Research on the Factors that Have an Influence upon the Structures and Properties of the A5 Steel Strips Intended for Deep-Drawing

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Abstract

The paper presents the results of the research on the influence of cold working by rolling upon the properties of the A5 steel strips intended for deep-drawing. The cold deformation degree and the thermic treatment recrystallization were considered to be more important, among the technological factors that influence the structure and the properties of the current research. The experiments lead to the conclusion that, in the case of bell-type furnaces, better results are obtained for a range of relative deformation degree by 35-40% so that the mechanical and technological are corresponsive and characteristic structures present uniformity and smooth grain size.

1. INTRODUCTION

At present the steels A5 for drawing plates (ZES) manufactured by S.C.SIDEX S.A, at present are much more accurately made and this calls for revised cold deformation by rolling and thermal treatments procedures without affecting the quality of the final products. An attempt is made in the paper to show how the cold plastic deformation and recrystallization thermal treatment affect both the mechanical properties and the structure of the steel plates. A number of five coils from the same charge were used. Based on the experimental results a proposal has been advanced to modify the cold and hot deformation technologies while using the existing equipment. The quality technical conditions for the strips ZES-CAR BODIES are in compliance with the standard STAS 10318/80 as follows:

Table 1. The composition of the strip ZES-CAR BODIES.

<table>
<thead>
<tr>
<th></th>
<th>C\textsubscript{max} [%]</th>
<th>Mn [%]</th>
<th>Si [%]</th>
<th>S\textsubscript{max} [%]</th>
<th>P\textsubscript{max} [%]</th>
<th>Cr\textsubscript{max} [%]</th>
<th>Ni [%]</th>
<th>Cu\textsubscript{max} [%]</th>
<th>Al [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.08</td>
<td>0.40</td>
<td>0.1</td>
<td>0.03</td>
<td>0.025</td>
<td>0.03</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>II</td>
<td>0.08</td>
<td>0.20-0.40</td>
<td>-</td>
<td>0.015</td>
<td>0.020</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.03-0.08</td>
</tr>
</tbody>
</table>

The chemical composition of the liquid steel, grade A5 is given in the table 2 (I-according to STAS-10318, II- according to the technological instructions provided by SIDEX).

The mechanical and technological fractures depending on the strip thickness according to table 2.

Table 2. Mechanical and technological fractures depending on the strip thickness

<table>
<thead>
<tr>
<th>Thickness [mm]</th>
<th>Yield Point [N/mm\textsuperscript{2}]</th>
<th>Ultimate Strength [N/mm\textsuperscript{2}]</th>
<th>Breaking Elongation A5 [%]</th>
<th>Erichsen Index [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>max.220</td>
<td>270-340</td>
<td>min.36</td>
<td>min. 10.65</td>
</tr>
<tr>
<td>1.5</td>
<td>max.220</td>
<td>270-340</td>
<td>min.36</td>
<td>min. 11.8</td>
</tr>
</tbody>
</table>
Mean size of ferrite grains should have 6-9 points. Ferrite grain non-uniformity of the same sample should be within the limits of there adjoining points at the most. Roughness should be within 1.2 – 1.8µm.

2. EXPERIMENTAL RESULTS
The experiments were carried out in two stages, in laboratory and industry.
In the first stage, cold working plate samples were provided by cold rolling mill factory was used. The A5 steel chemical composition is given in the table 3.

Table 3. A5 steel chemical composition

<table>
<thead>
<tr>
<th>C [%]</th>
<th>Mn [%]</th>
<th>Si [%]</th>
<th>S [%]</th>
<th>P [%]</th>
<th>Al [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04</td>
<td>0.25</td>
<td>0.10</td>
<td>0.09</td>
<td>0.012</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Samples were taken from the cold rolled strip of different degrees of deformation 2.2%, 6.5%, 15.2%; 32.5%; 50% and 65%.
In the second stage was used an experimental charge and the reductions of thickness, applied in TANDEM rolling mill of the five experimental coils are given in the table 4.

Table 4. The reductions applied in TANDEM rolling mill of the five experimental coils.

<table>
<thead>
<tr>
<th>Coil number</th>
<th>Thickness of strip [mm]</th>
<th>Thickness of cold rolled strip [mm]</th>
<th>Degree of deformation [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.36</td>
<td>1.50</td>
<td>36.0</td>
</tr>
<tr>
<td>2</td>
<td>2.42</td>
<td>1.50</td>
<td>38.0</td>
</tr>
<tr>
<td>3</td>
<td>2.60</td>
<td>1.50</td>
<td>42.0</td>
</tr>
<tr>
<td>4</td>
<td>2.85</td>
<td>1.50</td>
<td>48.0</td>
</tr>
<tr>
<td>5</td>
<td>2.97</td>
<td>1.50</td>
<td>49.0</td>
</tr>
</tbody>
</table>

The thermal treatment was applied into both stages in the cold rolling-mill factory of SIDEX, according to the diagram is presented in figure 1.

