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

Verona Biancardi Oliveira b,*, Aline Maria Frez Ouvreney a, Claudine Guimarães Leite Cardoso b, Carlos Sérgio da Costa Viana b

a Polytechnic Institute, University of Rio de Janeiro State, Department of Materials, Nova Friburgo, RJ 28625-570, Brazil
b Fluminense Federal University, Department of Metallurgy, Volta Redonda, RJ 27255-250, Brazil

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.

* Corresponding author.
E-mail: verona@iprj.uerj.br (V.B. Oliveira).
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2238-7854/© 2018 Brazilian Metallurgical, Materials and Mining Association. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
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 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:

\[ \sigma_t [\text{MPa}] = \frac{HB[\text{kgf}]}{3.45} \]  

(1)

\[ \sigma_y [\text{MPa}] = \frac{HV[\text{MPa}]}{3} \]  

(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 nonmagnetic material. It considerably reduces the possibility of having a magnetic attraction between the equipment and its...
Definition of items that shall be homemade manufactured

Assessment of the homemade procedure by mean of similarity of chemical composition, mechanical properties and microstructure

If not

If yes

Viable

Evaluation of the safety in use of the part

It is appropriate to maintain the spare part importation

If not

If not

Necessary information available

If yes

Developing the drawing of the part reporting the type of material that will be employed to fabricate it

Create a code for the material being tested

Choose the right suppliers for the part

Identify the amount of pieces to be tested

Issue the purchase requisition and purchase order

Componente inspection

Assessment and verification of constancy of the part performance

Create the document approving the performance of the component

If not

If yes

Approved

If yes

Assessment of the cost/benefit ratio

Further testing using the real amount of workpiece needed in the equipment

Parameterization of the homemade manufactured part

Create the document to show the savings in costs and delivery time.

Block the purchase of the imported part

Acceptance of the part dimensional and their first performance testing on the equipment.

Fig. 2 – The sequence of activities developed during the homemade procedure for manufacturing of the rod part.
Table 1 – Chemical composition (wt.%) of the imported and homemade manufactured parts, according to the data provided by the manufactures.

<table>
<thead>
<tr>
<th>Specification</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>X5CrNi18-9</td>
<td>≤0.08</td>
<td>≤1.00</td>
<td>≤2.00</td>
<td>≤0.045</td>
<td>≤0.030</td>
<td>18.00</td>
<td>9.00</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>AISI 304</td>
<td>0.022</td>
<td>0.68</td>
<td>1.88</td>
<td>0.032</td>
<td>0.027</td>
<td>18.2</td>
<td>10.1</td>
<td>0.33</td>
<td>0.38</td>
</tr>
</tbody>
</table>

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 2h followed by quenching in order to avoid the γ → α (ferrite phase) as well as the undesirable formation of carbidizes [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 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

<table>
<thead>
<tr>
<th>Test</th>
<th>Specification X5CrNi18-9</th>
<th>Specification AISI 304</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vickers hardness (HV)</td>
<td>190.0 kgf [1863.26 MPa]</td>
<td>184.0 kgf [1804.42 MPa]</td>
</tr>
<tr>
<td>Brinell hardness (HB)</td>
<td>188.9 kgf</td>
<td>174.80 kgf</td>
</tr>
<tr>
<td>Tensile strength, MPa</td>
<td>651.7</td>
<td>603.10</td>
</tr>
<tr>
<td>Yeld strength, MPa</td>
<td>621.1</td>
<td>601.5</td>
</tr>
</tbody>
</table>

Fig. 5 – The bottom end region of (a) an unused (wear-free) and (b) a wearing rod part.
manufacturing process [1]. Table 4 summarizes the values of parameter \( \eta \) and \( \eta_0/\eta_i \) ratio. The \( \eta_0/\eta_i \) 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.

### Table 3 – Values that were taken as reference in order to calculate the parameter \( \eta_i \).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X5CrNi18-9</td>
<td>AISI 304</td>
</tr>
<tr>
<td>Price/unit, R$</td>
<td>281.54</td>
<td>202.00</td>
</tr>
<tr>
<td>Useful life, days</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>Amount of parts/year</td>
<td>365/58 * 2 = 12.58</td>
<td>365/58 * 2 = 12.58</td>
</tr>
<tr>
<td>Annual cost, R$</td>
<td>12.58 * 281.54 = 3543.54</td>
<td>12.58 * 202.00 = 2542.00</td>
</tr>
</tbody>
</table>

### Table 4 – Values of the parameter \( \eta \) for imported and homemade manufactured rod parts.

<table>
<thead>
<tr>
<th>Specification</th>
<th>( \eta ), R$ x months/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>X5CrNi18-9</td>
<td>( \eta_i = 3.70 )</td>
</tr>
<tr>
<td>AISI 304</td>
<td>( \eta_i = 20.62 )</td>
</tr>
<tr>
<td></td>
<td>( \eta_i/\eta_i = 0.18 )</td>
</tr>
</tbody>
</table>

### Conflicts of interest

The authors declare no conflicts of interest.

### Acknowledgments

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### References


