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BRAZE WELDING OF ELEMENTS OF INDUSTRIAL FITTINGS

LUTOSPAWANIE ELEMENTÓW ARMATURY PRZEMYSŁOWEJ

Resistance to stretching, a quality of specimen made by braze welding method were examined as well as usefulness of this method in industry was described. Technology and materials, which are used during braze welding, are depicted on the base of an inspection of joints. The results of macroscopic examinations of sample joints (base material, heat-affected zone and braze weld) are given. Furthermore, the results of the resistance, plasticity and hardness tests of sample joints are presented.

Keywords: Braze welding, braze welded joint, braze welding technology, mechanical properties

Zbadano wytrzymałość na rozciąganie oraz jakość wykonanych próbek metodą lutowania, jak również określono przydatności tej metody w przemyśle. Na podstawie przeglądu wykonywanych złączy przybliżono technologię oraz materiały, które są stosowane podczas łączenia materiałów metodą lutowania. Przedstawiono wyniki badań makroskopowych wykonanych złączy próbnych (materiału rodzimego, strefy wpływu ciepła i lutospoiny). Przedstawiono wyniki badań wytrzymałości, plastyczności oraz twardości wykonanych złączy próbnych.

1. Technology of braze welding

Braze welding is a soldering method of joining materials. Its name comes from a connection of two notions: welding and soldering. A specific thing in this method is making a joint as in the process of soldering – without melting a base material, and preparing edges of materials as in the process of welding (beveling) [1-7]. Braze welded joints are made by gas and arc processes namely TIG and MIG/MAG. Arc processes are characterised by a lower linear energy than during a welding process, which considerably reduces an occurrence of stresses. It is also connected with a smaller welding shrinkage. Brazing brass and bronze solder are used as additional materials according to PN-EN ISO 17672, PN-EN 13347 and PN-EN 14640 standards (to weld copper and its alloys) [2,3]. Braze welding method is not free from drawbacks, the main one is a high cost of making a joint. It is particularly useful to joint galvanized materials, because it does not require an additional galvanization after making a joint. The second disadvantage is a necessity to guarantee a high cleanliness of additional and base materials. A material must be very precisely cleaned out of all kind of grease, paints, corrosion etc. Insufficient cleaning of material can cause a low quality joint. A considerable amount of bubbles is made inside a braze weld, as well as an incomplete fusion is characteristic (filler material does not

diffuse into the base material). Such joint will not fulfill the requirements of tightness and strength.

Braze welding is used to make anti-corrosive protections e.g. by applying zinc coatings. Unfortunately, due to a low strength of the braze weld, this method is not widely used in the industry. It is mostly used in the automotive industry, where anti-corrosive protection is one of the major criterion. The above method is also used in low-pressured pipelines e.g. fire protection systems.

2. Braze welding by TIG method

A technology of making a joint by the braze welding TIG method includes the following procedures:

- a precise cleaning of joint materials out of grease, paints, corrosion,
- beveling of the edges of materials on V or X,
- an accurate fitting of joined materials to each other (a slot should not be bigger than a thickness of a filler metal),
- covering with a flux (borax) cleaned joined materials.

A braze welded joint is made just after such a preparation. It is vital to control a temperature during a braze welding process. A brass wire is used to braze welding (in the described example). In order to avoid porosity caused by vaporising zinc, it is necessary to manage the process in a way not

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to surpass the temperature of zinc vaporising, which is about 907°C. It is hard because the parameters of braze welding cannot be clearly specified. Unfortunately, it is made by a trial and error method, but in much lower current intensity in comparison to welding. Material is heated by the an electric arc to the deep cherry colour. After heating, a brass wire is applied to the material. A solder should melt to fill the slot. When it does not happen, than the temperature of a base material is too low. If the temperature of the material is sufficient, than the whole process is the same like during welding. It is necessary to remember to make the whole process at once. It is not recommended to heat a braze weld, as it may cause a flow out of a filler material through the slot. A proper braze welded joint looks like a weld made traditionally i.e. a process of braze welding should be conducted so that a face of the weld is convex and a little wider than the groove. The following realization guarantees a proper tightness of joints and fulfil the expected requirements. Braze welded joint should be left to cool naturally. A sudden cool down of the braze weld may cause an occurrence of a fragile Widmannstätten microstructure. In the process of braze welding similar actions can be used like in the traditional welding. One of the actions is an application of argon from the root side, which aim is to prevent leaking a filler material and forming a root.

3. Base and filler materials

P235GH steel, which is non-alloyed steel used to operate in an increased temperature (GH), was used to make the samples. It is characterised by a good weldability, which makes it attractive and often used in the industry (power industry) in the high-temperature elements of systems and installations. It is mostly used to manufacture responsible elements such as pressure pipelines, pressure vessels [5].

