RESEARCH ON THE INFLUENCE OF HEAT TREATMENT PARAMETERS ON MECHANICAL PROPERTIES OF STEELS FOR LARGE DIAMETER PIPES

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Abstract

The RV52 steel plates are used to manufacture liquefied and compressed gas reservoirs, recipients and pressure vessels which operate at low temperatures, big pressures and highly loaded structures. The making technology and thermique treatment determine high properties such as: strength, wear resistance and tenacity.

To determine the optimal parameters for normalizing heat treatment is carried out research which shows the influence of heating temperature and time of maintaining the mechanical properties. Regarding the practice of heating temperature, usually higher temperature than $A_{C3}$, and if time maintaining values around 2min / mm thick plate.

Keywords: steel microalloy, normalizing heat treatment, strength, toughness

1. INTRODUCTION

The plates of RV52 steel are used to manufacture liquefied and compressed gas reservoirs, pressure vessels and devices operating at low temperatures and within heavily loaded metal structures.

During the processing and operation in the basic steel mass a number of phenomena can occur such as: lamellar spreading, fissures in the welded areas and easy breaking. Occurrence and development of these phenomena depend on the steel chemical composition and the semiblanks elaboration and processing conditions. The normalised plates of RV52 steel feature a ferrite-perlite structure, the obvious tendency being that of reaching an as low as possible content of perlite with the corresponding decrease in the carbon content. The heat normalising treatment of the thick plates took place in the roller continuing furnaces from the rolling mill of Arcelor Mittal S.A. Galati observing the following parameters: heating up to temperatures $A_{C3} + 20° – 40°$ C, air cooling.

The analysis of the relationship between strength and tenacity, on the one hand, and structure characteristics, on the other hand, shows that the heat tension-relieving treatment and especially, the normalising treatment considerably increase the strength/resistance and decrease the transition temperature due to the ferrite grain shrinking process [1].

Manufacturing plates of high chemical and structure homogeneity leads to an isotrophy corresponding to these properties, which attracted the researchers' interest.

2. RESULTS AND EXPERIMENTAL RESEARCHES

In order to carry out the researches on the correlation of microstructure with the properties of steel RV52, normalized and detensioned, the following working variants have been established:

- elaboration in a 50t electrical furnace of 15 t thick plates by ingot casting, normalising treatment, and sampling for heat treatment detension in laboratory
elaboration in a 150t converter, by 25 t ingot casting and continuing casting in slab, of thick rolled plates, normalizing treatment, and sampling for heat treatment detension in laboratory. The chemical composition of the steel investigated is given in table 1.

<table>
<thead>
<tr>
<th></th>
<th>C %</th>
<th>Mn %</th>
<th>Si %</th>
<th>P %</th>
<th>S %</th>
<th>V %</th>
<th>Al %</th>
<th>Ni %</th>
<th>N [ppm]</th>
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<tbody>
<tr>
<td>0</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
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Sampling the steel RV52 plates before and after normalising has been carried out according to the following scheme:

- the samples of the plates made by ingot rolling have been taken from the edges and the axis corresponding to the upper, middle and bottom parts;
- the samples of the plates made by cast frame rolling have been taken from the edge and axis.

Fig. 1. Metallographic structures of the samples without heat treatment from the 15t steel ingots made in the electrical converter: a) upper; b) middle; c) bottom

The metallographic structures of the samples without heat treatment, from the 15t steel ingots made in the electrical converter, for upper, middle and bottom sides are illustrated in Figures 1a, 1b, 1c.

The samples have been taken from the central axis of the plate corresponding to: a) upper side/head, b) middle part; and c) bottom side/foot of the ingot.

The microscopic structures of the plates made from steel elaborated in the LD converter and continuously cast, positions edge and axis, are illustrated in Figures 2a, 2b.
Fig. 2. Metallographic structures of the plates made from steel elaborated in LD converter: a) edge; b) axis

Metallographic slifs have been sampled from the normalized plate samples. The slifs have been prepared in longitudinal cross-section according to the classical procedure [2,3]. Determinations have been performed according to Standard, and the results are given in Table 2.

The elaboration technique has also been assessed by determining the non-metallic inclusions score as shown in Table 2.

Table 2. Non-metallic inclusions score

<table>
<thead>
<tr>
<th>Score</th>
<th>Types of non-metallic inclusions</th>
<th>Total score over the same field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sulphides S</td>
<td>Oxides OL+OP</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>b</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>c</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Max. score from types of inclusions</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>
The impurest zones, irrespective of the sample position, are those corresponding to the upper and middle side of the ingot. In the axis purity is lower as compared with the sample edge. When elaborated in the electrical furnace, a higher purity is reached than that in a converter. In the case of continuing casting, the differences reported between edge and axis are considered higher than with ingot casting. The purity results show that the C, Mn and S segregation zones are also zones which include the non-metallic inclusions [4,5]. A typical image in terms of purity is given in Figure 3.

