Sintered Structural Cu-Ni-Mo-C Low Alloyed Steels with Small Niobium Additions

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Abstract

The present paper investigates the possibilities of niobium using for the mechanical properties of the common low alloyed Cu-Ni-Mo-C sintered structural steels enhancing. On both thermodynamic and experimental bases there were demonstrated the Nb nitrides/carbides/carbonitrides preferential formation in these steels during sintering in dissociated ammonia at both common and elevated temperatures. The obtained results for 0.2 ÷ 1.0 % fine Nb powder and 0.3 % graphite additions to Distaloy AB iron base powder cold compacted and sintered in dissociated ammonia proved the expected strengthening effect, leading to higher mechanical properties of the processed steels than of the common Cu-Ni-Mo-C ones.

Keywords : Sintered structural steels, niobium alloying

1. Introduction

Sintered structural steel parts have an increasing market owing to the known Powder Metallurgy (PM) advantages in their production [1]. However, it is still limited by the PM limitations concerning the realizable mechanical properties. From the technical and economical points of view, alloying seems to remain the simplest and most convenient way of these limitations overtaking. So, to the traditional alloying elements of sintered steels, new ones, like Cr, Mn and even Si - expected to be more efficient, have been added [2]. However, the extension of principle of mechanical properties improving by precipitation strengthening, applied in the known HSLA steels, to the sintered steels has been less investigated [1]. Only few published papers have been found concerning small proportions of Ti/V using for this purpose [3, 4] and any one concerning the Nb using.

As the obtained results in the case of Ti and V small additions are very promising, in the present paper the investigations are extended to Nb additions in the commonly produced Cu-Ni-Mo-C sintered steels.

2. Experimental procedure

Mixtures of Cu-Ni-Mo partially alloyed steel powder (Höganäs Distaloy AB) with proportions of 0.2÷1.0 [wt.%] Nb fine powder (–325 mesh) and a purity of 99.98 [%]) have been adopted. For the carbides / nitrides formation at sintering – as potential strengthening components, a proportion of 0.3 [wt.%] C as graphite (UF 4 type) was added and a N_2 containing sintering atmosphere (dissociated ammonia of – 50 ^{0}C dew point) was used.

3. Results and discussion

Comparative thermodynamic study of compounds formation and stability. To establish the possibilities of the Nb carbides/nitrides preferential formation to get a similar effect like in the HSLA steels, a comparative thermodynamic study was firstly performed. Figure 1 presents the variation with temperature of the calculated values of Gibbs Free Energy of the possible carbides / nitrides formation, up to their melting points. As can be seen, by the far, at the both considered sintering temperatures (T_1=1423 / T_2=1558 [K]), the formation of

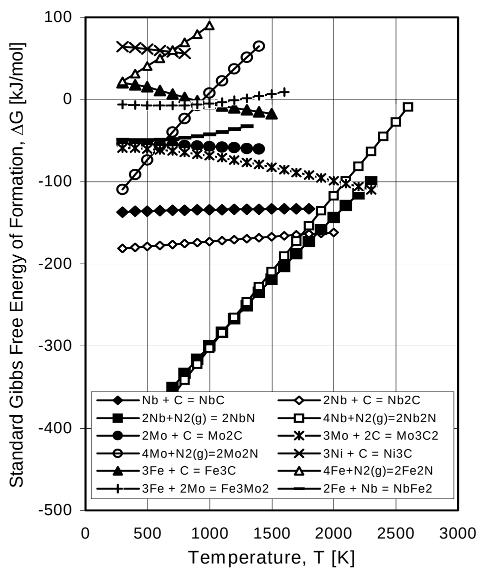

Fig. 1. Gibbs Free Energy of the possible carbides/ nitrides formation vs. temperature.

Nb nitrides and carbides has the highest probability, much higher than of the Mo, Ni and Fe ones. Also, they are stable up to temperatures of ~2000 [K]. So, their formation and preservation in the steel structure is possible. To avoid the Nb and C oxidation, on the basis of Ellingham diagram, it was established that a dew point of sintering atmosphere of – 50 ^{0}C is required - commonly assured by the modern equipment [2]. At high temperature sintering instead, Nb oxidation is less probable as the C one has a lower ΔG^0_r.

