

MAIA, Bruno Inácio^{1*}; FUTAMI, André Hideto²; DE OLIVEIRA, Marco Aurélio³; DALLA VALENTINA, Luiz Veriano Oliveira⁴

^{1,2,3,4} Centro Universitário SOCIESC - UNISOCIESC, Mestrado em Engenharia de Produção, Departamento de Pesquisa

* Correspondence author
e-mail: inaciodamaia@gmail.com

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ABSTRACT

Niobium alloy steels are still little known and debated when applied to the metallurgy industry, including cold forming process. It is not much clear about its characteristics and your mechanical performance when compared to traditional steels, which the market already uses. The possibility of input new materials, reducing costs and generating competitiveness is the basis for researches that can generate new opportunities for industries. In this article, we showed the possibility of withdrawing the heat treatment process, which guided the execution of the tests presented here. This paper deals with the performance comparison of SAE 1312 MOD steel compared to ISO 898-1, which deals with mechanical performance for bolts. The tests were correlated with the bolts of 8.8 resistance class, which currently have heat treatment. It is possible to evaluate the positive performance of the niobium-alloyed steel (SAE 1312 MOD), despite the occasional performance limitations in some attributes addressed in ISO 898-1.

Keywords: *Conformation, Niobium, Innovation, Competitiveness, Microalloyed*

1. INTRODUCTION

Over the years and especially in the 21st century, the production chain has faced various pressures for process optimization and competitiveness gains. Many studies have been trying for years to optimize metallurgical processes, either to achieve technological improvements, gain competitiveness, improve the environment, or simply test new technologies for the development of new products or innovations. This is no different in the fastener industry. In the production stages of the fasteners many inputs are used, and some of them have a strongly negative impact, such as the energy used in the heat treatment which is not (or very little) renewable and the tempering medium that needs a very specific treatment and destination to not become another pollutant [2,3,4].

The achievement of better mechanical properties of the steel, with the optimization of processes and reduction of manufacturing costs, is a permanent objective of the siderurgical companies today. The use of steels with microalloyed to achieve this purpose has been growing in recent years since with these

constituents, and it is possible to obtain a high quality product with lower production costs when compared to the conventional steel manufacturing process [1,5,6].

It is in this scenario that micro-alloyed steels assume a very peculiar role: By its use, some stages of the process can be eliminated, contributing to both the reduction of costs and the decrease of inputs such as energy or quenching medium (water or oil). Since the 1980s, several authors have explored the line of microalloyed for cold forging and present very consistent results in their work, guaranteeing products that combine good mechanical properties with sufficient ductility in the pieces. These studies are based on the use of various hardening mechanisms presented in metallurgy alternately to the phase transformation reactions represented by the quenching and tempering in the production of fasteners. Using the other hardening mechanisms (solid solution, grain size control, precipitation, and hardening), it is shown in this work the feasibility of producing screws of class 8.8 without the need for the tempering and tempering process [3,7,9].

For the successful use of microalloyed

steels, the development of chemical composition with a certain amount of microalloying is not enough. It is necessary to optimize the parameters of the productive process that influence the properties of the material [8,10,11].

Thus, parameters such as casting and rolling temperature, lamination cooling rate, and degree of cold reduction of the material are determinant for the performance of the properties. For the reasons described above, in this work, process conditions were tested in order to optimize the properties and obtain a product that meets the specifications of the standard ISO 898-1 - Mechanical Properties.

2. MATERIALS AND METHODS

The products were manufactured according to drawings, tools, specifications, and cold formed processes by a company, which produces these types of fasteners and has the appropriate machines and equipment to manufacture it. The first step was to cold form in bolt makers machines, the second was the automatic thread laminating, and the last was the heat treatment on automatic and continuous oven, only for bolts made by steel SAE 10B30. The steels used to manufacture the samples were SAE 1312 MOD and SAE 10B30, as shown in Table 1, it contains the chemical compositions of these materials. The reading and control of steel's chemical composition accomplished through the spectrometer Shimadzu PDA 7000.

Currently, the bolts are produced with SAE 10B30 steel, which fits the requirements for heat treatment and performance 8.8, according to ISO 898-1.

