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HIGH-CHROMIUM CAST IRON WITH HIGHER DUCTILITY

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SUMMARY

The cast iron with composition (in wt.%): C 2.6–2.8%, Cr 20–24%, Mo 0.7–1.5%, Ni 0.8-1.3%; 0.4-2% Mn, Si max. 1% with the trace amount of Ti and V was developed. Its foundry properties are very good and enable to cast the complex shaped castings with the section about 3 mm. The castings do not require the heat treatment, and in the range of wall section from 3 to 40 mm the as-cast material attains hardness from 47 to 53 HRC, ductility A5 of 1% minimally and is characterized by self-sharping effect.

Key words: high-chromium cast iron, austenitic matrix, alloying, foundry properties, abrasion resistance, mechanical properties, self-sharping effect

1. INTRODUCTION

The wear resistant chromium irons are known as the materials with extreme high resistance to a wear, but with very limited application in the service for its brittleness causing very low fracture resistance. Their development resulted from the demands on the material having the high resistance to abrasion, corrosion and at the same time, ductile for the cast parts with the casting's wall section from 3 to 100 mm used in the agricultural and building machines. Presented results show that the plastic properties of the chromium irons can be effectively improve using the proper alloying, what initiates the wide possibilities to apply this category of materials in the service.

2. HIGH-CHROMIUM CAST IRON WITH AUSTENITIC MATRIX

At the selected orientation on the Fe-C-Cr system and regarding the desired good foundry properties given by the minimal wall thickness of 3 mm, we narrowed the

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selection down to moderately hypoeutectic or eutectic chromium irons with the C content from 2.5 to 3.3% and Cr ranging from 17 to 24%. At real cooling rate of castings, these irons, containing only the basic components of C and Cr, have the structure formed by the massive carbides of $(FeCr)_7C_3$, $(FeCr)_{23}C_6$ and $(FeCr)_3C$ types in martensite-pearlitic matrix practically without the austenite occurrence, hence in compliant with the stable phase diagram of ternary Fe-C-Cr system [1]. The iron alloyed only by 17 to 24% of chromium with the carbon content ranging from 2.5 to 3.3% is extreme brittle and therefore, the research was intended to increase the toughness by forming the enough high portion of austenite in the matrix and by refining of carbidic phases using microalloying. The toughness depends in deciding rate on the austenite amount and we can support its portion in the matrix either alloying by elements extending the γ-area, or such ones that shift the temperature of martensite transformations towards the low temperatures and so the metastable nontransformed austenite retains in the matrix. According to [1, 2], from the technological suitable and economic accessible elements only the Ni, Mn, and Mo were considered.

At examining of the effect of the additional alloys showed that while they were introduced separately into the base Fe-C-Cr material, predominantly austenitic matrix was produced only by alloying more than 2.5% of Mo. The nickel, also at its high content, did not develop the desirable increase in the austenite portion and the separate alloying by Mn gave the completely negative result because the brittleness of iron worsened. The next text showed that the function of the critical Mo is unchangeable, but the low limit of the Mo content can be decreased upon 0.7% if the iron is alloyed additionally either 1% of Ni, or 1.5% of Mn. The combination of 0,7% Mo + 1% Ni + 1.5% Mn, which at the C content about 3% and the Cr content from 17 to 24% ensures to produce in as-cast the matrix containing the austenite of about 60% and this also in the section thicker than 50 mm and casted into the sand mould [3], proved very good.

The next development of the iron having the chromium content about of 20% indicated the possibility to increase more significantly the toughness by reducing the carbon content to 2.2% and increasing the contents of Mo and Ni. Regarding the shortfall and the high price of Mo, the effort was to specify its content as low as possible and to increase the contents of Ni respectively Mn, or Cu. The experiments showed that the extremely high toughness, nearly on the upper limit of the possibilities for given system, can be achieved by alloying with 1.4% Mo + 5% Ni. This cast iron attains in as-cast the hardness from 37 to 50 HRC, the strength R_m over 650 MPa and the elongation A5 of 6% minimally. During development there also showed that in the charge it is desirable to substitute the common steelmaking pig irons by the type of Sorel (with the content of S and P under 0.01%) with as lowest as the Si content because some amount of Si, which is undesirable for this cast iron, comes into the charge from ferrochromium.