P235GH steel is characterised by the following mechanical properties:

- yield point $Re > 235$ MPa
- resistance to stretching $Rm = 360-500$ MPa
- unit elongation $lw \geq 23\%$

Chemical composition: $C \leq 0,16\%$, $Si \leq ,35\%$, $Mn \leq 1,2$, $P \leq 0,025\%$, $S \leq 0,020\%$, $Al \leq 0,020\%$. Brass wire LM-60 was used as a filler material. It is a universal wire used to weld and solder brass, copper and cast iron. Its operating temperature ranges between 870-900°C. Borax was used as a flux.

4. Examination results

The following examinations of braze welded joints were taken:

- micro and macroscopic examinations,
- hardness tests,
- transverse stretching test of braze welded joint.

5. Micro and macroscopic examinations

Examinations were taken on conventionally prepared metallographic specimen etched by a metallographic reagent: by

nital (Mi1Fe) in case of steel, and a joint (brass) was etched by Mi17Cu. Austenite steel – specimen nr 6 was etched by a metallographic reagent Mi19Fe. Observation and registration of microstructures were made by the light microscope Axiovert 25.

A size of a grain was described by a comparative method according to the range of specimen using PN-EN ISO 643 ‘Steel. Micrographic description of a grain’ standard. In the base material (specimen nr 1-5) a size of a ferrite grain was 9,5 according to the range of specimen, and in the heat-affected zone – 10.

Specimen nr 1:

Thickness of a base material 3 mm

Prepared materials: V bevelled

Made by TIG (141) method with argon applied from the root side in order to form it

Braze welding parameters:

Current intensity: 52 [A]

Alternating current (AC)

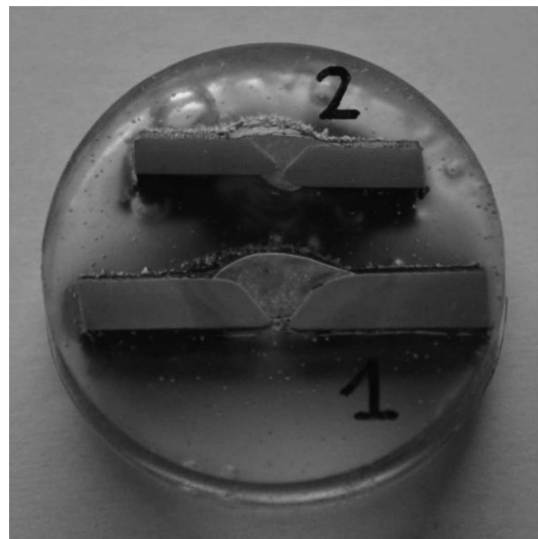
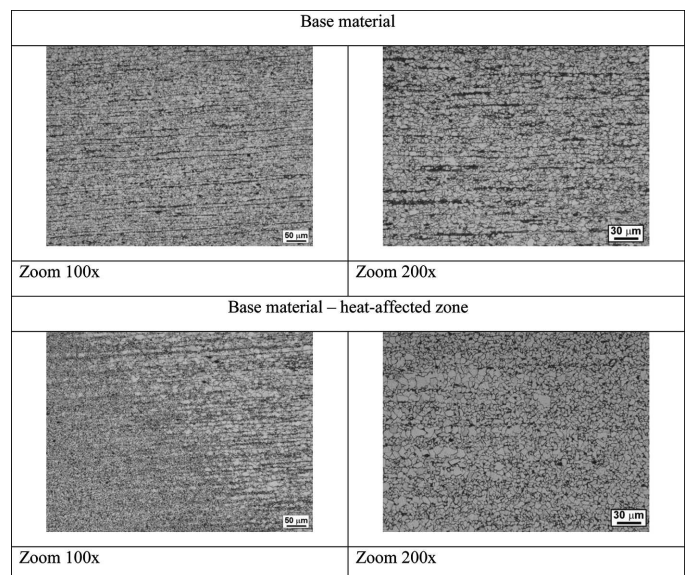
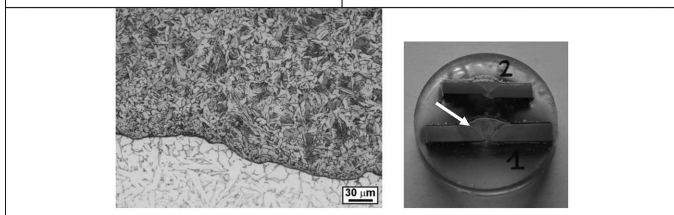
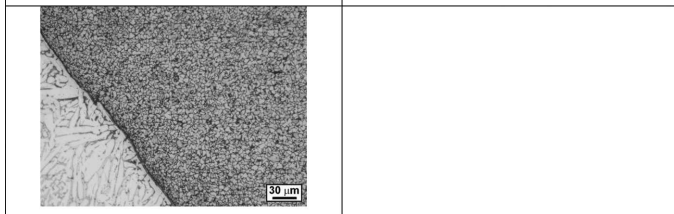
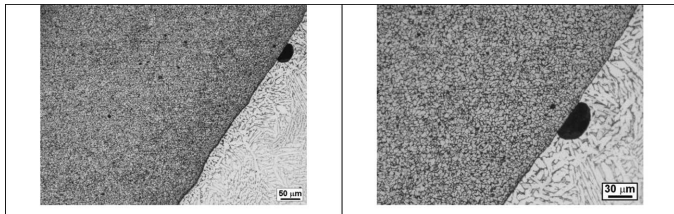
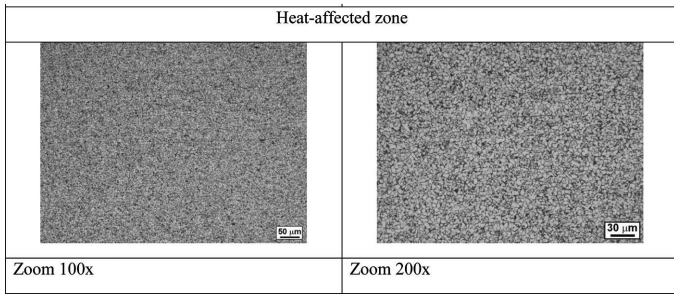