For the production of a lot of small and medium-sized bolts, the forging processes, especially in the cold, present several advantages in relation to the machining process, such as greater utilization of the raw material, higher speed, higher productivity and increased strength due to hardening. The production batch diameter was M16. The SAE 10B30 steel bolts went through the heat treatment process. However, bolts made SAE 1312 MOD steel did not pass – on heat treatment. Both used the same bolt maker for cold forming, and the same set of tooling, the only change in the process was the addition of the heat treatment for SAE 10B30 steel products.

During the process of reheating a

microalloyed steel, the microalloying elements are initially present in the form of carbides, nitrides, or carbonitrides. As the temperature is increased, these precipitates gradually dissolve, this dissolution be partial or complete. While present, such compounds inhibit grain growth austenitic. This temperature, solubility limit, can be determined thermodynamically and varies according to the carbon and metal content present in the steel.

Figure 1 confirms the mechanisms of SAE 1312 MOD microstructure. It is clearly observed that at high cooling rates (a), the material becomes predominantly bainitic-ferritic and that, by reducing the rate, the percentage of perlite in the microstructure of the material increases, favoring lower limit values of resistance and flow were not the mechanism of interphase precipitation. In Figure 2, the microstructure of SAE 10B30 without heat treatment can be assessed with an expansion of 500X. The SAE 10B30 micro-alloyed carbon steel does the Perlite matrix with a grain boundary ferrite network.

The tests used to evaluate the performance between samples were specified in ISO 898-1. They were composed of; minimum ultimate tensile loads, Vickers hardness, charpy, Strictness, and proof load. The tests were realized out in the internal metallurgy laboratory of organization, the same equipment was used, and the tests performed by the same operator, 25 samples each one, were used for each measurement type after the dispersion an average of each type of material were evaluated. For the charpy test were used just 5 samples.

After the numerical simulation and engineering projects, two types of samples as inspected, as can be observed according to Figure 3.

The forging forces values obtained with the numerical simulation, to forge samples with different materials can be seen in table 2. It is possible to visualize the differences in the force of conformation and the percentage of force put on SAE 1312 mod steel.

3. RESULTS AND DISCUSSION:

The results obtained can be evaluated in Table 3. According to the comparison between the specification of the standard and the average of the 25 results achieved for each steel type, the product performance and the steel change can be valid.

The results show the averages of values obtained in the measurement of the 25 types of steel samples, and only the charpy test had 5 samples. Comparing the results of the test force for the bolts manufacturing, approximately 50% plus force is required if using the SAE 1312 MOD micro-alloyed carbon steel. Therefore, it can be concluded that the wear of labor tends to be higher than that of the bonded SAE 10B30 carbon steel. It is important to consider that the lifespan also depends on other factors that are not oriented to the present, such as the type of lubrication used during the editing, the material used in the manufacturing of the dies (quality and type of tool steel), the thermal treatment of its operations and the surface condition, among others.

It was not possible to evaluate the tool wear because the batch was experimental and was manufactured a small batch. For a more in-depth analysis of the tools' performance, it is necessary to make lots of scales and measure the impacts in all tools, stage per stage.

Severe deformations can cause problems like cracks in the material or even the poor filling of material in the head of the bolts. This fact can be related to the presence of sulfur, found in the chemical composition of the micro-alloyed carbon steel, since the same influence in the decrease of the formability of the material.

In Figure 4, is possible to evaluate the photomicrography microstructure of SAE10B30 steel after austenitization. It is possible to prove the transformation of the material, and the martensitic structure, matrix martensitic revege level of transformation is 100%, which ensures that the products conforming to this steel comply with the requirements of ISO 898-1.

4. DISCUSSION:

It was possible to evaluate in the metallographic analysis that micro-alloyed SAE 1312 MOD steel does not present a martensitic microstructure, but, ferritic-pearlite. The results presented in Table 4, are almost totally in resistance class 8.8 according to ISO 898-1, except for the result of the strictness. The charpy assay is generally required for products with a strength class higher than 8.8, as ISO 898-1 states that this test may be required for smaller resistance classes, so this study has addressed this situation. The result was negative because it was not in accordance with the 27J requested in

the standard.

