**I. BOZGĂ, I. SĂRĂCIN, G. PARASCHIV, O. PANDIA, I. C. ANDRONIE**

ISSN 0543-5846
METABK 54(3) 535-538 (2015)
UDC – UDK 669.182.00261:621.791.052:620.178A=111

# THE INFLUENCE OF MELTED MATERIAL PROPRIETIES OVER THE CHARACTERISTICS OF WELDED JOINTINGS MADE FROM STEEL OL 52.4K

Received – Prispjelo: 2014-10-08
Accepted – Prihvaćeno: 2015-01-15
Preliminary Note – Prethodno priopćenje

In the paper we present the analysis of the hardness ($HV_{10}$) in more directions in transverse area of the joint, in the thermal-influenced area (TIA), in the basic metal (BM) and in weld, but we also analyze the embrittlement and stub-cracking effect and the angle at static bending. The hardness analysis of melted material and also the study of embrittlementand stub-cracking effect and the analysis of static bending angle under constant load offer very important information over the quality of welded joints and their behavior when exploiting them.

*Key words:* steel, proprieties of melted material, characteristics of welded, hardness analysis

## INTRODUCTION

The execution of the welded metallic constructions aggregates appeared on industrial scale first for road and railway bridges and then to maritime vessels. The damages that appeared proved the ignorance and lack of mastery of some technological aspects and also the usage of materials with inappropriate proprieties for the aimed purpose. The frequent fragile breaks determined the necessity of studies over the causes of damages, especially at the weld of complex metallic constructions. Among the factors that influence the life span of welded constructions there are reminded: the choice of materials and technological welding processes, chemical composition, thermal influence area etc. [1] Growing life span for welded constructions is possible by constructive improvements and optimization of weld parameters so that metallographic structures are more homogenous in welded joint [2].

Generally, the metallic welded constructions present more deteriorations in the jointing area compared to other areas of the constructions and all of these are determined by the proprieties and the inhomogeneous structure in welded jointing area. For welded structures the execution temperature generates conditions for certain types of degradations by breaking because of the inhomogeneous metallographic structures obtained during the application of different types of weld. The life span of welded constructions is very influenced by the evolution of material proprieties from their structure and these proprieties are much influenced by the structural constituents of material from the welded joint [3].

The steels for general purposes for constructions gained a large usage in making welded constructions of great importance compared with the carbon steel because of their characteristics which allow an appropriate behavior at combined requests, respectively mechanical with corrosive environment [4]. Making metallic constructions from steel OL 52.4k is often met, but these kind of welded constructions are indicated to be used especially for making very requested equipments. In practice, it is very important to know the proprieties of melted material from the welded jointing because of the strong requests to that they are exposed.

In terms of technological exploitations of certain welded constructions, the breaks or failures by breaking are the result of an uneven metallographic structure for welded jointing or the expansion of dimensions of a flaw appeared during welding process.

The welded constructions became more and more used in the last two decades because of their advantages compared with other structures obtained by other technological processes, but the technological making process of some products in welded construction in its specific character presents also a series of disadvantages that arise mostly from the operation with materials in liquid state [5].

The life span of these metallic constructions is very influenced by the evolution of dimensions and deformations suffered by it. Thus an important analysis that must be made refers to deformation evolution that can appear at welded metallic constructions, but also to the establishment of the main causes that determine the appearance of these deformations, mainly related to the proprieties of the melted material from the welded jointing [6, 7].

I. Bozgă, O. Pandia, University of Agricultural Sciences and Veterinary Medicine Bucharest; Romania. I. Sărăcin, University of Craiova, Faculty of Agriculture. G. Paraschiv, Polytechnic University of Bucharest. I.C. Andronie, Faculty of Veterinary Medicine, Bucharest, Romania

## MATERIALS

Choosing welding processes and addition material is related firstly to project provisions of the sub-ensemble and to the technical conditions that the executor disposes. Generally, the manual welding procedure with wrapped electrode is the most used for heavy aggregates and high gauge made from profiles, tin and other mechanical-processed elements, but in the last decades the MAG (metal active gas) procedure extended considerably for welding steel. The joint formation is made from addition metal and part of the basic melted metal, resulting in a chemical composition formed by mutual diffusion of the two components.

The electrical arch is a concentrated source of energy, emitted in the form of electrons on the conductive space between electrode and bath, caused by ionization. The released temperatures owed to Joule - Lentz effect reach approximately 3 000 °C and the stream density is approximately 100 A/mm$^2$.

The research was made to establish the main proprieties of melted material from a welded joint made from steel OL 52.4k so that superior characteristic for welded joint are obtained.

The usage of this type of steel is indicated at the manufacture of resistance elements (beams, poles, sections, sleepers, consoles etc.). Making welded joints from tins 10 mm thick was taken into account in the experimental research. The welding joints technology from steel OL 52.4k recommends that until the thickness becomes 10 mm the basic material should not be overheated, because the linear welding energy makes an overheat that is sufficient to the operations. The mechanical characteristics were established To obtain the desired results in the research and they are presented in Table 1 and the chemical composition is presented in Table 2.