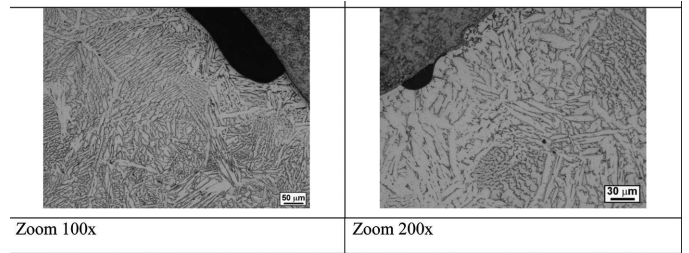
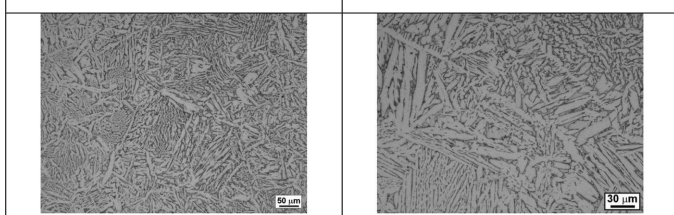
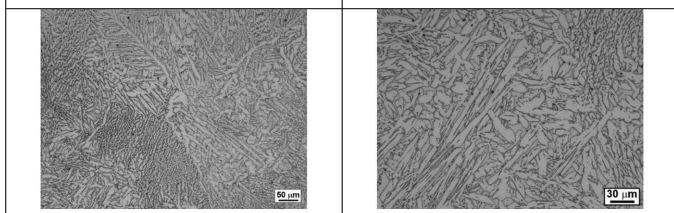
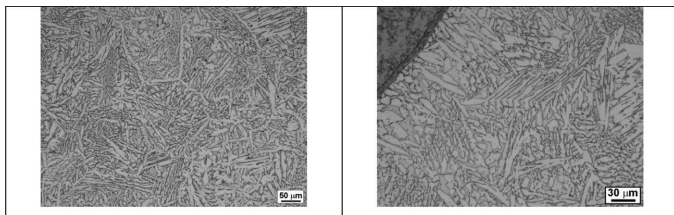
Fig. 1. A macroscopic specimen of a sample nr 1

Example microstructures of braze welded joint 1 are shown underneath.





Braze welded joint of brass



Specimen nr 2:

Thickness of a base material 2 mm

Prepared materials: X bevelled

Made by TIG (141) method with argon applied from the root side in order to form it

Parameters:

Current intensity: 48 [A]

Alternating current (AC)

