MECHANICAL PROPERTIES OF HEAT AFFECTED ZONES AT MACRO- AND MICRO-STRUCTURAL LEVEL, USING THERMAL CYCLE SIMULATION

MEHANIČKE OSObine ZONE UTICAJA TOPLOTE NA MAKRO- I MIKROSTrukturnom Nivou PRIMENOM SIMULACIJE TOplotNOG CIKLusa

INTRODUCTION

It is almost impossible to produce welded joints with homogeneous structure. This structure is composed from at least three different regions: base material, weld metal and heat affected zone (HAZ). In many welded structures the coarse-grained HAZ is considered to be the preferred location for initiation and propagation of cracks.

Since the HAZ is too small, and it is very difficult to obtain data on mechanical properties, in this paper a thermal cycle simulator is used to achieve some test specimens from P355NH steel for pressure vessels.

This paper offers information regarding the chemical content of welded joints in percent, estimation of macro- and microstructure in specific areas of the welded edge joints and determination of HV10 hardness of specific areas of the welded joints, both for butt welding and thermal cycle simulator specimens.

EXPERIMENTAL PROCEDURE

Chemical composition

First, the chemical composition of the used base material is verified. The chemical composition of the base material is determined with the INNOVIX-Systems and the results are in compliance with SR EN 10028-3 standard. /7/.

Macroscopic examinations

For butt welded specimens and also for thermal cycle simulated specimens, the macroscopic examinations are performed with stereo optical microscope, type MAK-MS. The results are presented in Figs. 1, 2, and 3. /8/.

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Abstract

It is almost impossible to produce welded joints with homogeneous structure. This structure is composed from at least three different regions: base material, weld metal and heat affected zone (HAZ). In many welded structures the coarse-grained HAZ is considered to be the preferred location for initiation and propagation of cracks.

Since the HAZ is too small, and it is very difficult to obtain data on mechanical properties, in this paper a thermal cycle simulator is used to achieve some test specimens from P355NH steel for pressure vessels.

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INTRODUCTION

It is known that welded joints are characterized by different regions with different strengths, which is referred to as the mismatching phenomenon. /1, 2/.

Different microstructures and mechanical properties of the base metal (BM), weld metal (WM) and heat-affected-zone (HAZ) leads to the presence of micro- and macroheterogeneities in welded joints and from this to a non-uniform distribution of stress and strain. /3, 4/.

Throughout this paper a comparison is presented between the results obtained using welded joints and thermal cycle simulator specimens made from material P355NH of thickness 22 mm, intended for pressure vessels. /5, 6/.

Two types of thermal cycle simulator specimens are used: one specimen without post-simulation heat treatment and the other one with post-simulation heat treatment. For the welded joint specimen, Mn3Ni1CrMo filler material is used.
Mechanical properties of heat affected zones at macro- and micro-

Microscopic examinations

The microscopic examination is performed with a MeF2 optical microscope.

Microscopic examinations performed on butt welded W1 specimen using MIG-MAG welding processes, indicate the formation of banded ferrite and pearlite in the base material, ferrite, pearlite and acicular ferrite in heat affected zone and ferrite and pearlite in a dendritic structure of the casting in weld metal (Figs. 4, 5 and 6).

Microscopic examinations performed on specimen S3, simulated with thermal cycle, with post-simulation heat treatment, indicate the formation of sorbite structure with acicular ferrite and pearlite areas crowded on sorbite background (Figs. 9 and 10).

Microscopic examinations performed on specimen S2, simulated with thermal cycle, without post-simulation heat treatment, indicate the formation of martensitic layer with unevenly distributed acicular ferrite (Figs. 7 and 8).
Determination of HV10 hardness

Based on the determination of HV10 hardness performed on the characteristic areas of the W1, S2, S3 specimens, the values of the hardening of structure estimator $\Delta$HV10 /9/, between the characteristic areas (weld, HAZ, BM) (Table 1), are determined using the mathematical equation /1/:

$$\Delta \text{HV10} = \frac{\text{HV10}_{\text{max}} - \text{HV10}_{\text{min}}}{\text{HV10}_{\text{max}}} \times 100 \%$$ (1)

where: $\text{HV10}_{\text{max}}$ – is the maximum HV10 hardness determined in one investigated area of the sample; $\text{HV10}_{\text{min}}$ – is the minimum HV10 hardness determined in another investigated area of the sample.