Solubility in austenite / ferrite. The solubility of NbC and NbN in austenite and ferrite has been too investigated on the basis of the solubility product (Fig. 3). As can be seen, the solubility of NbN in austenite is less than of NbC and decreases as temperature decreases. Instead, for both, the solubility in austenite is much higher than in ferrite. Consequently, at the Fe $\gamma \rightarrow \alpha$ transformation, a part of them precipitates along the new formed interfaces, limiting the ferrite grain growth. Another part is solved by ferrite and

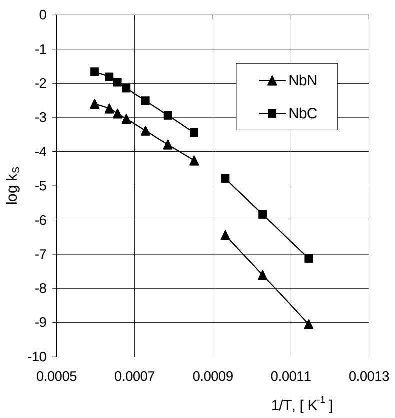

Fig. 2. Logarithm of the solubility product of NbC and NbN in austenite/ferrite vs. 1/T.

precipitate inside its crystallites at the subsequent cooling.

Microstructure. The SEM image of the obtained steel sintered at high temperature, sinterquenched and aged is presented in Figure 3. Very well defined crystal grain limits can be seen, as well as fine precipitates inside the grains. The linear analysis (not given in the figure) highlights a notable increasing of Nb, C and N_2 contents at the grain limits, proving the NbC and NbN expected precipitation. A similar microstructure was obtained for the normal cooling.

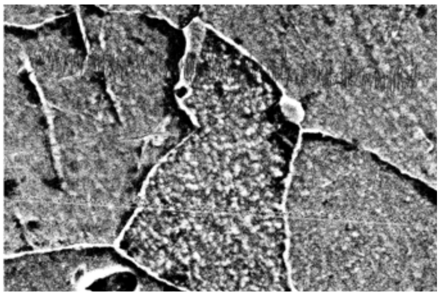

Fig. 3. SEM image of sintered steel with 0.4 [%] Nb.

Mechanical properties. The above presented micro-structural features have a determinant effect on the mechanical properties of sintered steels. As results from figures 4 both tensile strength and elongation increase as Nb content of the initial powder mixtures increases. In the same figure are presented, for comparison, the corresponding values for steel obtained, in the same conditions, from the powder mixture with the same C content but without Nb. However, for sintering at 1150 ^{0}C and normal cooling, both NbC and NbN completely precipitate from austenite. As a result, UTS and elongation increases only up to about 0.6 [%] Nb, as at higher proportions the too high precipitate quantity at the grain boundaries weakens them. Hardness, instead (not included), increases up to the maximum Nb content.

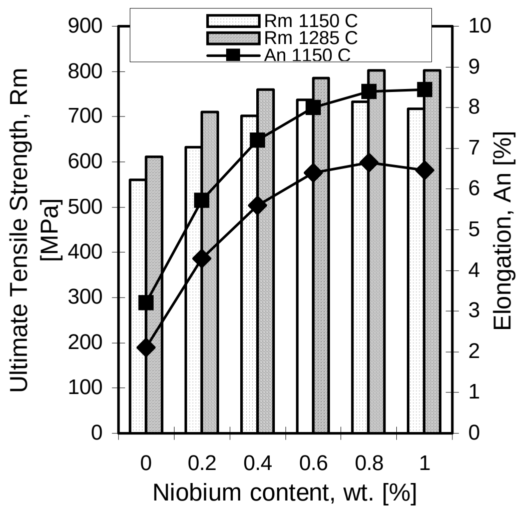

Fig. 4. Ultimate Tensile Strength and Elongation of sintered steels vs. Nb content.

4. Summary

The presented results prove the beneficial effect of small Nb additions in structural low alloyed steels sintered in a N_2containing atmosphere. For sintering in common conditions, a notable increase in UTS and elongation occurs up to ~0.6 [%] Nb, while hardness continuously increases. For high temperature sintering, UTS and hardness increase continuously, while elongation decreases over ~0.8 [%] Nb.

5. References

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