carbides VC.

References

[1] I.I. Tsipin, *Wear-resistant White Iron*, Moscow, Metallurgiya, 1983, pp. 11–15.

[2] O.Yu. Elagina, Perspektiv. Materialy **50/4**, 17–22 (2006).