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Original Article

Application of a homemade procedure for manufacturing of a rod mechanical spare part

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ABSTRACT

This paper presents the application of a homemade procedure for manufacturing of mechanical replacement parts installed in machinery to produce steel rod frames. The homemade procedure was applied to the imported rod part selected here due to its paramount importance for the proper functions of the equipment, the intensity of service loads, its high costs and poor availability. The imported rod part, which is produced by the original manufacturer of the equipment, is used to move a hammer part up and down to correctly position the steel wire during welding. It ensures that the steel rod frames can be properly constructed. The homemade procedure here adopted for manufacturing of the rod part is based on obtaining comparable chemical composition, microstructure and mechanical properties of the imported part. The main goal is to reduce the costs and delivery time for the acquisition of the rod part as well as have an adequate stock of it. The index used here for the assessment of the homemade procedure applied to the rod part is less than unity (0.18). This means an economic efficiency in the equipment of about 28.0% and confirms that the manufacturing of the rod part in Brazil is a viable procedure.

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1. Introduction

Currently in the world market there are many key components in commercial mechanical machinery that must be imported. More specifically, in the construction industry several imported operational and maintenance spare parts are needed in machineries for manufacturing elements that comprise structural frames such as steel rod frame.

Operational spare parts are different from maintenance ones only because they are in direct contact with the raw material that comprise the production line. However, both operational and maintenance spare parts are frequently submitted to mechanical stresses and wear so that after reaching the end of their service life, they must be replaced to ensure proper operation of the process as well as the quality of final products. Demand forecasting of mechanical spare parts frequently occurs at often unpredictable intervals and the

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common practice of importing such mechanical components can lead to problems caused by high investments (including import tariffs) and delay in deliveries. This means that these components may not be always available in stock when needed which can significantly affect equipment efficiency and hence the amount of produced steel rod frames. One alternative for the reduction of spare parts imports is the development of a systematic homemade procedure to manufacture mechanical replacement parts. This can enable a shorter production cost and delivery times as well as a direct contact with domestic suppliers. In Brazil, for example, this practice has proved workable and beneficial for the guide ruler part installed in commercial mechanical machinery to produce steel rod frames [1]. In such a case, the application of the new manufacturing procedure to the guide ruler part allowed an increased economic efficiency in the equipment of about 83.0%. Based on the previous results herein [1] and on the fact that works related to homemade procedures for manufacturing of mechanical replacing parts are very scarce in the technical literature, the presented work follows the homemade procedure developed by Oliveira et al. [1] and points out results of its proper implementation to the imported rod part.

2. Materials and methods

Based on its relevancy on the equipment performance, demand and amount of operational hours, as well as price and stock level, the investigated part is a rod installed in commercial mechanical machineries to produce steel rod frames. The rod part is responsible for moving a hammer part up and down in order to place the steel wire directly on the weld position, so the rod frame can be properly built, as displayed in Fig. 1(a)–(c). The principles and methods of sequence analysis that constitute the homemade methodology here used for manufacturing of the rod part are very well explained in our previous work [1]. Fig. 2 gives an overview of homemade procedure. At the time of this study, the most suitable technique

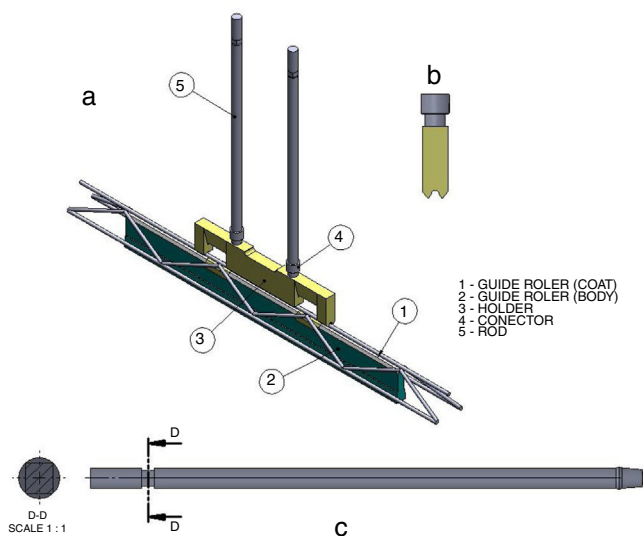


Fig. 1 – (a) Overview and (b) lateral view of the components of welding machinery used in steel rod frames manufacturing process; (c) lateral view of the rod part.