It is considered that if $\Delta \text{HV10} \geq 50\%$, accentuated local hardening develops in the examined area, with the high risk of producing brittle fracture, /9/.

RESULTS AND DISCUSSION

Butt welded joints made of P355NH material, welded with Mn3Ni1CrMo alloy (marked as W1), showed no welding defects such as cracks when subjected to macroscopic examination (Fig. 1). Thermal cycle simulation of S2 specimen without post-simulation heat treatment, and also of S3 specimen with post-simulation heat treatment, subjected to macroscopic examination, showed no defects such as cracks after the simulation (Figs. 2 and 3).

Microscopic examination revealed normal pearlitic-ferritic structures in the heat affected zone of welded joints, although in the simulated heat affected zone the structures with hard martensitic areas are detected, with maximum hardness of 437 HV10 for specimen S2 without post-simulation heat treatment.

In the S3 specimen with post-simulation heat treatment, the structures are sorbitic in the heat affected zone, with maximum hardness of 268 HV10.

Microscopic examination of the area showed no microcrack defects.

Figure 11 shows the variance of the $\Delta$HV10 estimator on the butt welded W1 specimen and on the thermal cycle simulation S2, S3 specimens.

Figure 12 presents the variation of hardness for W1 specimen (butt welded joints), S2 specimen (thermal cycle simulation without post-simulation heat treatment) and S3 (thermal cycle simulation with post-simulation heat treatment) for specific area (BM, HAZ, weld).

<table>
<thead>
<tr>
<th>Specimen</th>
<th>BM Minimum values</th>
<th>BM Maximum values</th>
<th>HAZ Minimum values</th>
<th>HAZ Maximum values</th>
<th>WELD Minimum values</th>
<th>WELD Maximum values</th>
<th>$\Delta$HV5 estimator (%)</th>
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<tr>
<td>W1</td>
<td>144</td>
<td>154</td>
<td>181</td>
<td>302</td>
<td>247</td>
<td>270</td>
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<td></td>
<td>40.06</td>
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<tr>
<td>S2</td>
<td>150</td>
<td>186</td>
<td>230</td>
<td>437</td>
<td>-</td>
<td>-</td>
<td>19.35</td>
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<td>47.37</td>
</tr>
<tr>
<td>S3</td>
<td>146</td>
<td>150</td>
<td>150</td>
<td>268</td>
<td>-</td>
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<td>2.66</td>
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<td>44.03</td>
</tr>
</tbody>
</table>

Table 1. Values of the hardening of structure estimator $\Delta$HV10 between characteristic areas.

Tabela 1. Vrednosti procene ojačavanja strukture prema $\Delta$HV10 u karakterističnim oblastima

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Mechanical properties of heat affected zones at macro- and micro-

carbon content on the mechanical properties of steel. 

Figure 12. Hardness HV10 Variation for specimen W1, S2, S3.

CONCLUSION

The absence of cracks in welded joints proves that the thermal cycle simulation and MIG-MAG welding processes were performed in accordance with welding thermal cycles applied during heating and cooling.

In the analysed case the values obtained for the hardening estimator for heat affected zone are less than 50% (47.37% for S2 specimen – thermal cycle simulation without post-simulation heat treatment, and 44.03% for S3 specimen – thermal cycle simulation with post-simulation heat treatment), indicate that the obtained structures do not lead to the development of brittle fracture.

A good correlation is observed between the results of thermal cycle simulation with post-simulation heat treatment and results obtained by welding.

REFERENCES

5. SR EN 10028 – 3 Produse plate din oțel pentru recipient sub presiune, Partea 3: Oțeluri sudabile cu granulatie fină, normalizate (in Romanian).