European Journal of Academic Essays 2(2): 87-89, 2015
ISSN (online): 2183-1904
ISSN (print): 2183-3818
www.euroessays.org

Mechanical Studies of the Novel Nickel-Free Stainless Steel as Alternative To the Conventional Stainless Steels

Moreno, João Roberto Sartori[1]; Slewinski, Anderson[2]

[1] Technological University Federal do Paraná, Department of Mechanical Engineering
Av. Alberto Carazzai,1640, Cornelio Procopio – PR, Brazil
joaosartori@utfpr.edu.br

[2] Technological University Federal do Paraná, Department of Mechanical Engineering
Av. Alberto Carazzai,1640, Cornelio Procopio – PR, Brazil
Anderson_sle@live.com

Abstract: This study aimed to analyze the mechanical behavior of an austenitic alloy high strength and free of Nickel taken as an alternative to replace the alloys commonly used in Ni-Ti and Cr-Ni for performance in prosthesis, instrumentation and devices both in the medical field as dental. The higher nitrogen and carbon contents in the alloy second ASTM F 2581 – 07, with 0.19%C; 0.42%Si; 10.38%Mn; 17.10%Cr; 3.05%Mo; 0,48%N and 0,02máx Ni, ensure a high purity, a combination of high strength and toughness and, simultaneously, a stable, completely austenitic, microstructure without ferrite and grain boundary precipitates. Tensile strength tests, toughness and hardness showed an important provision of care for biotechnologically application in the human body, for patients allergic to nickel. The biocompatibility, proved in testing, in combination with the very good corrosion resistance, provides the optimum condition and necessary safety for use in or in contact with the human body. An excellent polishability is ensured by the homogenous microstructure and the high purity of the material. A high potential for work-hardening, enabling strength of 1895MPa/micro hardness of 400HV showed particularly in tensile strength (1.8 times greater than alloys Ni-Ti and 2.9 times greater than alloys Cr-Ni), allows the use in high strength applications**.**

Keywords: austenitic alloy high strength; biotechnologically; polishability

---

1. Introduction

Nickel (Ni) is impregnated within the metals to stabilize austenite, nonmagnetic face centered cubic structure, and to improve mechanical strength.

But, the Nickel-containing stainless steels are only potential allergen or carcinogen, they are safe unless they are corroded and the high doses of nickel ions interact with body tissues as show the Figure 1. The conventional austenitic stainless steels such as type 304 and 316 have been widely used as structural materials due to their advantage of excellent corrosion resistance and formability. Manganese is a cheaper austenite stabilizing element than Ni and increases the solubility of N, a strong austenite stabilizing element.

However, it has been reported that the Mn addition causes a significant degradation in localized corrosion resistance due primarily to the formation of manganese sulfide inclusions.

In many austenitic stainless alloys, austenite structure is very unstable at room temperature and tends to transform into martensite to 10% when the steel is cold worked as reports [1].

But, the nitrogen controversially can lead to stabilization of austenite in these alloys, but high amounts of manganese likely to perform the role of to form the austenitic nickel matrix as [2].

The nickel-free alloys with nitrogen are technologically important because they have unique combination of strength, toughness and corrosion resistance properties. However, it is necessary to understand that the very process of manufacturing the same generates forced stabilization of austenite with nitrogen, because of its difficult solubility in alloy matrix as [4,5].

Corresponding Author: Joao Roberto Sartori Moreno, Technological University Federal do Paraná, *joaosartori@utfpr.edu.br*, +554335204083

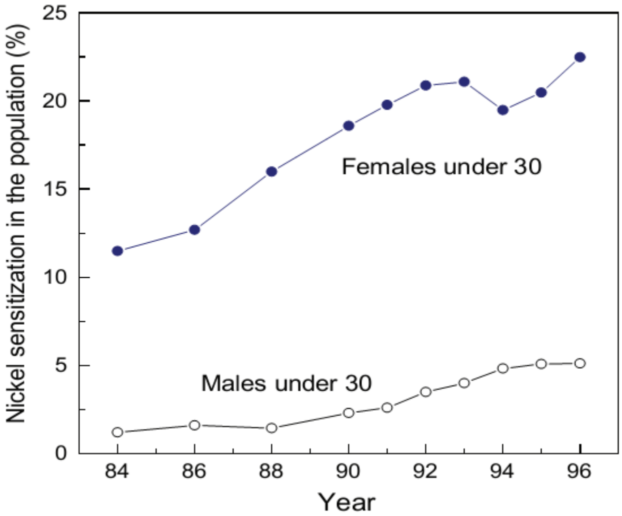

Figure 1 - Percentage of people sensitized to nickel allergy has risen dramatically over the years as shown [3]

2. **Materials and Methods**

The sample used in this investigation has the chemical composition (Table 1), where the nickel content is very low.

