FACTORS INFLUENCING FORMABILITY, STRUCTURE AND MECHANICAL PROPERTIES OF HIGH ALLOY HEAT RESISTANCE STEEL

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Abstract

High alloy heat resistance steels based on 12% Cr content are characterized by specific structure and properties, which can substantially complicate technological procedure of their forming. These 12 % Cr based steel are characterized by increased resistance to deformation that affects-their formability significantly, quit narrow interval of forging temperatures, non-uniform formability and high sensitivity to stresses. Paper deals briefly with effect of various factors on formability, microstructure and mechanical properties. Effect of some chemical elements, grain size and volume of delta ferrite is discussed and compared. Effect of forming temperature is also discussed.

Keywords: Heat resistance steel, forging temperature, structure

1. INTRODUCTION

Forming of heat-resisting steels containing approx. 12% of chromium takes place in a two-phase state austenite - delta ferrite. Forming of steels in a two-phase state austenite - delta ferrite is more difficult since during forming cracks can be formed at the boundary of both phases [1]. Structures of heat-resisting chromium steels containing approx. 12 % of chromium, in dependence on modification of chemical composition and on mass of ingot, can be at forming temperatures either single-phase - austenitic, or two-phase, which means that structure contains apart from austenite also delta ferrite.

Presence of delta ferrite and its quantity is controlled by contents of carbon in steel and by quantity of carbide forming elements. The lower the carbon contents and the higher the contents of carbide forming elements, the higher is the delta ferrite contents in the structure. When the temperatures is higher than 1200 °C a delta ferrite appears in the structure, and its quantity increases with the increasing temperature. Presence of delta ferrite in non-modified chromium steels is suppressed by smaller addition of nickel. If the carbon content is lower, the delta ferrite appears in the structure already at lower temperatures.

Addition of modifying elements Mo, V, Nb, B increases possibility of occurrence of delta ferrite and there can occurs even a case, when the delta ferrite occurs in the structure already at temperatures of approx. 20 °C [2, 3]. According to the equilibrium diagram below the transformation temperature the austenite is transformed to ferrite and carbides. If the cooling is sufficiently quick, the martensite is formed in heat-resisting steels containing approx. 12% of chromium [4]. We have carried out experiments on two steels, the chemical composition of which is given in the **Table 1**.

Table 1 Chemical composition of investigated steels

Steel grade	Contents of elements [%]											
	C	Mn	Si	P	S	Ni	Cr	Mo	W	V	Nb	B
X20CrMoV 12	0.19	0.8	0.31	0.025	0.017	0.60	12.24	0.80	-	0.33	-	-
Cr12MoWNbV	0.22	0.68	0.37	0.022	0.012	0.52	11.45	0.60	0.59	0.27	0.22	0.003

2. STRUCTURAL CHANGES IN THE ZONE OF FORGING TEMPERATURES

2.1. Classical steels

Micro-structure of classical heat-resisting steel without alloying elements niobium, tungsten and boron is austenitic up to the temperature of 1150 °C. At the temperature of 1200 °C a small quantity of the delta ferrite begins to be formed. After heating to 1250 °C to 1300 °C there is being formed apart from the delta ferrite along boundaries of austenitic grains dark mesh of carbides, which manifests enrichment of grain boundaries by alloying elements (**Figure 1**).