In addition, the conformation of this material presented difficulties in its use, since the simulations showed a greater stamping force necessity for the conformation of the samples. These data may indicate greater wear of the tooling and a limitation according to the severity of the deformations. It's observed as positive results the full attendance to the tests of minimum ultimate tensile loads, proof load, and Vickers hardness. Carbonation, as well as decarburizing, are characteristic of thermally treated parts after forming. Therefore, bolts made of SAE 1312 MOD steel do not suffer from these phenomena.

Due to the results obtained with the physical and mechanical tests carried out in this work, it can be inferred that the SAE 1312 MOD micro-alloyed niobium steel is characteristic because it is a lower ductility material and has less tenacity. Because of this, the physical and mechanical properties established by ISO 898-1 were compromised on strictness test.

5. CONCLUSIONS:

This study presents in a succinct and direct way, the possibility of innovating in steel specifications to obtain new products, reducing the process of thermal treatment and to make possible the use of micro-alloyed steel (SAE 1312 MOD) in the cold forming of bolts.

Some immediate benefits can consider the change of steel used may bring to the organization:

- Reduction of operational costs and waste management;
- Optimization of the use of resources, waste, disposal / reduction of waste, effluents, and emissions;
- Gaining environmental awareness throughout the the organization;
- Employee risk reduction and improvement health and safety conditions of the worker;
- Improved operational efficiency of the plant, energy efficiency, increased productivity competitiveness;
- Recovery of some wasted materials, minimization or elimination of raw materials and other inputs that impact the environment;
- Improved company image and greater Clients satisfaction;
- Better compliance with environmental standards, reduction of fines and penalties for pollution, and better relationships with environmental agencies

and with the community.

For future studies, it is advisable to develop manufacturing batches in smaller gauges to be able to make service comparisons with ISO 898-1. This study complements the current literature in the knowledge field of cold-formed steels involving niobium alloys.

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Table 1. Chemical composition (wt%) of the SAE 1312MOD and SAE 10B30

Steel	SAE 1312 MOD	SAE 10B30
C	0,12	0,32
Si	0,23	0,28
Mn	1,74	0,9
P	0,022	0,01
S	0,021	0,02
Cr	0,23	0,37
Mo	0,06	0,05
Nb	0,04	-
Ni	0,25	-
Ti	0,03	-
Cu	0,33	-
Al	0,027	-
N	0,100	-
B	-	0,0025

Table 2. Forging Force

Material	Forging Force (kN)			
	1st Stage	2nd Stage	3rd Stage	4rd Stage
SAE 1312 MOD	52	136	15	12
SAE 10B30	34	93	10	6
Plus forging force (%) SAE 1312 MOD / SAE SAE 10B30	52,94%	46,23%	50%	50%

Table 3. Tests results for SAE 1312 mod. and SAE 10B30

Test Specification M16 Class 8.8 per ISO 898-1	Specification ISO 989-1	Results of SAE 10B30	Standard Deviation SAE 10B30	Results of SAE 1312 MOD.	Standard Deviation SAE 1312 MOD.
Minimum Ultimate Tensile Loads (N)	125.000	142.200	7.280	128.600	1.055
Proof Load (N)	91.000	91.000	-	91.000	-
Vickers Hardness, (HV)	250 - 320	309	10.81	260	8.77
Charpy (J) "V" -20°C	>27	16	2.4	14	1.8
Strictness (%)	>52	54.8	1.45	28.4	3.68

Table 4. Results of testing SAE10B30 vs SAE 1312 mod

Test Specification M16 Class 8.8 per ISO 898-1	Specification n ISO 989-1	Results of SAE 10B30		Status SAE10B30	Results of SAE 1312 MOD		Status SAE 1312 MOD
		Min.	Max.		Min.	Max.	
Minimum Ultimate Tensile Loads (N)	125.000	134.920	149.480	OK!	127.545	157.155	OK!
Proof Load (N)	91.000	91.000	-	OK!	91.000	-	OK!
Vickers Hardness, (HV)	250 - 320	298.19	319.81	OK!	251,23	285.63	OK!
Charpy (J) "V" - 20°C	>27	13.60	18.40	X	12.20	16.60	X
Strictness (%)	>52	53.35	56.25	OK!	24,72	47.88	X

