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EFFECT OF Ni CONTENT ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF Fe-Cr ALLOYS

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ABSTRACT

The aim of this work is to study the influence of Ni content on the microstructure and mechanical properties of Fe-Cr alloys. For this purpose alloys were prepared with 18%Cr-0.01%C-0.2%Si-0.4%Mn base composition and variable Ni content (0, 10, 20, 30, 40, 50 and 60 weight %). The alloys were characterized by optical microscopy, X-Ray diffraction, hardness and tensile tests. The aim of this work was characterize the alloys for, in the next step, to correlate the microstructure and machinability.

Keywords: Stainless steels, Ni alloys, Fe-Cr-Ni alloys

1 INTRODUCTION

Stainless steels become more and more important due to mechanical properties and optimum corrosion resistance. However, the required composition to reach optimum properties, makes its usinability more difficult because they suffer high amounts of strain hardening. In general, stainless steels machining requires higher machine power, lower cutting speeds and stronger tools, with special geometry and coatings. Chromium and nickel are the main alloy elements in stainless steels. Chromium greatly raises corrosion resistance. Nickel promotes austenite formation and stabilization resulting in better mechanical resistance. Alloying these elements brings out different crystal structures, once chromium crystal structure is body centered cubic (BCC) and nickel is face centered cubic (FCC). This enables to obtain different properties in machining, forming, welding, etc. Nickel base super alloys tend to suffer strain hardening and retain a great amount of the cutting power, during the machining; this raises the temperature in the interface sample/cutting tool, what causes a higher wear of the cutting tool. To avoid this problem, it is common to use coating cutting tools, in a way to raise wear and deformation resistances [1,2]. In this paper will be presented the Fe-Cr-(Ni) alloys characterization, in terms of mechanical properties and microstructure. The second part, to be presented later, will be about the machinability of these alloys. The scope of the whole work is to understand how nickel affects the machinability of Fe-Cr-(Ni) alloys.

2 EXPERIMENTAL PROCEDURES

The alloys studied in this work were produced by Villares Metals with 18%Cr-0.01%C-0.2%Si-0.4%Mn base composition and variable Ni content (0, 10, 20, 30, 40, 50 and 60 weight %). The alloys were forged and rolled in the temperature range 1150 to 1180ºC. The 0% Ni alloy was annealed for 1 hour at 790ºC and cooled in forced air. The others were annealed for 1 hour at 1050ºC and cooled in water. X-ray spectrums were obtained using an X-ray Diffractometer

DMAX2200, Rigaku Co., with Co-Kα radiation. Hardness data were obtained in a Heckert WPM machine, using 10 kg load. Tensile tests were performed in a MTS machine, using cylindrical samples with the dimensions: 30 mm long and diameter of 4,95 ± 0,05 mm. The microstructural aspects of the Ni alloys were revealed using the eatching: 10 ml HNO_3, 10 ml acetic acid, 15 ml HCl, 5 ml glycerin. For 0% Ni alloy Vilella's etching was used. Microstructural observations were performed in a Image Processing System, consisting of an optical microscope Neophot 32 Carl Zeiss and the image analysing software Quantimet 500 MC, Leica Imaging Systems Ltd.

3 RESULTS AND DISCUSSION

Figure 1 shows the X-ray patterns obtained: the 0%Ni alloy was fully ferritic and the Ni alloys fully austenitic, without other phases or precipitates.