Table 1 **Mechanical characteristics of steel OL 52.4k**

| $R_m$ / MPa | $R_{02}$/ MPa | $z$ / % | $A$ / % | $K_{CV}$ 20°C / J | $K_{CV}$ 0°C / J | $K_{CV}$ -20°C / J |
|---|---|---|---|---|---|---|
| 568 | 402 | 23 | 31 | 79 | 64 | 52 |

Table 2 **Chemical composition of steel OL52.4k / wt. %**

| C | Mn | Si | S | P | Al |
|---|---|---|---|---|---|
| 0,217 | 1,6583 | 0,053 | 0,025 | 0,021 | 0,011 |

## RESULTS AND DISCUSSIONS

The relation for calculating the equivalent carbon is the starting point to establish the main proprieties of melted material $C_e$.

$$C_e = C \cdot Y + \frac{Mn}{6} + \frac{Si}{2} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14} \quad (1)$$

In this relation the last four terms can be excluded because in steel for low-alloyed construction for welded structures that do not contain nickel, chrome, molybdenum and vanadium from which steel OL 52.4k takes part, where Y is the thickness of the tin (as a basic material, being represented in mm).

The information about melted metal proprieties in joint area can be obtained by measuring hardness ($HV_{10}$) along some directions, in the transverse joint area, in the thermal-influenced area (TIA), in the basic metal (BM) and in weld, after metallic bath solidified.

The maximum hardness ($H_M$) in the thermal-influenced area (TIA) must be under 350 units ($HV_{10}$). The calculus of maximum allowed hardness is made with the empirically determined relation 2.

$$H_M = 660 \cdot \left( C + \frac{Si}{24} + \frac{Mn}{6} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14} \right) + 40 \quad (2)$$

When the parenthesis from relation 2 represents the equivalent carbon, the restrained relation 3 results by replacement.

$$H_M = 660 \cdot C_e + 40 \quad (3)$$

The tendency of cracking because of the thermal influence and accumulated gases in addition material (AM) is correlated with the relation 4.

$$H_M \leq 350(HV10) \quad (4)$$

where: $HV_{10}$ – the hardness in thermal-influenced area.

The qualities requested to the joint for reducing the risk of embrittlement are different from those of basic metal (BM) because it does not contain always flaws capable to become crack primers, as in the case of addition material (AM) at solidification because of the diffusion, precipitation and cooling phenomena which are hard control in the whole cord mass.

The attempts made for determining the weld, TIA, basic or additional material qualities specific to each area but also the delimitation of these areas for the constructions of specimens necessary to attempts is sometimes difficult but they are suited to statistic interpretations.

The most dangerous phenomenon owed to technological factors appeared in TIA at welding laminated pieces (weld made transverse on the laminated fiber) with a thickness larger than 25 - 30 mm is the lamellar crack. This is owed to the tensions appeared in the direction of the piece thickness between layers, because of the local chemical inhomogeneity between BM and AM and also to the uneven tensions that lead to step cracking.

The lamellar cracking (unraveling) is very dangerous for the whole construction because the cracks do not reach the surface, being primers for later fragile breaking. The inclusions from the structure are made from various impurities agglomerations such as silicates, manganese sulfides, oxides that group in ferrite-pearlite structure accentuated by lamination.

Calming by deoxidation with silicon and aluminium for obtaining steel OL 52.4k assures the minimum breaking energy that has the value of 27 J at – 30 °C and lowers the tendency of lamellar cracking, being obtained at specimens trials with V notch. However, there

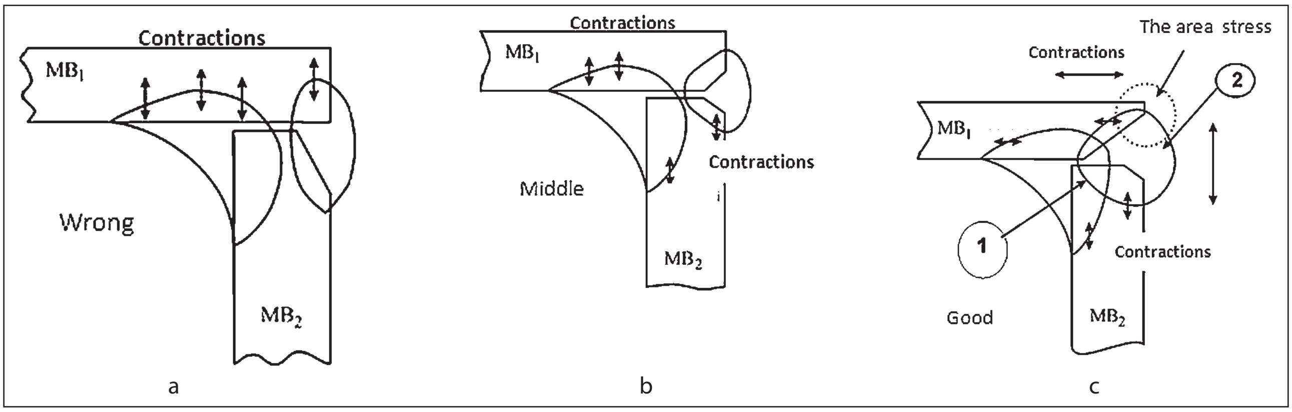


**Figure 1** Solutions for removing the lammelar unraveling at corner welding

are not recommended solutions that request transversally the laminated layers at resistance welding. In these cases, there is recommended the constructive re-projection of welding joint, as well as the modification of the joints on the board with the tendency of cracking (Figure 1 a), with big joints having a large penetration (Figure 1 b) and the weld in more passes (Figure 1 c), when the tendency of lamellar cracking is provided.

