STRUCTURAL TRANSFORMATIONS IN ELECTRON BEAM WELDED JOINTS OF CONTINUOUS SAW BLADES

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Abstract

The active part of the endless saw blades is made of rapid steel, HS2-10-1-8, and the and the holder from a X32CrMoV4-1 alloyed steel. The joining of the both parts is realized by electron beam welding which provides the obtaining of narrow seams, small heat affected zones (HAZ), good reproducibility of the results and uniform microstructure in welded joint zones.

In case of the small series production or by the reshuffling of saw blades broken in exploitation, one propose the replacement of the electrical welding process by butt fusion from intermediate to direct melting with the TIG welding method [1].

The present paper analyzes the structural and chemical composition modifications produced in the welded joints zones obtained by the electron beam welding between two dissimilar steels. The phenomena which guide the continuous evolution of the chemical composition of the weld are highlighted by energy dispersion X-ray technique (EDX) and scanning electron microscopy.

Keywords: fusion welding, tool steels, microstructure

1. INTRODUCTION

Saws for cutting of metallic materials show both producer and user, some features about the shape and size of the blade, the mode of action and the hardness of the material to be processed.

The selection activity of the steels used for the execution of these tools is based on their geometrical shape and the nature of stresses occurred during operation. The most representative general characteristics of such tool steels are: hardness, wear resistance and toughness.

The saw blades examined in this paper are bimetal type, made of two materials, namely: an alloyed Cr-Mo-V steel, X32CrMoV4-1 grades, for their support, characterized by good toughness characteristics and satisfactory welding behaviour, respective a rapid steel, alloyed with approx. 8% Co and 10%, HS2-10-1-8 grades for cutting crown, which provides a high resistance to wear and fatigue [1,2].

The two materials are joined through the process of electron beam welding. To obtain a continuous, endless saw blade, and by the reshuffling of the saw blades broken in exploitation the TIG welding method is economically justified [1]. This paper analyzes the morphological changes of welded joints obtained by electron beam welding.

2. EXPERIMENTAL RESULTS, DISCUSSIONS

Electron beam welding belongs to welding processes which are using optical energy sources. The emission of an electron beam is produces by heating of a W or Ta filament at a high temperature. The kinetic energy
of the focused electrons on the material surface is converted mostly into heat (energy density exceeds $10^6$ W/cm$^2$) so that the material from the joint zone not only melts, but also instantly evaporates at a temperature of approx. 25 000 °C. As the electron beam is highly focused, the heat inserted in the material is much lower than in arc welding processes. Therefore, the effect of the welding process on the material near the weld is minimal, and the heat affected zone has small expansion. The distortions occurred are reduced, cooling of the welded zone is done at high speed, which can lead to cracking of steels with high carbon and alloying elements.

According to Figure 1 usually are welded unalloyed and low-alloy steels with reduced carbon content, stainless steels, nickel and cobalt based alloys, etc [3]. The process is used also by welding of a wide variation of materials combinations [4].

![Fig.1 Materials and material combinations weldable by electron beam](image)

In figure 2 a, b is shown the profile of such welded joint, one can see that the metallic continuity obtained after the contact between the liquid and the solid metal is appropriate, being absent the oxidation and cracking phenomena. Moving step by step the molten bath, this reaches practically to a quasi-stationary size due to the heat balance provided respective evacuated.

![Fig.2 Weld joint microscopic image of the two dissimilar steels: a – 50 x, b – 100 x](image)
The molten bath shows in this case symmetry with a median plane which passes through the welding axis (welding direction). Since the mixing degree (dilution) of the two materials that participate by the formation of the molten bath is 100%, the solidification microstructure is close to that of the Cr-Mo-V high speed steel in the material zone adjacent to the tool body (fig. 3, 4, 5).