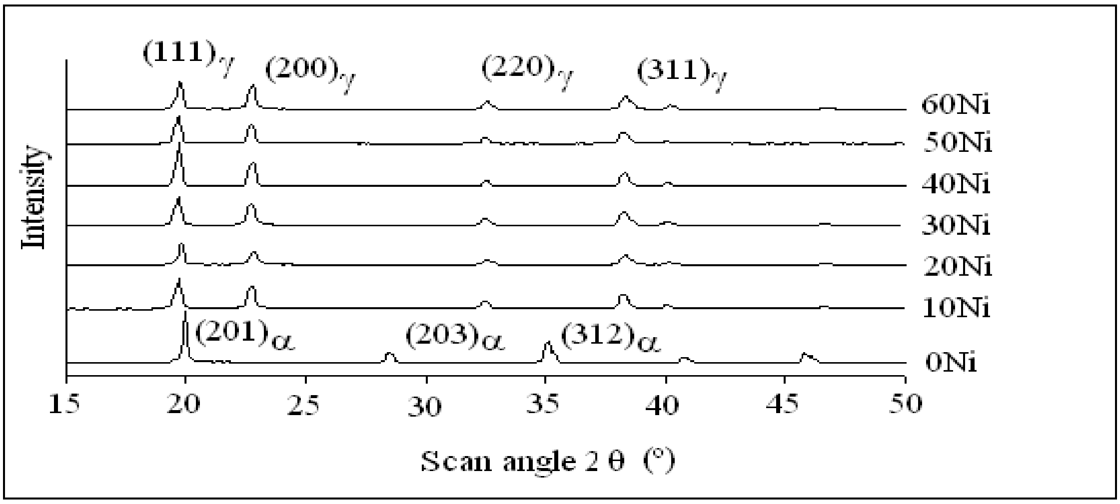
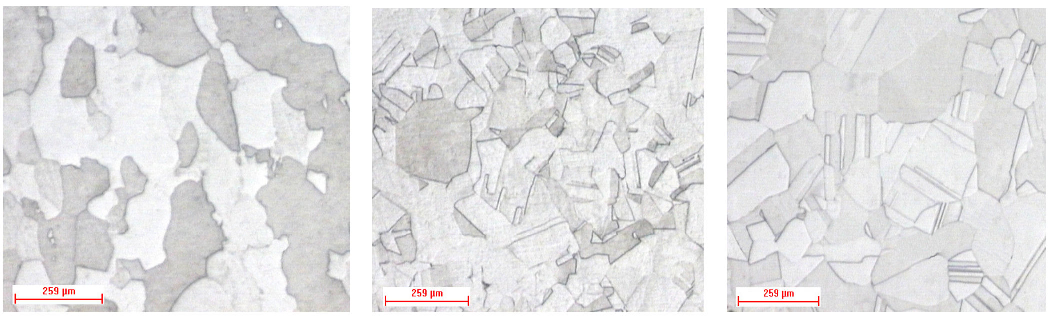


Figure 1: X-ray diffraction patterns for the investigated alloys.

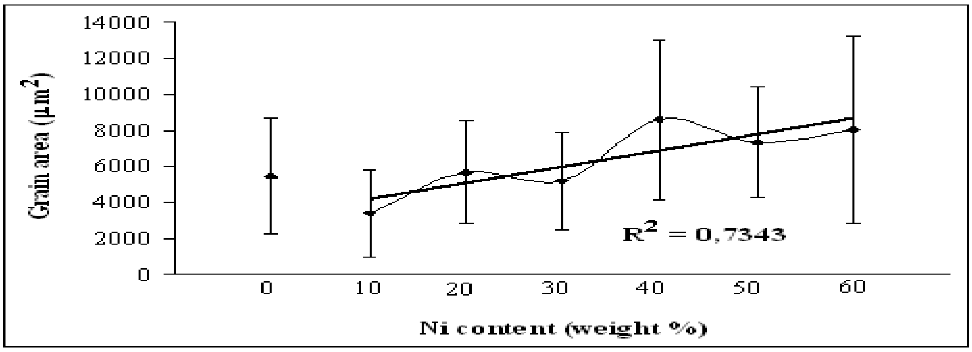
To insure the absence of precipitates, or other phases, the microstructural observation of the alloys was performed, and the microstructures are shown in figure 2.



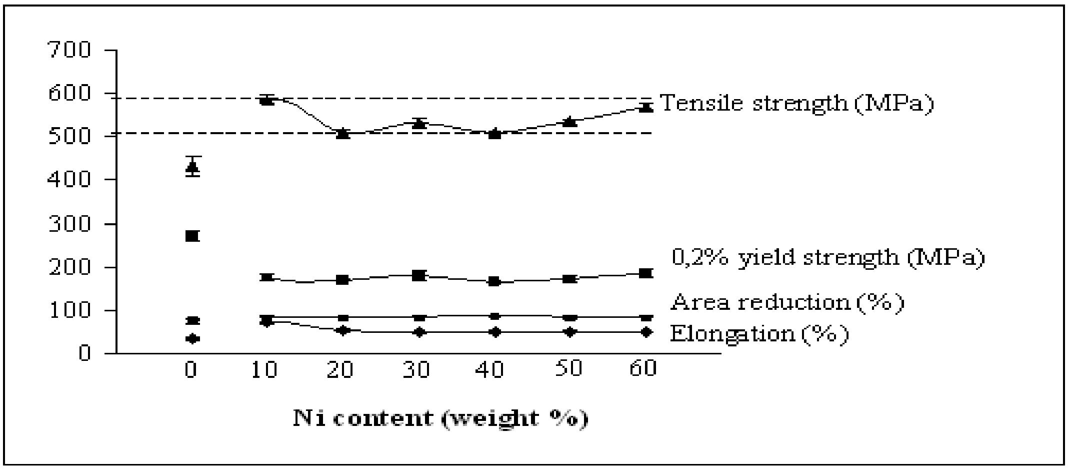
0Ni 10Ni 60Ni

Figure 2: Microstructures of Fe-Cr-(Ni) alloys. Sample 0%Ni is fully ferritic. Samples 10%Ni and 60 % Ni are fully austenitic with twins.