The important parameter of this iron category is the relative resistance to abrasion Ψ that was found as the ratio of the weight loss per 1 cm^2 of the drinded sample surface made from the standard steel STN 12 060 quenched on 61 HRC to those casted from the tested iron. Because of the values of the abrasion resistance Ψ finding on the various devices markedly depended on the type of abrasive medium, the rate and the pressure of the samples to the abrasive carrier, the tests were strictly based on the comparison of the etalon's weight loss with the groups of more iron types. The test results showed that the irons with predominantly austenitic matrix had the hardness from 50 to 53 HRC in as-cast, but their relative abrasion resistance Ψ ranging from 2.8 to 4.6 was comparable, or also higher to the heat treated martensitic cast irons that have the equal content of C and Cr and hardness above 60 HRC. The material is also characterized by the high resistance to corrosion and scaling at the temperatures up to 1000°C.

Attained complex of the results enabled to valuate complexly the influence of the individual constituents of the iron. The abrasion resistance increased nearly linearly as the contents of C and Cr were risen. After overrunning the 3% limit of C, the brittleness increased irespectable and the increase of the Cr content over 22% did not have more significant effect on the abrasion resistance. Alloying by Mo had the markedly positive effect on the abrasion and also the fracture resistance, alloying by Ni had moderately positive influence, but only if the nickel wad applied together with Mo. The additions of B in amount about 0.01% or the 0.05% Ti + 0.05% V combination, which were added into the molten metal immediately before pouring, have also the favourable effect. The positive effect of Mn on the wear resistance did not prove, but it occurs in the final chemical composition because the running property improves obviously at its content over 1%. Another increase in the running property was attained, when the molten metal was processed by the synthetic slag based on CaF_2 with CaO and Al_2O_3 in amount about 0.1% just the finish of melt. Striking high running property of the hot metal having the Mn content about 2% could cast the surfacing welding rods (STN G586) having the diameter from 5 to 6 mm and the length from 400 to 500 mm [4]. Resulting from laboratory and service tests, for mostly thin walled castings designated for the parts operating in the soil conditions the follow chemical composition of cast iron was suggested (in wt.%): 2.6-2.8 C; 20-24 Cr; 0.4-2 Mn; 0.6-1.0 Si; 0.8-1.3 Ni; 0.7-1.5 Mo. Presented composition is the compromise, at which the material of castings has the high wear resistance and also the sufficient toughness with the ductility value A5 over 1%. The detailed information on the technological and mechanical properties including the wear resistance for the castings' material, which have the various wall thickness in as-cast and after the heat treatment are stated in [3, 4, 5].

The molten metal preparation is not difficult, there proved the melting in the induction furnaces with the crucible of 40 or 100 kg, when the charge was composed from the steelmaking pig iron, granules of Ni and ferroalloys, while the hot metal could not be killed. The melt began with charging of Ni granulate and Sorel pig iron. After liquid metal rising and cleaning the pool surface, we charged the preheated ferrochromium with the C content of 0.1%. When the ferrochromium was fully melted, into the hot metal of the temperature about 1450°C we charged together the highly preheated (about on 1000°C) ferromolybdenum and ferromanganese. When the molten metal attained again the temperature about 1450°C, the granule mixture of ferrotitanium FeTi35 with ferrovanadium were added, and after their melting-down we used the synthetic slag of 0.1% to clean the melt surface. At the hot metal temperature of 1450°C, after slag flushing we began with pouring.

The linear shrinkage of castings made from this type of cast iron is about 2% and the demands on feeding are similar to those for the lowcarbon unalloyed steels. For the castings that have the section from 10 to 40 mm, the material can not be heat treated because the cooling rate in the sand mould ensures the hardness from 47 to 53 HRC and the sufficient toughness. Lower hardness in the section thinner than 10 mm and mainly on the sharp working wedge is favourable from the function viewpoint because in this area the material is essentially tougher.

The microstructure character of the heat nontreated cast iron in the section of 4 mm documents the Fig. 1. It is formed by austenitic matrix, in which big amount of the massive carbides occur, mainly of M_7C_3 type with the small area of eutectoide – the mechanical mixture of ferrite and discrete fine carbides. The specimen was electrolytic polished in the solution of VUZ 16 and to visualize the structure the etcher specified for the corrosion resistant steel could be used.