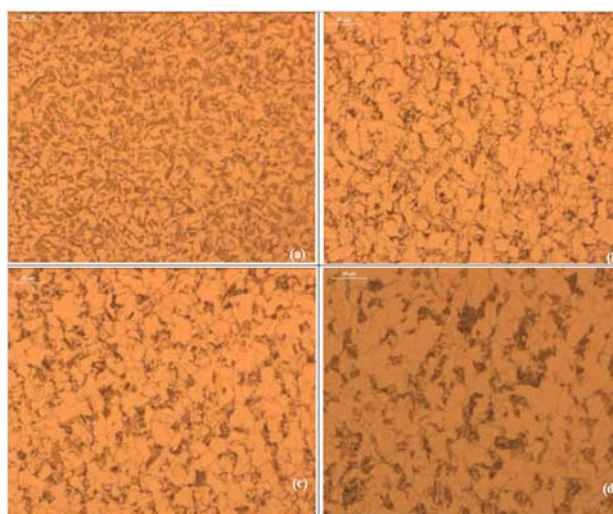


Figure 1. Optical micrographs of SAE 1312 mod steel coiled at high temperature with cooling rate: (a) high; (b) mean; (c) low and (d) very low.

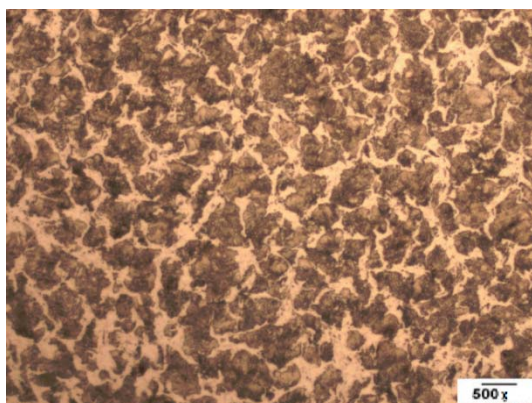


Figure 2. Photomicrography of SAE 10B30 without heat treatment (expansion 500X)

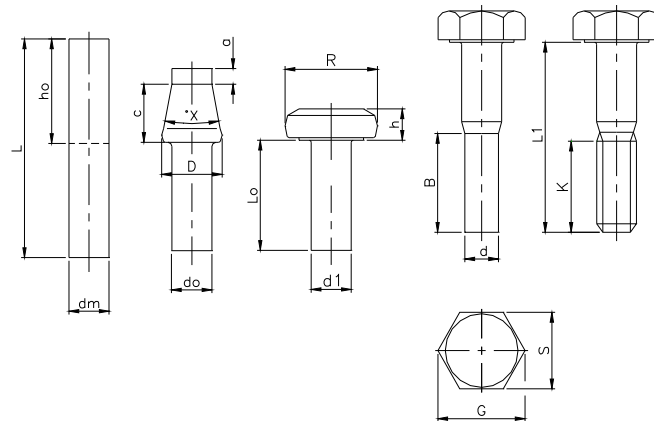


Figure 3. Bolts Samples. SAE1312 Mod. Steel.

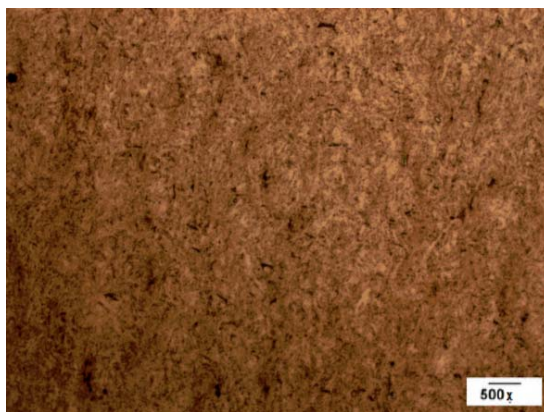


Figure 4. Photomicrography of SAE 10B30 with heat treatment (expansion 500X)