

# Types of Surface Impurities versus the Quality of Brazed Joints

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**Abstract:** Brazing is one of the primary joining processes increasingly often applied in industry. Because of their mechanical properties, overlap joints are particularly popular when making brazed structures. The use of brazed joints in structures of critical importance requires that particular attention be paid to joint quality, e.g. by the appropriate cleaning of surfaces to be joined. The article presents results of non-destructive tests of brazed joints made in steel S235JRG2. Surfaces used in the tests were deliberately contaminated to simulate the presence of welding imperfections. Afterwards, the test specimens were subjected to non-destructive (visual and radiographic) tests aimed to determine the effect of surface impurities on the quality of brazed joints.

**Keywords:** brazing, brazing imperfections, radiographic tests, inclusions, non-destructive tests

**DOI:** [10.17729/ebis.2018.4/6](https://doi.org/10.17729/ebis.2018.4/6)

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## Introduction

Brazing and soldering are joining process without the partial melting of edges, i.e. where a joint is formed through capillary phenomena (wetting, spreadability, entering/penetrating gaps) and diffusion processes. Melting points of filler metals determine the terminology of the aforementioned joining methods, i.e. soldering is a process taking place below 450°C, whereas brazing is performed at temperatures exceeding 450°C [1]. The permanent development of soldering and brazing translates into the growing popularity of these techniques in various industrial sectors. In particular, the popularity of brazing is significantly affected by the fact that this process enables the joining of material characterised by significantly varying

properties and chemical compositions, making such materials difficult or impossible to join using other methods. Brazing enables the joining, of among other things, stainless steels, titanium alloys, nickel alloys, aluminium alloys (including those in the foamy forms) or magnesium alloys [2-10]. The wide range of materials joinable by means of brazing determines the development of industrial sectors, particularly aviation and automotive industries, applying the above-named process.

Because of the fact that brazing is often applied when making joints in critically important structures, it is particularly important to check brazes for brazing imperfections responsible for the reduction of mechanical properties [11]. As a rule, the first group of tests brazed

joints should be subjected to non-destructive tests [12-14].

The classification of brazing imperfections is provided in PN-EN ISO 18279:2008 *Brazing. Imperfections in brazed joints*. The above-named standard divides imperfections into the six primary groups, i.e.:

- I – cracks,
- II – cavities,
- III – solid inclusions,
- IV – bonding imperfection,
- V – shape and size-related imperfections,
- VI – miscellaneous imperfections.

The PN-EN ISO 18279:2008 standard divides imperfections into internal, i.e., among other things, cracks (inside), solid inclusions (flux, metallic inclusion, oxides), no joint, gas cavities and incomplete fusions and external, including surface cracks, porosity, size and shape-related imperfections, braze roughness, discoloration and a flux seepage into brazes.

### Objective of tests and materials

The tests aimed to determine the effect of surface contamination types on the quality of gas (oxy-acetylene) overlay brazed joints. The tests involved the use of 1.5 mm thick sheets (125 × 30 mm) made of steel S235JRG2. The sheets were used to make 10 joints presented schematically in Figure 1. Table 1 presents the chemical composition of the base material.

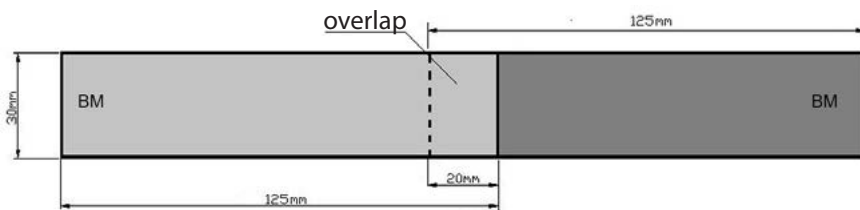


Fig. 1. Schematic overlay brazed joints, BM – base material

Table 1. Chemical composition of steel S235JRG2 according to PN-EN 10025:2002

**Maximum chemical element content, % by weight**

| C    | Mn   | Si | P     | S     | N     |
|------|------|----|-------|-------|-------|
| 0.17 | 1.40 | -  | 0.045 | 0.045 | 0.009 |

The brazing process was performed using silver brazing metal grade Ag203 (B Ag-44CuZn-675/735) according to PN-EN ISO 17672:2016 (having the form of a wire) and flux 1802 N Atmosin (Castolin), used to dissolve oxides present in the base material. The presence of the flux provided the wetting of elements in the joint by the molten brazing metal and intensified the capillary action in the brazing gap. The flux was used to cover the area referred to as an “overlap” (Fig. 1).