For each degree of deformation, a number of minimum 5 samples were provided for the three directions: 0°, 45° and 90° with respect to the rolling direction.
After the manufacturing cycle (cold rolling, recrystallization, annealing, dressing and adjustment) had finished, samples were taken from the middle part of the steel coil and test hars (specimens) were made under the same conditions.
The samples were thermal treated for recrystallization in a bell type furnace at S.C. SIDEX.
Fig 2. Histograms of the values taken by the mechanical characteristics and the anisotropy coefficients for cold deformation samples by rolling over the three sampling directions ($0^\circ, 45^\circ$ and $90^\circ$) by rolling directions.
The degree of deformation significantly affects the structure and the mechanical and technological properties of the A5 steel strip as well as their distribution in the corresponding directions with respect to the rolling direction (0°, 45° and 90°).

The mechanical characteristics are mainly affected by the reduction cold deformation while high reduction cold deformation affects elongation only.

A degree of deformation of 32.5% provided the best results in terms of properties and their distribution on the plate plane (fig. 2).

The correlation between the structured features, as indicated by the optical microscope, and the mechanical and technological properties is neither directly obvious nor of the same intensity in all the cases investigated. Starting from these conclusions the authors made further experiments at industrial level using a number of 5 coils from the same charge. The charge chemical composition is given in table 5.

Table 5. The chemical composition by charge for the five coils used in industrial experiment.

<table>
<thead>
<tr>
<th>C [%]</th>
<th>Mn [%]</th>
<th>Si [%]</th>
<th>S [%]</th>
<th>P [%]</th>
<th>Al [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.04</td>
<td>0.31</td>
<td>0.03</td>
<td>0.018</td>
<td>0.015</td>
<td>0.04</td>
</tr>
</tbody>
</table>

The results of the mechanical, ultimate-strength, lower yielding limit, breaking elongation tests and the anisotropy coefficient are shown as histograms in Fig. 3. The mechanical characteristics of the coils used in the industrial experiments were well within the required limits as provided by the standard in force for the drawing class A5. The best results were obtained with the cold rolled coil of 38% degree of deformation; mean breaking elongation $A_{5m}=40\%$; mean anisotropy coefficient $r_m=1.7$ (Fig. 3) and $I_e=12.1$. The microstructures show a relatively uniform granulation in the cross and longitudinal sections, with fine and globular separations of the tertiary cementite in the ferrite matrix (fig. 3).

Fig. 3. The microstructure of the steel coil strip A5 obtained by rolling cold deformation with 38% relative degree reduction of thickness: a) cross section; b) longitudinal section. (magnification 250x).

Significant differences were found between the values of the mechanical properties in the initial, middle and end areas with each coil and also within these areas there were differences.
Fig. 3. Histograms showing the values of the mechanical characteristics and anisotropy coefficient from middle of coil in longitudinal (0), transverse (90) and diagonally (45) direction and the mean values calculated with formula: \[ x_m = \frac{x_0 + x_{90} + 2 \cdot x_{45}}{4} \]
between the three directions (parallel, perpendicular and 45° inclined to the rolling direction). The testing conducted on the sampled specimens according to the 45° direction show that the steel plate features less favorable drawing behavior, having min. values of the breaking elongation and anisotropy coefficient, while the yielding limit and the ultimate strength take max. values as compared with the same characteristics determined in cross and longitudinal sections.

As for as the coils are concerned, it can be seen that the evolution of their characteristics cannot be repeated along the strip length; thus for each coil specific values of the initial, middle and end crease are obtained.

3. CONCLUSIONS

The industrial experiment also shows that A5 drawing strip of lower reduction when cold rolled can be obtained (about 35-40%); the advantages are:

- improved strip quality due to a lower anisotropy of the mechanical characteristics (A5, Rp0.2, Rm) and the anisotropy coefficient in the plate plane;
- smaller number of cylinders of the cold rolling due to the lower deformation force applied to a less hard strip (lower quenching);
- lower risks of accidental strip breaking during rolling;
- lower power consumption for cold rolling;
- lower power consumption for the whole (cold and hot) deformation process.

4. BIBLIOGRAPHY

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