VeKo25Cr: A Corrosion and Wear Resistant Powder Metallurgical Alloy with a Basic Hardness of 52 HRC

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Abstract

To meet the demands for use in extremely abrasive and corrosive environments, a new material was developed. The VeKo25Cr distinguishes itself through specifically selected amounts of carbon and carbide forming elements such as Cr, Mo, V, W and Nb. The alloy is based on a Fe matrix. The strength after heat treatment and the wear and corrosion properties are compared to those of other materials. VeKo25Cr can be combined with easy-to-process materials such that the difficult handling is minimized to those places on the piece most subjected to operational wear.

Keywords : Wear, Corrosion, Carbides, Hot isostatic pressing, Composite

1. Introduction

Polymers are increasingly replacing traditional materials. That's why the requirements for machines in polymer production and processing become more and more demanding. Thus, machine parts must meet requirements such as high wear and corrosion resistance and also high mechanical strength.

Table 1. Chemical composition (in wt%).

Material	VeKo25Cr	X245	X260	GP27M	HIP65S	HIP1
C	3.75	2.45	2.7	2.7	1.1	2.5
Si	0.8	0.9	0.6	0.6	4.3	-
Mn	0.3	0.5	0.5	0.5	-	-
Cr	25	5	26	26	17	33
Ni	-	< 0.5	< 0.5	< 0.5	bal.	-
W	5		-	-	-	13
Mo	3	1.3	1.1	1.1	-	-
Co	-	-	-	-	-	bal.
V	5	9.8	2.4	2.4	-	-
Nb	1	-	1.3	1.3	-	-
Fe	bal.	bal.	bal.	bal.	< 1	-
B	-	-	-	-	3.3	-
Remark	PM	PM	PM	cast	PM	PM

2. Choice of chemical composition

VeKo25Cr is a steel with the composition shown in Table 1. Each of the following elements influences the properties of the alloy and has been specifically selected to achieve a combination of high resistance to wear and corrosion.

Carbon forms carbides at various stoichiometries with Fe, Mn, Cr, Mo, V, W, and Nb. Its amount hardly influences the corrosion resistance to water, acid and hot gasses. The high content of 3.75 % provides sufficient carbon to form wear-inhibiting carbides with one of the mentioned elements. ***Chromium*** is a carbide former and responsible for the good corrosion resistance. A minimum amount of 13% is required in the matrix. ***Tungsten*** is a strong carbide former and increases the high-temperature strength. ***Vanadium*** is also a strong carbide former and binds nitrogen. ***Molybdenum*** is a strong carbide former as well and increases the hardenability by lowering the critical cooling rate. ***Niobium*** is another strong carbide former and acts as a chemical stabilizer, thus increasing the corrosion resistance. ***Silicon*** deoxidizes the alloy and narrows the γ range. It also increases wear resistance and strength. ***Manganese*** deoxidizes too and binds sulfur to form manganese sulfides. ***Iron*** as matrix is also a carbide former and thanks to the addition of chromium, the corrosion resistance is improved.

The amount of carbon was selected high enough to allow all carbide formers to create carbides. Thus, no undesirable phases have to be expected. If weak carbide formers are present in small amounts, the alloying elements are absorbed by the cementite as solid solution and a mixed carbide is created. At large amounts of weak carbide formers or small amounts of strong carbide formers special carbides are created with a lattice and composition different from the cementite. Usually, the special carbides still absorb iron and create a solid solution. Sometimes double carbides are formed such as the iron-tungsten double carbide Fe_3W_3C. The carbon affinity of the alloying elements varies considerably. In the following sequence it increases from left to right: Mn→Cr→W→Mo→V→Nb (also according to [1]).

The distribution of the carbides and alloying elements in the matrix can also be altered through heat treatments. With increasing temperature the solubility of carbon in the matrix increases, and the stoichiometry of the carbides is changed and moved towards a more stable equilibrium.

3. Fabrication of samples

Globular atomized powder with a grain size of <500 µm was poured into steel capsules which were evacuated and sealed air-tight. These bars were then fully densified in a hot isostatic press at 1100°C resp. 1160°C for 3 hours at 1000 bar. A low cooling rate was selected intentionally in order to achieve a soft microstructure.

The bars were then sawn and machined to the final dimension of ∅ 50x30 mm. These segments were divided into 3 lots and heat treated at 1080°C, 1140°C and 1180°C respectively for 30 minutes in vacuum. After that, the samples were tempered 3 times for 2 hours at different temperatures and the hardness was determined. The maximum hardness of 67 HRC was found after hardening at 1140°C and tempering at 450°C.

Above the tempering temperature of 300°C, the hardness increases due to the secondary hardening. The peek was found to be at 450°C. This phenomenon is due to the appearance of finely distributed precipitations created from the supersaturated solid solution. Above 450°C, the hardness decreases considerably since the alloy approaches its equilibrium.

4. Characterization

Bending and compression strength tests (Table 2) were carried out on samples which were hot isostatically pressed, hardened and tempered to maximum hardness.

The results show high strength in combination with a fairly high ductility ratio (ratio of yield stress to compression strength) from which good toughness can be derived.

Wear tests based on the ball and disk method [2] were carried out using the same samples as above. A carbide ball of type K 20 was rolled on the test material disk on a circular path with a load of 5 N. VeKo25Cr was compared to other powder metallurgical materials produced through HIP (Table 1). Fig. 1 compares the wear height which is the depth of the grove in the disk. In this test, VeKo25Cr performs similarly to the other materials and can thus be considered highly wear resistant.

Corrosion resistance of VeKo25Cr and other materials was tested using the potentio-dynamic corrosion measurement [3] according to ASTM G5 on the same samples as above. VeKo25Cr shows a passivation plateau and is thus highly corrosion resistant. However, depending to the environment and the type of stress these findings have to be verified.

Table 2. Bending and compression strength

Sample	VeKo25 (1)	VeKo25 (2)	X245
HIP-Temp. (°C)	1100	1160	1000
Hardness (HRC)	67	67	63
Bending strength (MPa)	1939	1905	2833
Yield stress (comp.) (MPa)	2712	2784	2675
Compress. strength (MPa)	3574	3581	4154
Ductility ratio	24%	22%	36%

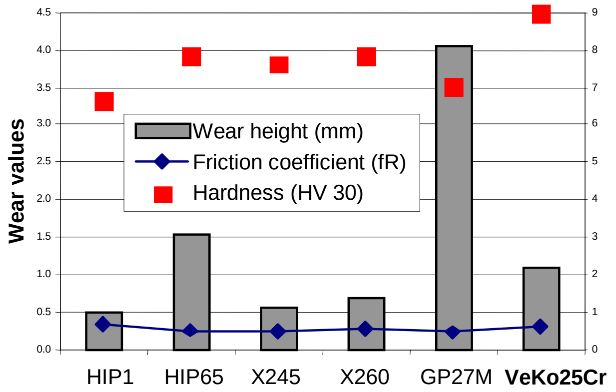

Fig. 1. Wear resistance

5. Use in composites

The HIP technology allows to combine different materials [4]. In the case of VeKo25Cr, this possibility would be employed to produce composite bars with soft cores or to clad soft steel housings which serve as raw material for screws and barrels in polymer extruders.

6. Summary

The corrosion and wear properties of VeKo25Cr and the effect of HIP and heat treatment on the hardness were presented. This steel is suitable for components exposed to extreme corrosion and wear. To reduce brittleness of the material, the HIP composite solution is recommended.

7. References

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