### Experimental conditions

The schedule of the brazing process assumed the making of 10 joints, out of which one was made properly, whereas the remaining nine were made failing to meet the requirements of the brazing technique. The improper technique included, among other things, uncleaned test surfaces or surfaces covered with a brazing flux. The foregoing aimed to make it possible to compare the effect of the preparation of the base material surface on the quality of joints. In addition, the specimens were provided with metallic inclusions and the flux used in the SAW method. This was made to assess the effect of the above-named factors on the quality of the braze and to determine the types of resultant brazing imperfections. Flux inclusions can appear in brazes because of an overly low temperature or an overly short brazing time. In turn,

metallic inclusions are usually of external nature, e.g. from fixing or fastening elements [1]. One of the specimens was immersed in water (after the completion of the brazing process and the solidification of the filler metal), thus significantly increasing the rate of cooling. The schedule of the brazing process is presented in Table 2.

The brazing of specimens nos. 1-4 was not accompanied by any problems. The only visible differences were longer brazing times

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in cases of the specimens, the surfaces of which were not entirely covered with the flux. In cases of specimens 5-7, the time of brazing was significantly longer (3-5 times) than previously. In addition, an increase in the amount of copper inclusions was accompanied by the higher consumption of the filler metal. The brazing of specimen no. 8 proved not problematic. The immersion of the above-named specimen in water was accompanied by the emission of a characteristic sound, implying the cracking of the joint. The most problematic was the brazing of specimen no. 9, in relation to which the largest amount of the filler metal was used and the duration of the brazing process was the longest. The brazing of the last joint proceeded without any problems. After the completion of the brazing process the specimens were subjected to non-destructive visual tests and radiographic tests in accordance with the PN-EN 12799:2003 standard.

## Non-destructive tests

### Visual tests

The visual tests revealed a number of brazing imperfections including primarily shape-related imperfections, porosity and discolorations. The most numerous imperfections were present in the specimens, the brazing of which proved most problematic. The intentionally contaminated surfaces of specimens led to the excessive spread of the brazing metal. Visual tests results related to brazed joints are presented in Figure 2.

### Radiographic tests

Table 2. Schedule of the making of specimens

| Spec. no. | Brazing conditions  |
|-----------|---|
| 1         | Lack of flux  |
| 2         | 50% of the overlap (Fig. 1) covered with flux, 50% covered with grease and flux                                 |
| 3         | 50% of the overlap left uncleaned before the process  |
| 4         | 30% of the overlap left uncleaned before the process  |
| 5         | Three copper foil discs having a thickness of 0.2 mm and a diameter of 3, 4 and 5 mm placed in the overlap area |
| 6         | One copper foil disc having a thickness of 0.2 mm and a diameter of 5 mm placed in the overlap area             |
| 7         | One copper foil disc having a thickness of 0.2 mm and a diameter of 3 mm placed in the overlap area             |
| 8         | Specimen immersed in water directly after brazing (before the solidification of the filler metal)               |
| 9         | Flux used in the SAW method placed in the overlap area  |
| 10        | Proper technique  |



Fig. 2. Visual test results; a) specimen 5 – three copper inclusions, excessive spread of the brazing metal (ellipse), a crack of the braze and gas pores (arrow), the overlap on the upper edge not filled with the filler metal, b) specimen 8 – immersed in water, a crack of the braze (arrow), the overlap on the left edge not filled with the filler metal c) specimen 9 – provided with the flux used in the SAW method, excessive spread of the brazing metal (ellipse), gas pores, the overlap on the upper edge not filled with the filler metal

The radiographic tests were made using an Andrex X-ray tube (300 kV) and an AA 400+

Pb foil (0.05 mm) made by Kodak. The tests were performed using the following parameters: FFD = 700 mm, U = 130 kV, I = 4,5 mA and an exposure time of 3 minutes. The radiographic tests revealed that the most numerous imperfections were present in the specimens, the surfaces of which were intentionally contaminated with pieces of copper foil. The above-named inclusions precluded the formation of a complete joint and led to the formation of smaller inclusions located nearby. A similar result was observed in relation to specimen no. 9 provided with the flux used in the SAW method. The above-presented results confirmed the

results of the previous tests concerning the effect of impurities during joining processes [15]. Figure 3 presents examples of radiographic test results. Table 3 presents the test results in relation to all of the specimens.