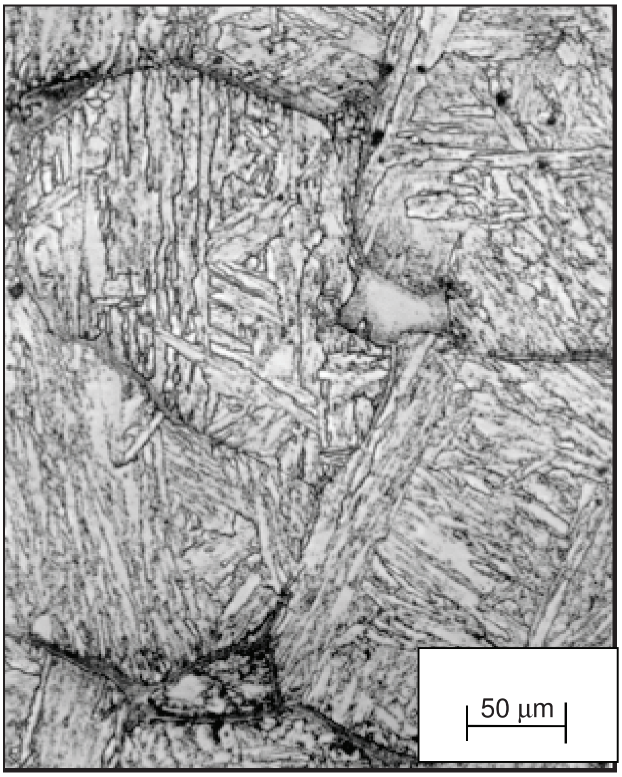

Figure 1 Structure of steel X20CrMoV12

Figure 2 Structure of steel X20CrMoV

Non-homogeneity in distribution of alloying elements caused by heating to a high temperature was demonstrated also on other samples, which were repeatedly austenitised at lower temperatures. With increasing temperature of austenitisation there occurs gradually a back diffusion, and at the temperature of 1150 °C the mesh at the grain boundaries is removed (**Figure 2**). In the heat-resisting steel X20CrMo V12, modified by addition of B in the whole interval of forming temperatures from 900 to 1300 °C the delta ferrite has not been identified (**Figure 3**), probably due to influence of carbon and nickel. In steels with the similar chemical composition, but with lower carbon contents than in the previous case, reduction of the carbon contents has strong impact on the increased occurrence of the delta ferrite, the quantity of which in the structure varies at the temperature of 1000 °C around 50 % (**Figure 4**).

Contents of delta ferrite in this steel increases with the increasing upper forging temperature. Due to the fact that forging of free forgings is made with several re-heatings, it is possible, particularly at the stage of finish forging, that some part of the forged piece will not be forged at all after the last re-heating and size of grain and contents of ferrite in this part will be substantially bigger than in remaining parts. In the steels with high contents of delta ferrite the size of grain and the contents of delta ferrite increases at high temperatures of re-heating.