to determine the chemical composition of the type of alloy used to manufacture the imported and homemade rod parts was not available for chemical analysis. Thus, the chemical composition of these parts here used for comparison is that informed by their original manufacturers. Representative specimens were mounted in epoxy resin and ground using SiC abrasive paper down to 4000 grid and then polished using 3 μm diamond as well as 0.05 μm colloidal silica solutions. The specimens for optical microscopy were etched with 10% ferric chloride solution for 20 s. Ten images were taken for each concerned condition to evaluate the average grain size in the imported and homemade materials, according to the standard test procedures [2]. Rockwell hardness tests were performed using a load of 150.0 kgf along the transversal sections of the imported and homemade manufactured specimens. Using Eqs. (1) and (2) [3–5], respectively, tensile strength (σ_t) and yield strength (σ_y) were estimated from the hardness values:

$$\sigma_t [\text{MPa}] = \text{HB}[\text{kgf}] \times 3.45 \quad (1)$$

$$\sigma_y [\text{MPa}] = \frac{\text{HV} [\text{MPa}]}{3} \quad (2)$$

Ten indentations were made, and the average was taken as the representative value for the material.

3. Results and discussion

The DIN X5CrNi18.9 alloy, an austenitic stainless steel in the quenched condition (without any subsequent thermochemical treatment), is the original material used by the supplier of the imported rod part. The microstructure of the DIN X5CrNi18.9 alloy is basically polygonal γ -austenite with an ASTM grain size of 8 (around 17 μm), as shown in Fig. 3. The presence of an external magnetic field created during the welding process requires a rod component made of a material with fully austenitic microstructure, i.e., a non-magnetic material. It considerably reduces the possibility of having a magnetic attraction between the equipment and its

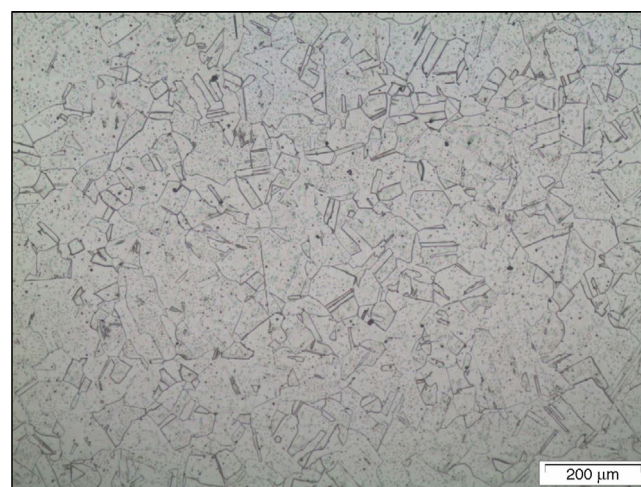


Fig. 3 – Optical micrograph of the imported rod part cross section. DIN X5CrNi18.9 alloy inhibiting polygonal austenite grains.