![Typical aspect of purity of RV52 steel plates, without attack; Magnified x100](image)

Micro-structural measurements have confirmed the presence, in the max C and Mn segregation zones, of higher perlite proportions of these substances as shown in Figures 1a,1b,1c and 2a,2b.

The metallographic structure of the heat treated plates is given in Figure 4 which highlights a fine-granulation ferrite-perlite structure.

![Micro-structure of normalized RV52 steel plates Magnified x 100](image)

Variations and distributions of the mechanical properties: ultimate strength ($R_m$), yielding point ($R_{p0.2}$), breaking elongation ($A_b\%$), resilience on-v-grooved longitudinal samples, tested to -20°C and -50°C, from upper, middles and bottom sides are graphically illustrated in Figures 5,6,7,8.
Sample position in comparison with the ingot

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Fig. 5. Tensil strength (Rm) values distribution of samples in various zone of the sheet

Fig. 6. Yield strength (Rp_0.2) values distribution of samples in various zone of the sheet

Fig. 7. Elongation A5 values distribution of samples in various zone of the sheet

Fig. 8. Break energy at shock (KV_T) values distribution on the longitudinal piece test at -20°C.

Fig. 9. Break energy at shock (KV_L) values distribution on the transverse piece test at -20°C.
The resilience of the cold-deformed and heat-treated samples under the above mentioned conditions has been determined at temperatures of -20°C and -50°C, acc to Figures 9 [6,7].

In order to establish the influence of the heating temperature subsequent to cold deformation of the samples subject to 4%, 8%, and 12% degree of deformation, these have been treated acc to the treatment cycle described below: heating: 250°C, 500°C, 650°C; exposure: 160 min. As a result of 2 min/mm exposure; air cooling. [%]

From the analysis of the tension-relieving graphics, it has been found that:
- as a result of the tension-relieving heat treatment at 250°C, the shock ultimate strength at -20°C and -50°C decreases with respect to the values of the samples from plates of 4%, 8%, and 12% degree of deformations, and the values of the normalized samples Figures 10, 11.
- determining the shock behavior is more obvious when the degree of deformation is higher [8].
- with degrees of deformation of 12%, the shock ultimate strength at -20°C and -50°C takes lower values than those min admissible as indicated by Standard.
- heating to 650°C results in recovery of the tenacity properties of RV52 steel, without having reached the level of normalization.
- heating at 250°C has disastrous consequences, because tenacity is completely damaged both with respect to normalization and deformation states;
- by heating at 500°C, the values of the shock ultimate strength increase as compared with those rached by cold deformation, while keeping however the influence of the cold deformation, i.e., lower values for higher degrees of deformation [9].

![Fig.10. The influence degrees of deformation and heating for values break energy at shock KV_L (-20°C)](image1)

![Fig.11. The influence degrees of deformation and heating for values break energy at shock, KV_L (-50°C)](image2)

3. Conclusions

The researches were focused on determining the factors that cause properties variation in different zones of the RV52 steel plates manufactured by Arcelor Mittal Galati.

In order to obtain highly improved properties a good correlation should be achieved between the conditions of elaboration, deformation and heat treatments highlighted by the chemical composition and structure.
The cold plastic deformation of low degrees of deformation: 4, 8, 12% results in poorer tenacity properties as compared with the normalised state values, which is more sensitive with higher degrees of deformation.

The best values of shock ultimate strength both at -20°C and -50°C have been obtained after a tension relieving treatment at 650°C for 6% degree of deformation.

The measurements of the sulphide, carbon and manganese segregation, purity, microscopic structures and the mechanical properties in these zones have all shown that:

The C, Mn, and S segregation phenomena and therefore the variation of the properties according to different directions are much more obvious in a less careful elaboration in the 150t converter, as compared with the elaboration in the vacuum-degasing electrical furnace.

The chemical, structural and properties anisotropy is much more obvious in case of 25t ingot casting as compared with 15t ingot casting.

In case of ingot plates, the segregation and anisotropy phenomena are more pregnant in the plate axis than in its edges, i.e. in the upper and middle sides than in the bottom side.

Taking into account the results obtained, in order to diminish the chemical segregation which causes the structure modification and properties anisotropy, it is necessary to take technological steps able to eliminate this phenomenon. Such steps should include both the elaboration technological parameters (casting temperature, vacuum technology) and the casting parameters (ingot size) along with the use of some raw materials (liquid cast iron, refractory staff) which should cause a min. impurification of the steel.

REFERENCES