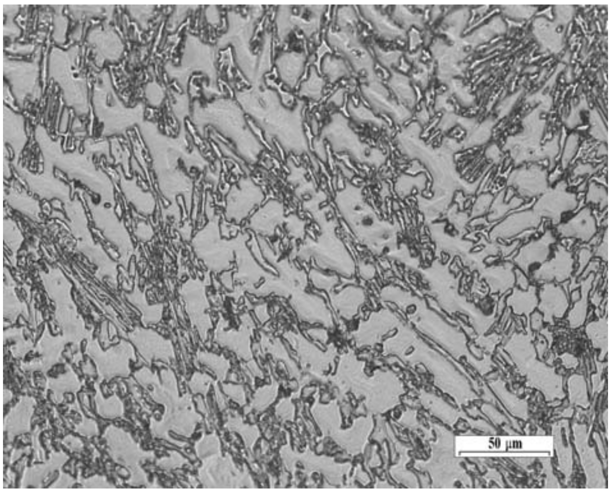

Fig. 1. The microstructure of the casting in the section of 4 mm

About from 1986, the described tough type of the cast iron is used to produce the extreme castings stressed dynamically and by wear, e.g. the mill hammers, the stonemasonry tools etc., where it proved very good. At present we test its application for tools that are used for turning of the pressed ceramics specified for the high-voltage insulators. The cutting surface of the tool, which is in the distance of 100 mm from the clamping part, forms the slim triangle body with the dihedral angle of 14° curved into the half-circle with the radius of 7 mm, so that at the turning the rake angle was about 67° and the cutting clearance angle of 9°.

The tool life was comparable with the identical tools made from the high-speed steel, but the character of the cutting surface wear was different. The tool from the chromium austenitic iron did not require the grinding of the cutting surface during the whole tool life (about 100 hours). It became inoperative, when on the cutting key the wide surface of 3 mm with a zero cutting clearance was formed, as presented in Fig. 2.

Fig. 2. The cutting tool after 100 hours of service

Then the abrasive effect of the cutted ceramics caused the such loss of material that the tool height decreased from original 19 mm to about 14 mm and the angle of the cutting key enlarged from 14° to cca 20°, but the cutting surface was enough sharp during the whole time of turning and its radius did not exceed r = 0.2 mm (Fig. 2). Keeping the cutting edge res. the self-sharping effect can be explain by the way that in the location of the tool point the highest level of the deformation occurs and hence, the highest hardening due to the formation of martensite. Lesser hardened side part of the tool body resists to abrasion less and abrades speeder by that the sharp cutting key is formed permanently.

The high wear resistance of both described chromium irons is in the seeming disagreement with the generally accepted opinion about the poor resistance of austenite to the abrasion that is known at the austenitic nickel LGG, chromiumnickel steels, but also manganese ones. However, the austenite of the presented chromium irons has other properties. It has lower stability consequently the plastic deformation produced by the abrasive particles caused the martensite transformation of austenite not only in the deformed area, but also in their nearest vicinity resulting in strengthening of the relatively large volumes of material. For the very good running property these types of irons are suitable to cast the thinwall castings and for the low casting temperature the high quality of the surface is achieved.

3. CONCLUSION

At present the cast irons are taken for the most perspective category of the metal material. The basic near eutectic system Fe-C ensures that the irons have the good foundry properties and the liquid temperature about 1200°C, hence the low power requirements for the hot metal preparation. The presented types of cast irons show what service properties can be attained with the carbidic chromium iron having the matrix formed by metastable austenite.

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WYSOKOCHROMOWE ŻELIWO O PODWYŻSZONEJ PLASTYCZNOŚCI

STRESZCZENIE

Badano żeliwo o składzie chemicznym (wg. %): C 2.6–2.8%, Cr 20–24%, Mo 0.7–1.5%, Ni 0.8-1.3%; 0.4-2% Mn, Si max. 1% ze śladową ilością tytanu i wanadu. Jego właściwości odlewnicze są bardzo dobre i umożliwiają wykonanie odlewów o złożonych kształtach z przekrojem około 3 mm. Odlewy nie potrzebują obróbki cieplnej i w przedziale grubości ścianki od 3 do 40 mm materiał ma twardość od 47 do 53 HRC, plastyczność A5 min 1% jest charakterystyczna wynikom samoostrzenia.

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