University Review, Vol. 15, Issue 4, p. 7-10, 2021.

UNIVERSITY REVIEW

MICROSTRUCTURAL ANALYSIS OF HETEROGENOUS FRICTION WELD STEEL 23B2 WITH COPPER

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ARTICLE INFO

***Article history*:**
Received:26.11.2021
Received in revised form: 7.12.2021
Accepted:13.12 2021

Keywords:
Boron steel
Copper
Friction welding
Heterogenous weld
Microstructural analysis

Abstract:

Friction welding is effective method of joining materials, widely used not only on field of joining two different types of materials. This article is focused on friction welding of boron steel 23B2 with DHP copper. Welded workpieces were cylindrical with 10 mm diameter. Microstructural analysis was used as a control method of friction welds.

1 Introduction

Complications occur during welding of materials with different mechanical and physical properties due to different material strength during high temperature and different thermal conduction, which leads to various grade of plastic deformation. [2]

In some cases when is welded material with lower material strength with stronger material, as in the steel 23B2 and copper case, is weaker material (copper) extruded from the friction area and occurs the greater plastic deformation. Optimal conditions for weld formation of similar materials can be supervised by: machining the contact areas (various shapes), increasing the diameter of softer workpiece, preheating the stronger workpiece with external source of heat, regulation of pressure program or using support jig for softer workpiece. Some adjustments for specific materials are shown in the figure 1. These adjustments slow down deformation of the weaker material. However, these adjustments are increasing labor and metal consumption. In our case was used the manual pressure system regulation during the friction welding. [1]

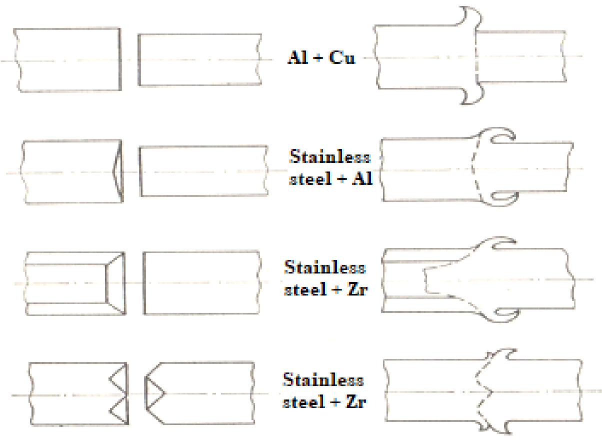

Figure 1 Some adjustments of welding workpieces to ensure uniform plastic deformation

2 Experimental details

2.1 Welding device information

Welds were made on SV 18 RA lathe (TOS Trenčín), which was not in any special way for friction welding purpose modified. As a locking element of non-rotating workpiece was used jig, which was fixed in tail stock of lathe and pressure of the workpieces ensures ejection of tail stock spindle.

2.2 Boron steel 23B2

Steel which was used during the experiments was boron steel marked as EN 23B2 (Number 1.5508), chemical composition and mechanical properties are shown in tables 1 and 2. In general contain boron steels 0,1 – 0,3 weight percentage of carbon, which guarantees good weldability.

Table 1 Chemical composition of boron steel 23B2

Chemical composition (%)							
C	Si	Mn	P	S	Cr	Cu	B
0,2 - 0,25	max 0,3	0,6 - 0,9	max 0,025	max 0,025	max 0,3	max 0,25	0,0008 - 0,005

Table 2 Mechanical properties of boron steel 23B2

Mechanical properties	
Rm (MPa)	$Rp_{0,2}$ (MPa)
625	505

2.3 Copper Cu-DHP

Copper which was used during the experiments is marked as Cu-DHP, chemical composition and mechanical properties are shown in table 3. Cu-DHP has excellent weldability properties and also is cold and hot malleable. Cu-DHP is oxidation and hydrogen cracking resistant. [4]

Table 3 Mechanical properties of boron steel 23B2

Chemical composition (%)		Mechanical properties	
Cu	P	Rm (MPa)	$Rp_{0,2}$ (MPa)
99,9	0,015 - 0,040	240 - 300	Min. 140

2.4 About the experiment

For the first bymaterial was choose copper, because copper has attractive characteristics for different requirements, which depends on mechanical properties and at the same time high formability. The main advantages of copper are high thermal conductivity, high elasticity and oxidation resistance. It is widely used in electrical and mechanical components. Welding materials based on copper is not simple, because high input heat is from joint dissipated in short time. Besides that, solders between copper and other materials like aluminum or titan have weak mechanical properties because of interlayer which contains IMC (Intermetallic Compound), this problem does not occur in friction welds.

To demonstrate the functionality of the technology was made 2 heterogenous welds steel 23B2 with copper. In figure number 2 is specimen without modification after friction welding process. On the both specimens were machined outgrowth by lathe and subsequently abbreviated to length 20 – 25 mm (fig. 3). Specimens prepared in this way was cut lengthwise, etched and thus ready for microstructural analysis, which realized on the basic on images made by optical microscope NEOPHOT 32 and evaluation software Axio vision from Zeiss company.