### Summary and concluding remarks

The research-related tests involved the performance of visual and radiographic tests of 10 brazed joints made in steel S235JRG2, out of which only one was brazed properly, i.e. following all the process-related requirements. The remaining specimens were made inappropriately, i.e. without the cleaning of surfaces to

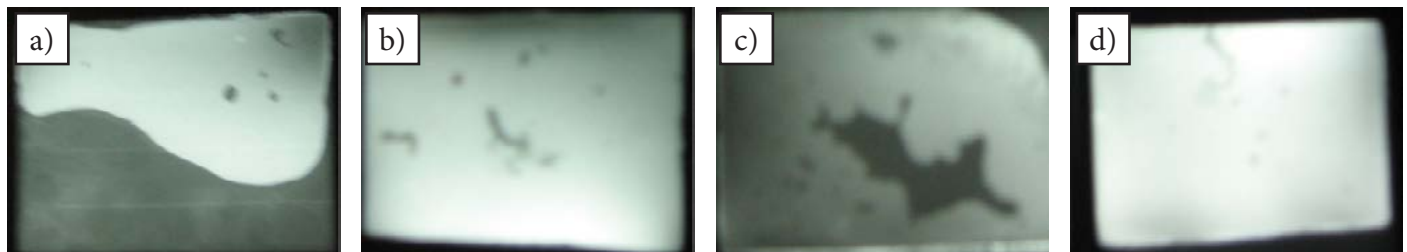


Fig. 3. Radiographic test results; a) specimen 1 – lack of the flux, a complete joint covering approximately 50% of the surface subjected to brazing, inclusions, oval gas cavities, b) specimen 3 – improperly cleaned surface, a longitudinal gas cavity having a length of 5 mm in its central part and oval gas cavities, c) specimen 8 – immersed in water, a gas cavity having a length of 20 mm and a width of up to 7 mm, oval gas cavities, d) specimen 10 – made properly, a longitudinal gas cavity having a length of 3 mm, small inclusions

Table 3. Results of radiographic tests

| Spec. no. | Brazing conditions   | Conditions of radiographic tests   |
|-----------|--|--|
| 1         | Lack of flux   | Lack of a complete joint, inclusions, gas cavities   |
| 2         | 50% of the overlap (Fig. 1) covered only by flux, 50% covered by grease and flux     | Lack of a complete joint, inclusions having a diameter of up to 5mm                                      |
| 3         | 50% of the brazing area not cleaned before the process                               | Complete joint, a longitudinal gas cavity having a length of 5 mm  |
| 4         | 30% of the brazing area not cleaned before the process                               | Complete joint, longitudinal gas cavities being 3 mm - 5 mm in length and gas pores                      |
| 5         | Three copper foil discs having a thickness of 0.2 mm and a diameter of 3, 4 and 5 mm | Lack of a complete joint, very numerous inclusions and gas cavities near the location of the copper foil |
| 6         | Copper foil disc having a thickness of 0.2 mm and a diameter of 5 mm                 | Lack of a complete joint, numerous inclusions and gas cavities near the location of the copper foil      |
| 7         | Copper foil disc having a thickness of 0.2 mm and a diameter of 3 mm                 | Lack of a complete joint, some inclusions and gas cavities near the location of the copper foil          |
| 8         | Specimen immersed in water directly after brazing                                    | Complete joint, a vast gas cavity having a length of 20 mm and a width of up to 7 mm, oval gas cavities  |

be joined, without the use of the brazing metal, by contaminating the surface and by immersing a specimen in water to trigger the formation of cracks.

The experiment justified the formulation of the following concluding remarks:

1. Contaminants of the surface to be subjected to brazing such as grease, copper foil and flux used in the SAW method affected adversely the quality of joints precluding the formation of complete joints and triggering the formation of various inclusions. The inclusions led to the formation of additional clusters of imperfections located nearby and worsened the quality of the brazes.

2. The lack of additional flux on the ground surface during the brazing of steel S235JRG2 precluded the formation of complete joints. However, it proved possible to obtain complete joints by brazing uncleaned specimens, yet it was necessary to use a flux.

3. The greasing of the surface precluded the proper interaction between the flux and the surface subjected to brazing, resulting in a failure to obtain a complete joint.

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