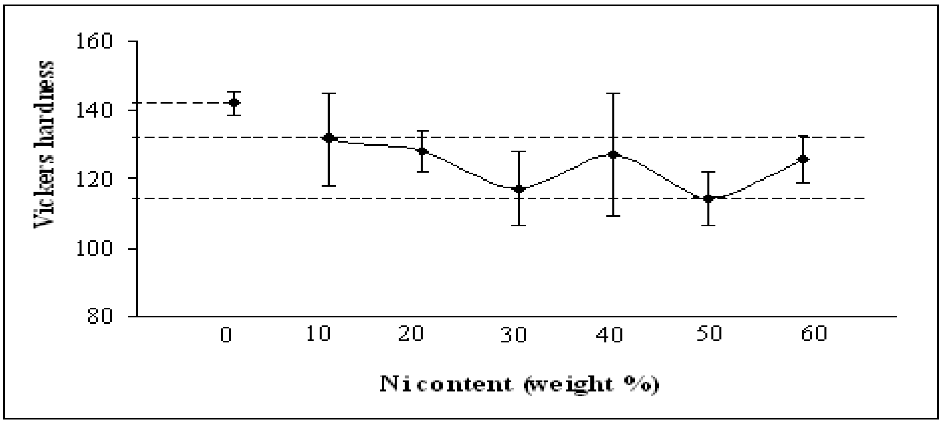
Figure 3a shows that the grain size was heterogeneous (high standard deviation) in all samples, with a linear correlation with Ni content. Tension tests are presented in figure 3b.



(a)



(b)



(c)

Figure 3: Effect of Ni content on (a) grain area, (b) mechanical properties and (c) Vickers hardness.

The 0%Ni alloy presented the highest 0,2% yield strength (271 MPa). The austenitic samples presented lower values for the 0,2% yield strength (160 to 185 MPa). This behavior can be associated to the crystal structure, once BCC materials, like ferrite, offer a higher resistance to crystalline planes sliding during deformation than FCC materials, like austenite. As can be seen in this figure, further Ni addition did not change significantly the yield strength. In the other hand, the 0%Ni alloy (ferritic) presented the lowest tensile strength (430 MPa), while in the austenitic samples, the Ni addition did change significantly the tensile strength, varying in the range from 507 to 580 MPa. The 10% Ni alloy composition is very similar to the 304L stainless steel (0.03 C, 1 Si, 2 Mn, 0.045 P, 0.03 S, 9-13 Ni, 18-20 Cr in weight %). Literature [4] gives for 304L: 170 MPa for yield strength and 450 MPa for tensile strength. The values obtained for 10% Ni alloy were 173 MPa for yield strength and 501 MPa for tensile strength. From these results can be said that the behavior of the studied alloy was compatible with the commercial steels. The area reduction and elongation were near the same for all alloys, independently of Ni content or structure (ferrite or austenite). Figure 3c shows that the 0%Ni alloy (ferritic) presented the highest hardness (142 HV). In austenitic alloys the hardness ranged from 115 to 130 Vickers, independent of Ni content, in a similar behavior as showed for yield strength.

4 CONCLUSIONS

Adding 10 to 60 weight % in a 18%Cr-0.01%C-0.2%Si-0.4%Mn base alloy was sufficient to change the structure from fully ferritic to fully austenitic, but was not observed significant changes in area reduction and elongation measured by tensile test. The ferritic alloy (without Ni) showed higher yield strength (270 MPa) than alloys with Ni addition (~170 MPa, independent of Ni content) and similar effect was observed in Vickers Hardness (142 for ferritic alloy against 115 to 130 in alloys with nickel additions). In the other hand, the ferritic alloy presented lower tensile strength (430 MPa) compared with austenitic alloys (507 to 580 MPa, independent of Ni content).

ACKNOWLEDGEMENTS

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REFERENCES

[1] WARBURTON, P. *Iron and Steel Institute Special Report*, nº 94, pp. 161, 1965.
[2] TAKATSU, S. Recent development in hard cutting tool materials. *High Temp. Mat. Proc.,* Vol. 9, pp.175, 1990.
[3] CHOUDHURY, I.A. and EL-BARADIE, M.A. Machinability of nickel-base super alloys: a general review, *J. Mat. Proc. Tech.*, pp.278, 1998.
[4] WASHKO, S.D. and AGGEN, G. *Wrought Stainless Steels.* ASM Handbook. Properties and Selection: Irons, Steels and High-performance Alloys. Vol. 1, pp. 841, 1990.