If after hardening at 1200 ±10 °C followed by tempering at 550 ±10 °C of the rapid steel one obtains a microstructure consisting of carbides embedded in a tempered martensitic matrix (Fig. 3) and in the steel holder of the tool, the microstructure resulted after the secondary hardening heat treatment at 1030 ±10 °C followed by tempering at 600±10 °C is composed of tempered troostite (fig.4), the weld presents a microstructure consisting of fine particles of carbides arranged in a martensito-troostitic matrix base (fig. 5).

![Fig. 3 SEM image of HS2-10-1-8 steel](image1)

![Fig. 4 SEM image of X32CrMoV4-1 steel](image2)
In the first moments when the welding bath is formed some important movements take place caused by the action of the thermal and dynamic heat source. The overheated liquid is the place of a complex peripheral movement which begin from the melting front to the back ozone of the bath, with an immediate generation of a transfer of matter. The maintaining time of the atoms in the liquid phase is variable. Some of them are blocked by the advancing of the solidification front and the others reach to this front later, depending on the path it is imposed. The rest of the atoms leave the environment by volatilization or through various chemical reactions. As a result, the chemical composition of the molten zone evolves both continuously and discontinuously.

Metallographic investigations together with EDX analysis (Fig. 6, 7 and Tab. 1) come to confirm these local changes of chemical composition and microstructure.
Fig. 6 Linear distribution of the chemical elements on the weld surface: a-cobalt, b-molybdenum, c-chromium, d-vanadium, e-nickel, f-iron, g-manganese, h-silicon
Fig. 7 SEM image of the welded joint (a) and EDX spectrum of the weld (b)

Tab. 1 Compositional analysis of the weld

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight%</th>
<th>Atomic%</th>
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</thead>
<tbody>
<tr>
<td>Si K</td>
<td>0.55</td>
<td>1.12</td>
</tr>
<tr>
<td>V K</td>
<td>0.96</td>
<td>1.07</td>
</tr>
<tr>
<td>Cr K</td>
<td>4.21</td>
<td>4.63</td>
</tr>
<tr>
<td>Mn K</td>
<td>0.67</td>
<td>0.69</td>
</tr>
<tr>
<td>Fe K</td>
<td>81.47</td>
<td>83.48</td>
</tr>
<tr>
<td>Co K</td>
<td>4.23</td>
<td>4.10</td>
</tr>
<tr>
<td>Ni K</td>
<td>0.48</td>
<td>0.47</td>
</tr>
<tr>
<td>Mo L</td>
<td>7.45</td>
<td>4.44</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

Since the welding is performed without filler material, the participation of the two metals to form the molten zone is complete. In this way it is justified the chemical composition of the weld, which differs little from both of the rapid steel and of the Cr-Mo-V steel (Table 1).

Beside dilution, the continuous evolution of the chemical composition of the weld is caused by volatilization phenomena of some chemical elements (W, Mn, Co, Mo, etc.), by the gases emissions of both steels due to melting, by the variation of the heat regime, by the fluctuation of the solidification rate, constitutional subcooling, dendritic segregation, etc..

From the presented data it can be seen that the chromium concentration in the weld is similar to that of the base metals, this element favours the increasing of hardening penetration and participate to the carbides formation.

Cobalt is present only in the chemical composition of the rapid steel and if it is assumed that the two base metals participate in approximately equal proportions to the weld formation it can be justified its concentration of approx. 4%. It plays an important role in increasing of the tempering stability and the hot hardness.

Molybdenum is present in both base metals and consequently is found in the weld at a high enough concentration so that has a positive effect on the increasing of the toughness and the wear resistance (by the formation of special carbides) and of the tempering stability.
Also vanadium is as an alloying element in both steel so that it appears in weld. It causes an improvement of the wear resistance.

3. CONCLUSIONS

Compared to the conventional welding processes as well as laser welding, the electron beam welding process input in the material the lowest specific heat and provides the narrowest melting zone with the lowest oxidation and the lowest strains.

The heterogeneous welded joints between the rapid steel HS2-10-1-8 and the alloyed X32CrMoV4-1 steel show a suitable geometry without metallic continuity defects, with a chemical composition and microstructure close to the two base metals

REFERENCES