Table 1 - The composition of BÖHLER P558 alloy

Elements	**Cr**	**Ni**	**C**	**Mn**	**Si**	**Mo**	**N**
Content (%)	17.1	<0.02	0.19	10.38	0.42	3.05	0.48

The P558 alloy present in its composition a high Mn and N content and a negligible Ni content accordance with ASTME 112: 4–5 according to [6].Tensile test were performed according to ISO 6892/2002 ASTM E 8M and carried out in the test machine mark EMIC model DL-2000, as Figure 3, with test speed of 10 mm/min, however the micro hardness were made in the central cross section by a Micro Test Hardness, HV 1000B with Vickers indenter at a range of loads varying between 0.05 to 800g with three repeats for each measurement according to ASTM F 2581 as related [7,8].

Figure 2 - Machine EMIC model DL-2000 used for tensile tests.

3. Results and Discussion

The alloy structure of this study shown in Figure 3 below, where only shows an austenitic matrix. Because these alloys have a high content of Cr increases the solubility of N and solid formation occur δ ferrite during processing of the melt to the solid state and thus the solubility of N decreases. However, this is offset by the solubility of Cr and Mn presence leads to the formation of the austenitic phase increases the greater solubility of N in solid state according to [9,10].

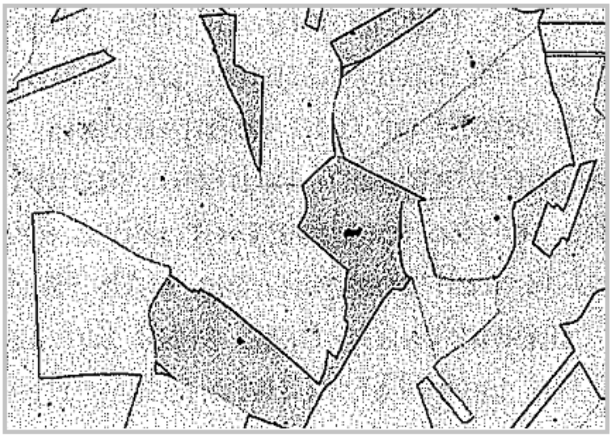

Figure 3 – Microstructural analysis of BÖHLER P558 alloy attacked in acid oxalic 10%

The tensile results showed an important point of these alloys where high resistance of the same, above 1800MPa, shows its superiority compared with standard alloys.

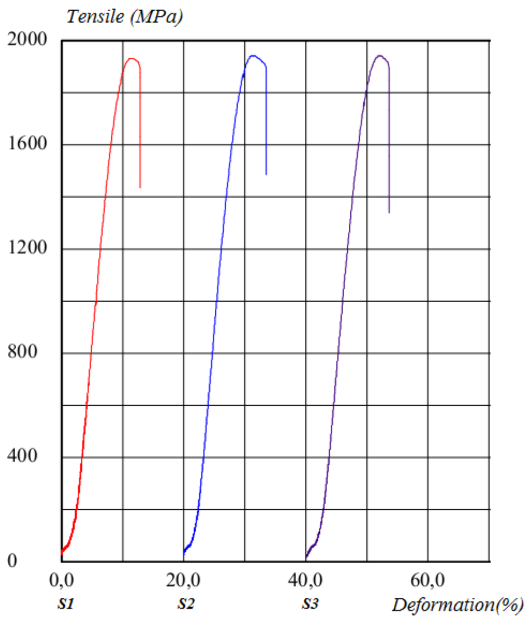

Figure 3 - Experimental curve tensile x deformation for 3 samples of the alloys

The Micro-Hardness at different loads on ASTM F2581 was shown in figure 4 where there has been nearly zero decrease from 400g load.