Changing the way of preparation of joint and its size, starting from the solution from Figure 1a leads to changing contraction effects of the additional material as contraction direction. Instead some perpendicular contractions on lamination direction (Figure 1a) contractions parallel to lamination direction appear, (Figure 1c).

The basic material $BM_1$ must not take efforts on transversal direction where there are perpendicular on lamination direction (Figure 1c). In case of unilateral corner welding with short lengths in pilgrim step made on one side and then on the opposite side as in Figure 2, for one single pass the stub-cracking that can be avoided by pre-heating the pieces and increasing the number of passes simultaneously with lowering the length between cords compared with the length of the cord ($L_n < L_s$) for $L_s$ < 40 mm when the thickness of basic materials is $g_{MB1} \cong g_{MB2} \cong 6$ m.

Besides the maximum hardness in the thermal-influenced area, other correlations for a metallurgical behavior at weld have in view the equivalent carbon and the angle obtained at static bending and the values are:

$$C_{max} = 0,2 - 0,22\ \% \tag{5}$$

$$\alpha \geq 20\ °C \tag{6}$$

Where: $\alpha$- the angle of static bending of the specimens under constant force, until fragile breaking

The bending angle correlated with the maximum hardness in TIA and with carbon content of C ≤ 0,25 % where the content of S and P in the steel is low are the information that warn that there is no danger of fragile cracking.

The size of the grain is also important and it influences positive the flow limit and the beginning of plastic deformation. The steels with a good plasticity support overloads without deterioration which is important for the life span of the welded aggregate, also having a fine structure of grains.

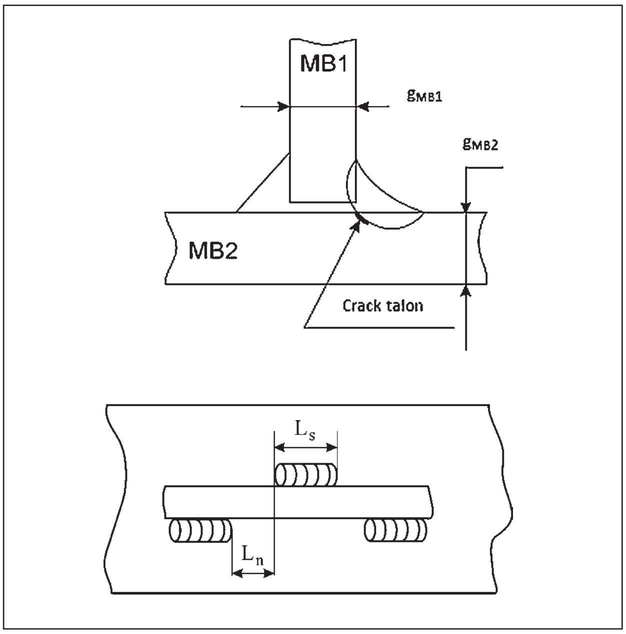


**Figure 2** The embrittlement and stub-cracking effect

By the successive submission of layers is also made the microstructure regeneration because when melting a layer the one submitted before heats over the transformation point $A_{C3}$, resulting a mainly perlitical finer eased structure for the steel OL 52.4k after cooling in the air. The only layers that remain unregenerate are those that submit the last. Preparing the joint has in view the equilibration of the contraction tensions and the avoidance of deformation in assembly area.

## CONCLUSIONS

The research made in the paper demonstrated the next:

- technological and constructive factors influence directly the sub-aggregates characteristics made by welding. The deviations from the quality norms increase the negative influence in all the phases of technological process.
- technological and constructive factors have direct influence over sub-aggregations made by welding. The deviations from the quality norms increase the

negative influence in all the phases of technological process.
- respecting the technology in all the phases of the process with the effectuations of controls in the imposed stationary points makes better the characteristics of the welded joints.
- the quality deviations and the unevenness in transverse sections due to welding process have negative effects over the metallic constructions by appearing degradations in welding area.
- the hardness analysis of melted material and also the study of embrittlementand stub-cracking effect and the analysis of static bending angle under constant load offer very important information over the quality of welded joints and their behavior when exploiting them.

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**Note:** The responsible translator for English language is S.C. TOTALTRAD S.R.L., Craiova, lecturer Nicoleta Truică, nr. 13626, Romania