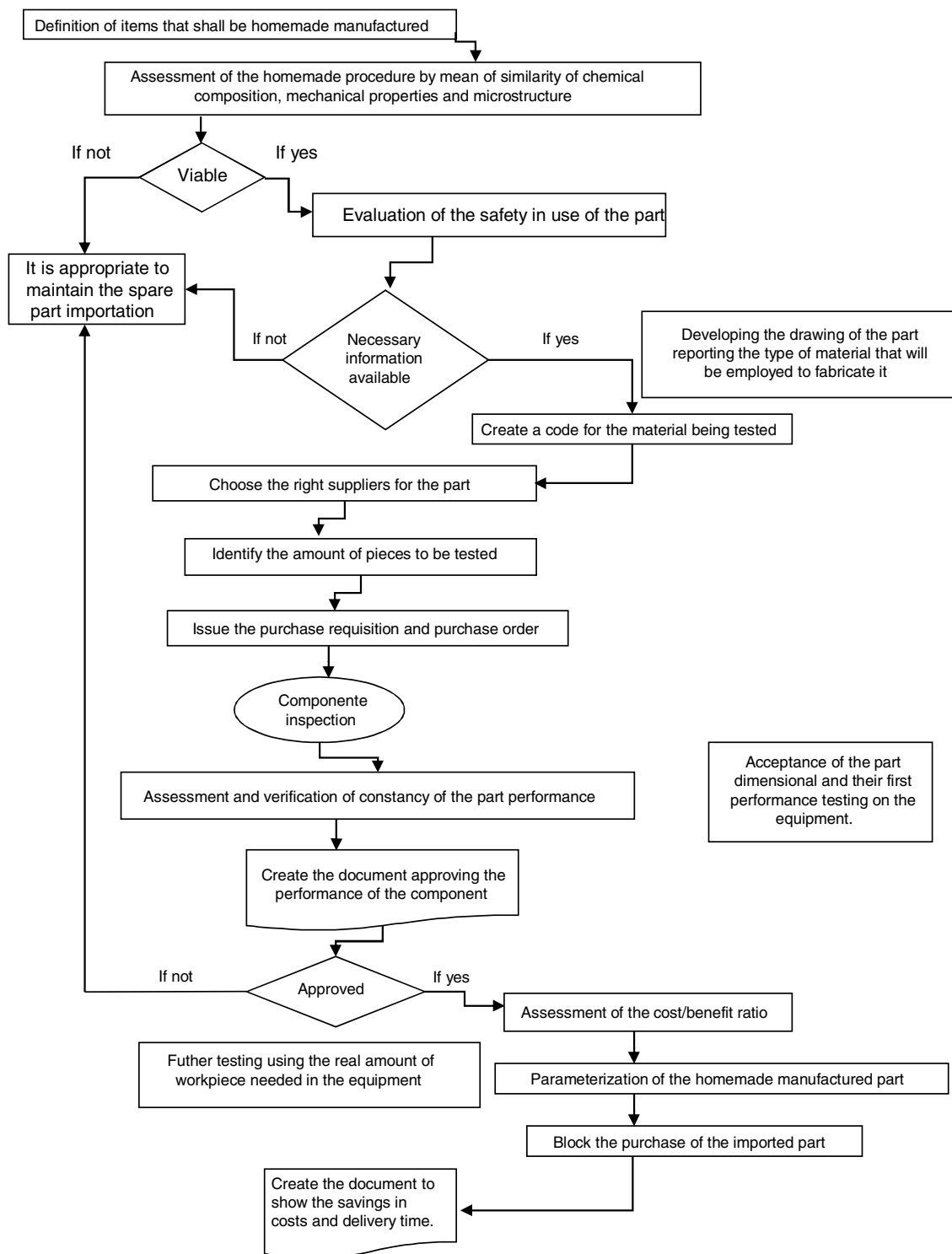


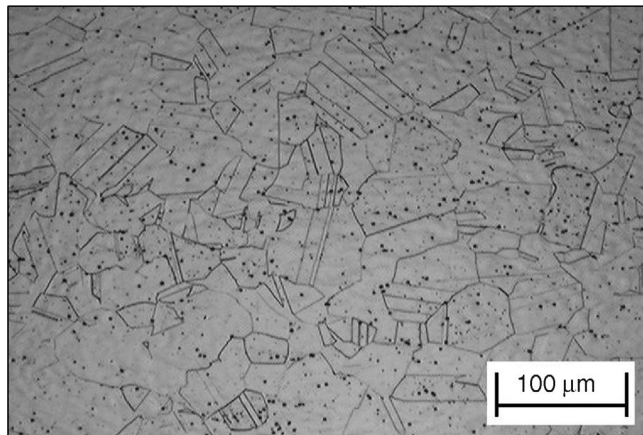
Fig. 2 – The sequence of activities developed during the homemade procedure for manufacturing of the rod part.

mechanical spare parts and, consequently, minimizes the friction between them and the excessive components wear. Such excessive components wear is detrimental to the manufacturing process, because it leads to a slack between the pieces. A consequence of this is that the wire misaligns and escapes from the guide ruler part during welding, a leading cause of wire bending and poor welding quality. Taking into account

all these minimum requirements for an efficient performance of the rod part, the austenitic stainless alloy selected was the AISI-SAE 304 steel to produce the homemade manufactured rod part. It is similar to the DIN X5CrNi18.9 alloy and contains between 18% and 20% chromium with addition of 9.0–11.0 (in wt.%) nitrogen (both of which also contribute to their high corrosion resistance). As noted in [Table 1](#)

Table 1 – Chemical composition (wt.%) of the imported and homemade manufactured parts, according to the data provided by the manufactures.