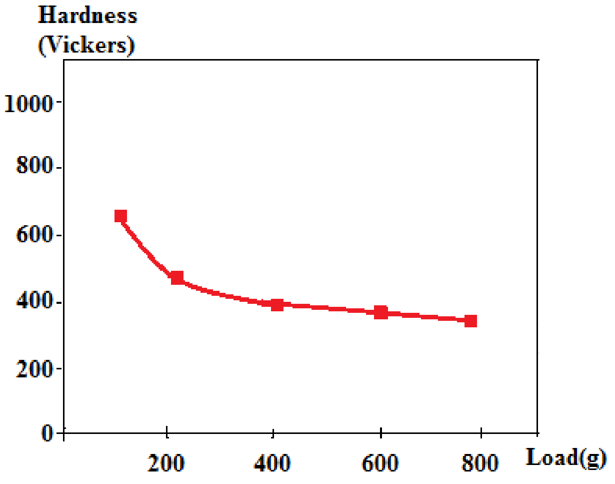

Figure 4 - Micro-hardness measurements at different loads up to 800g

The tensile strength of 1895MPa and medium micro hardness of 400 HV, for the three samples shows certain superiority over other usual alloys.

4. Conclusions

The adverse effects of nickel ions release in human body have prompted the development with nitrogen/manganese nickel-free austenitic stainless steels for biomedical applications.

In such alloys, nitrogen not only replaces nickel for austenitic structure stability but also significantly improves steel properties.

By combining the benefits of stable austenitic structure, high strength and good plasticity, better corrosion and wear resistance, and superior biocompatibility compared to the currently used 316L and 304 stainless steels the newly developed high-nitrogen nickel-free stainless steel will be a reliable substitute to the conventional medical stainless steels.

Acknowledgment

The authors gratefully acknowledge to all who believed in search

References

[1] P.C.Pistorius and M. Toit, “Low-Nickel Austenitic Stainless Steels: Metallurgical Constraints”; The Twelfth International Ferroalloys Congress Sustainable Future, 2010 Helsinki, Finland

[2] G. Balachandran, M.L. Bhatia, N.B. Ballal and P. Krishna Rao, "Some theoretical aspects on designing nickel free high nitrogen austenitic stainless steels", ISIJ International, 41(2001), pp.1018-1027

[3] M.O. Speidel and P.J. Uggowitzer “Materials in Medicine: Biocompatible Nickel-Free Stainless Steels to Avoid Nickel Allergy”; 1998; (Hochschulverlag AG an der ETH Zürich) p 191

[4] G. Balachandran, M. L. Bhatia, N. B. Ballal and P. K. Rao, "Some theoretical aspects on designing nickel free high nitrogen austenitic stainless steels", ISIJ INT, 41(9), 2001, pp. 1018-1027

[5] H. Berns; “Manufacture and application of high nitrogen steels” ISIJ Int., 1996, v. 36(7), p. 909-914

[6] H. Hanninen; J. Romu; R. Ilola; J. Tervo and A. Laitinen A. “Effects of processing and manufacturing of high nitrogen containing stainless steels on their mechanical, corrosion and wear properties” Journal of Materials Processing Technology 2001; 117, p. 424-430

[7] REN, Y.; WAN, P.; LIU, F.; YANG, K. and ZHANG, B.; “Nickel-free austenitic stainless steels for medical applications, Topical Review” Science and Technology of Advanced Materials; 2010; 11: 014105 (13pp) doi:10.1088/1468-6996/11/1/014105

[8] S. Weiss; A. Meissner and A. Fischer; Journal of Mechanical Behavior in Biomedical Materials; 2009, 2: 210.

[9]M. Inoue; M. Sasaki; Y. Katada; T. Taguchi, “Quantitative biocompatibility evaluation of nickel-free high-nitrogen stainless steel in vitro/in vivo”; Journal of Biomedical Materials Research B: Applied Biomaterials, 2014; 102b(1)

[10] M. Finia, N. Aldini, P. Torricelli, G. Giavaresi, V. Borsari, H. Lenger, J. Bernauer, R. Giardino, R. Chiesa and A. Cigada, “A new austenitic stainless steel with negligible nickel content: an in vitro and in vivo comparative investigation”; Biomaterials, 2003, 24:4929–4939

Author Profile

Joao Roberto Sartori Moreno received the PhD. degree in Materials Engineering from Federal University of San Carlos in 2000; Since 1996 I am Adjunct Professor UTFPR and researching in the Lab Materials.