Problem occurred before microstructural analysis because of etching heterogenous weld since they are two different materials. Copper requires stronger etchant or longer time of etching as steel, so there is not so visible grain beside steel. If we were to etch joint longer or with stronger etchant, copper would etch better but in the case of steel it would occur overetching and blacked. [1]

Figure 2 Heterogenous friction weld steel 23B2 - copper, specimen without modification [1]

Figure 3 Heterogenous friction weld steel 23B2 - copper, modified specimen [1]

Heterogenous welds was realized by 710 revolutions per minute. Rotation speed was chosen on the basis of previous experience with homogenous friction welds of 23B2 steel.

3 Results and discussion

Microstructure from the weld area clearly demonstrates the grain refinement in weld area and graduated transition of grain thickness, in the following direction weld → weld affected zone → basic material.

We further evaluated, during welding two mechanism of materials mixture was occurred, which created good conditions for the formation of the joint – weld.

The first mechanism concerns about plastic deformation during the heat and thus a combination of heat, pressure and centrifugal force. This materials mixture are clearly visible capillary and cracking regions, indicated in figure 4.

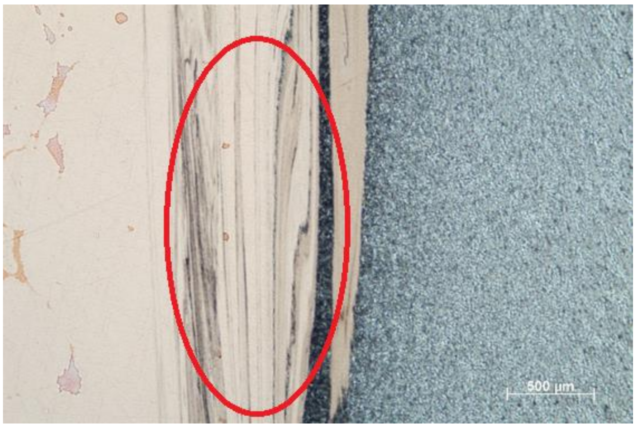

Figure 4 Microstructure of heterogenous friction weld and the area around the weld steel 23B2 – copper [1]

The second mechanism of materials mixture we attributed to diffusion of steel in copper (figure 5,6). During friction welding a group mechanism of diffusion is applied on the one hand, which is characterized as a coordinated particle motion. And other individual mechanism of diffusion, which means motion of interstitials and vacancies, which can in the welding area increase some mechanical properties, comparted to the base material. Interstitial atoms (similarly vacancies) which are smaller than ferrite atoms, they can diffuse through free spaces in the crystal lattice of the material. There are known cases, where elements from hydrogen to oxygen have diffused in iron alloys. This argumentation confirms the theory, which stated that, no alloy is leached from the weld zone during friction welding, because elements such as nickel have higher atomic weight as the ferrite, that means they have worse conditions for movement such as elements with the lower atomic weight.

I tis necessary to add, with the alloy elements, such as chrome – which has similar atomic weight as the ferrite, energy required for diffusion will become even greater, than with elements such as hydrogen, oxygen or carbon (where their diffusion from the material is desired and request relatively little activation energy), so they will diffuse to a very limited extent. Mechanism of vacancy diffusion requires more activation energy than interstitial. [1]

Figure 5 Microstructure of heterogenous friction weld steel 23B2 – copper [1]

Figure 6 Microstructure detail of heterogenous friction weld steel 23B2 – copper [1]

For the already mentioned diffusion mechanism are during the friction welding process are created ideal conditions, because of the diffusion rate in crystalline materials also increasing with increasing temperature. Another input parameter is centrifugal force which acting on atoms, alternatively groups of atoms. Centrifugal force is created by rotation of the

workpiece during the friction welding and also accelerates the individual diffusion mechanism.
Heat generation is mainly affected by selected material and the involved factors – acting axial pressure, quality of contact surfaces, friction coefficient, rpm, time, etc.

But the important thing is, whether creating welds from the same or different materials, set optimal parameters, which are suitable for selected material. Each material has different properties that need to be considered in process.

Before the friction welding is also necessary to predict the best geometry of the welded surfaces of the individual workpieces. The reason is to ensure the best possible connection of materials. This is obstacle of friction welding materials with various mechanical properties. In our case (23B2 + Cu-DHP), geometry of the contact surface has not been modified in some special way, because steel and copper which were used do not have such different mechanical and thermal properties. Especially from mechanical

- Strength
- Plasticity
- Toughness

and thermal properties

- Melting point
- Thermal conductivity
- Thermal expansion

of materials it is possible to predict the correct geometry of welded workpieces. Here I see the mentioned obstacle, because in production, it is easier to ignore the geometry of the welded surfaces, simply said – welding as it comes. This is also possible with most welded materials however, when are welded materials with very different mentioned properties, a certain preparation of the workpiece is necessary, namely in the introduction mentioned modification of the welded surfaces.

4 Conclusion

We described the theory of weld formation in rotary friction welding from available data and on the basis of physical principles before the start of experiments. From the obtained data it is possible to state that the theory has so far succeeded. Many experiments are prepared with different materials, geometries and using catalysts which confirm, supplement or refute the information described in this article.

By studying the microstructure of friction welding joints, it is possible to better understand homogenous, heterogenous welds or multimaterials structures and actually overall structural interconnection of different materials, while maintaining the condition of quality joint.

Process of the weld formation, especially the weld between two different materials, is very complex and there is a wide possibility to adjust the parameters of the machine or workpiece geometry, alternatively use of the catalysts, to obtain quality results.

5 Acknowledgement

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