Specification	Composition, wt.%								
	C	Si	Mn	P	S	Cr	Ni	Mo	Cu
X5CrNi18-9	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	18.00 20.00	9.00 11.00	–	–
AISI 304	0.022	0.68	1.88	0.032	0.027	18.2	10.1	0.33	0.38

**Fig. 4 – Optical micrograph of the homemade manufactured rod part cross section. AISI-SAE 304 alloy inhibiting polygonal austenite grains.**

, both materials (DIN X5CrNi18.9 and AISI-SAE 304 steels) have a very similar chemical composition. And, according to the data provided by the manufactures, the main difference between these alloys is the amount of molybdenum and copper elements present in them. The stainless steels of series 200 and 300 such as the DIN X5CrNi18.9 and AISI-SAE 304 steels are those which exhibit a no-magnetic single-phase, the face-centered cubic (fcc) structure, that can be maintained at room temperature. The homemade manufactured rod part was hot rolled and solubilized at around 1100 °C for 2 h followed by quenching in order to avoid the $\gamma \rightarrow \alpha$ (ferrite phase) as well as the undesirable formation of carbides [6]. Subsequently it was machined in order to produce a shape very close to the imported one. Fig. 4 shows an optical micrograph of the homemade manufactured rod part. The microstructure basically consists on austenitic grains with an ASTM grain size of 7 (around 32 μm). Both (DIN X5CrNi18.9 and AISI-SAE 304) steels show a similar average grain size in the presented conditions

Table 2 – Properties of the imported and homemade manufactured part.

Test	Specification X5CrNi18-9	Specification AISI 304
Vickers hardness (HV)	190.0 kgf [1863.26 MPa]	184.0 kgf [1804.42 MPa]
Brinell hardness (HB)	188.9 kgf	174.80 kgf
Tensile strength, MPa	651.7	603.10
Yield strength, MPa	621.1	601.5

which is in turn responsible for their observed mechanical properties, as listed in Table 2. As noted in Table 2, the rod part produced in austenitic stainless AISI-SAE 304 steel has very similar measured mechanical properties with those presented by the DIN X5CrNi18.9 one. It should furthermore be mentioned that a wide range of austenitic stainless steels can suit such application as they present similar microstructure and mechanical properties to those of AISI-SAE 304 one [7]. However, it is not feasible for financial reasons due to their higher levels of chrome and nickel. The AISI-SAE 304 steel possess, for example, the minimum nickel content of 8% required to fully stabilize the austenite phase at room temperature without any martensite formation and intergranular corrosion occurrence [6]. In such manner, it can be affirmed that the homemade manufactured rod part in AISI-SAE 304 steel is suitable and more financially favorable for its application in the machinery.

The main homemade manufactured rod part failure mechanism responsible for the end of its service life is the excessive wear on its bottom end (the region of connection between the rod and hammer parts). The features of pre-test performance and post-test performance AISI-SAE 304 steel parts are shown in Fig. 5(a) and (b). Both the imported and homemade manufactured rod parts showed an excessive wear after 58 days of use. From Fig. 5(b) it is evident the wear at the bottom end region of the part. Table 3 exhibits the Equation as well as the parameters used to calculate η index for each type of rod part. The η index is used here to assess the feasibility of the homemade

**Fig. 5 – The bottom end region of (a) an unused (wear-free) and (b) a wearing rod part.**

Table 3 – Values that were taken as reference in order to calculate the parameter η .

Parameters	Specification X5CrNi18-9	Specification AISI 304
Price/unit, R\$	281.54	202.00
Useful life, days	58	58
Amount of parts/year	$365/58 * 2 = 12.58$	$365/58 * 2 = 12.58$
Annual cost, R\$	$12.58 * 281.54 = 3543.54$	$12.58 * 202.00 = 2542.00$

Table 4 – Values of the parameter η for imported and homemade manufactured rod parts.

Specification	η , R\$ × months/ton
X5CrNi18-9	$\eta_{\eta} = 3.70$
AISI 304	$\eta_i = 20.62$
	$\eta_{\eta}/\eta_i = 0.18$

manufacturing process [1]. Table 4 summarizes the values of parameter η and η_{η}/η_i ratio. The η_{η}/η_i ratio is less than one, which defines the homemade procedure as viable and their implementation into operation resulted in an annual economy saving of about 18.0% per equipment, i.e., R\$ 638.00 per equipment considering values and buy-prices of 2009.

4. Conclusions

The homemade procedure performed by Oliveira et al. is a feasible alternative development strategy of replacement parts in Brazil. Its application to the rod part resulted in an annual economy per equipment of about 18.0% (i.e., R\$ 638.00), considering the data of 2009.

Solubilizing treatment after hot rolling showed to be a suitable and feasible metallurgical procedure to manufacture the rod part. The amount of removed material from the bottom end region of both imported and homemade manufactured rod parts was comparable (about 3%) during the same tested period of the equipment.

Delivering time can decrease from 120 to 30 days considering the data from 2009 and the direct contact with national suppliers can be very positive reason to implement the homemade manufactured guide ruler.

Conflicts of interest

The authors declare no conflicts of interest.

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