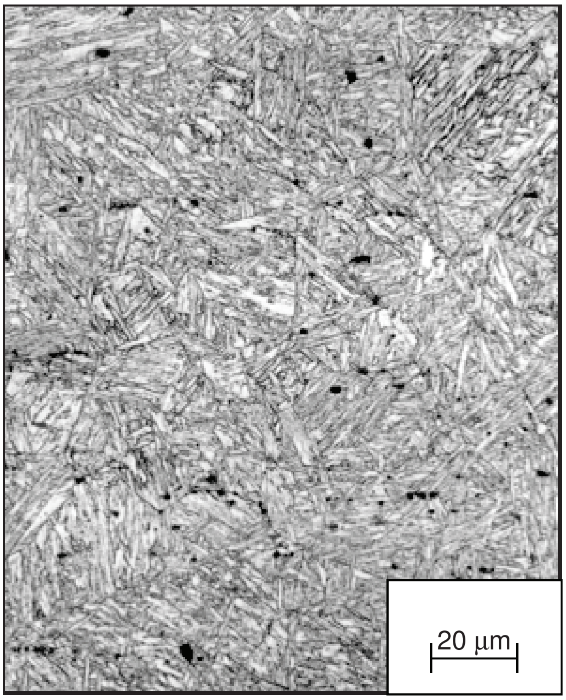

Figure 3 Structure of steel X20CrMoV(B) 12

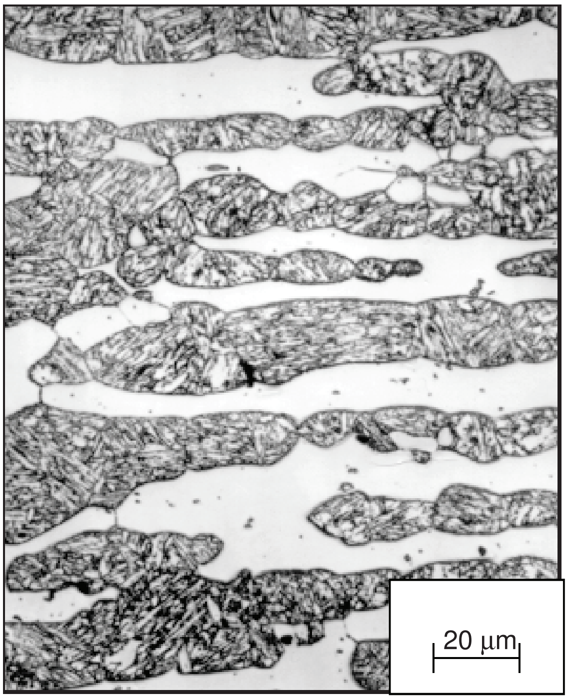

Figure 4 Structure of steel (B) 12 with lower carbon contents

2.2. Grain size

Optimal size of grain after thermal treatment is the decisive factor for obtaining of satisfactory mechanical properties of forged pieces. Size of grain is important also during forming of steel, since too coarse grain impairs formability of steel. One of the reasons why high forging temperatures are not used, is the fear of forming of coarse grain, which increases with the increasing re-heating temperature. Although coarse grain, which was formed during re-heating to forging temperatures, gets finer during forging, in large forged pieces, which are forged with use of several re-heatings, there can occur places, which are not re-forged after the last re-heating and the grain remains to be coarse. In spite of the fact that in heat-resisting steels containing approx. 12 % of chromium there occurs a transformation of austenite to martensite, the delta ferrite, which occurs in the structure during forging, does not change.

2.3. Distribution of delta ferrite in structure

It is obvious from the metallographic photos given above that the delta ferrite is distributed in the steel structure after forging always in rows. The photos were taken from samples made of forged bars and direction of the ferrite rows is parallel to the axis of the forged bar, i.e. that deposition of ferrite is oriented by forging in direction of elongation of the bar.

3. FORMABILITY OF HEAT-RESISTING STEELS

Due to the fact that heat-resisting modified steels with 12 % of chromium contain in structure apart from austenite also delta ferrite, this is forming of two-phase steels. According to these studies the steels in a two-phase state austenite-delta ferrite are formable with difficulties, since cracks occur during forming at the interface between the two phases. Formability was verified on forged bars with use of hot tensile test, which was completed with dup setting tests **Figure 5**. Assessment of formability was made on the basis of final values of strength, contraction, as well as by evaluation of appearance of the fracture surface and upsetting test after deformation.

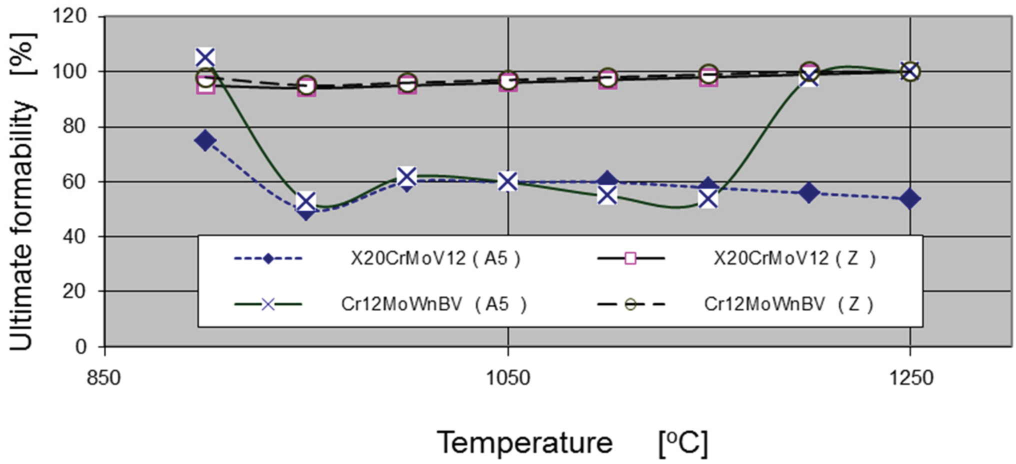

Figure 5 Formability of the steel grade X20CrMoV12 and steel grade Cr12MoWNbV

4. CONCLUSION

Optimal forming temperature of steels varies in the interval of temperatures between 1000 to 1200 °C. Due to lower recrystallization rate and possibility of segregation of carbides in deformed grains of steel at the low forming temperature it is appropriate to make big deformations at higher temperature, and finish-forming temperature may not fall under the temperature of 1000 °C. Influence of addition of niobium and boron (only up to 0.005 %) does not impair significantly the formability. Due to unfavorable properties of boron at high temperatures of re-heating it is necessary to limit the upper forming temperature to 1200 °C. Higher contents of boron ion steel (around 0.025 %) distinctively deteriorates formability in the whole interval of forming temperatures. Steels containing 0.033 % of boron have substantially impaired formability and possibility of their processing with use of classical forging technology is thus limited.

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