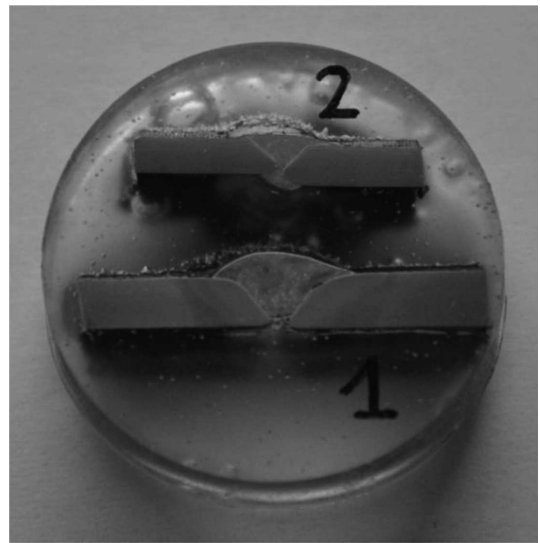
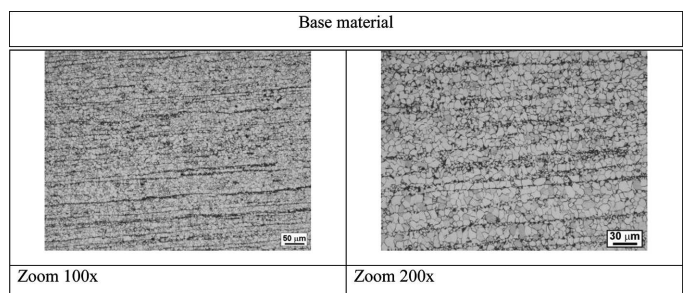
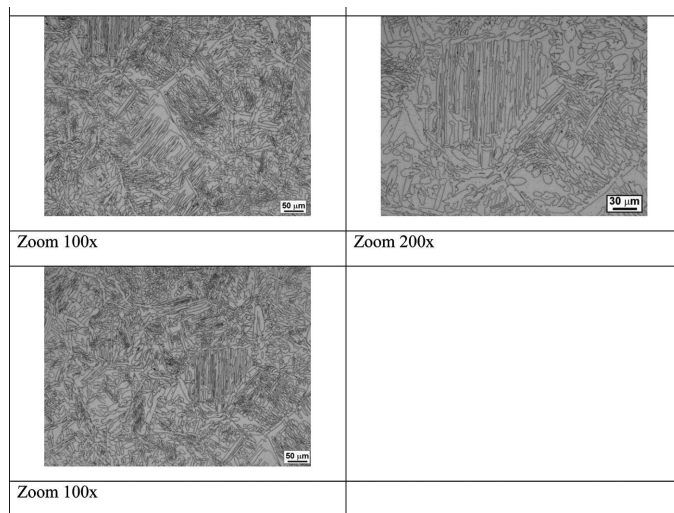
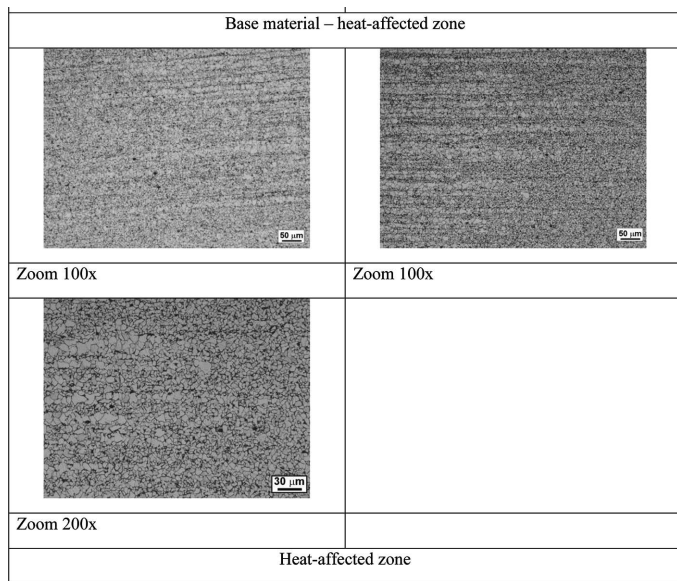


Fig. 2. A macroscopic specimen of a sample nr 2

Example microstructures of braze welded joint 2 are shown underneath.





Specimen nr 3:

Thickness of a base material 2 mm
 Prepared materials: X bevelled
 Made by TIG (141) method with argon applied from the root side in order to form it
 Parameters:
 Current intensity: 48 [A]
 Alternating current (AC)

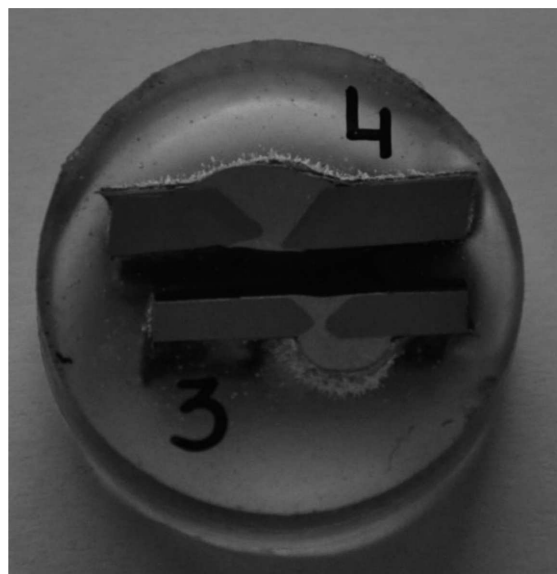
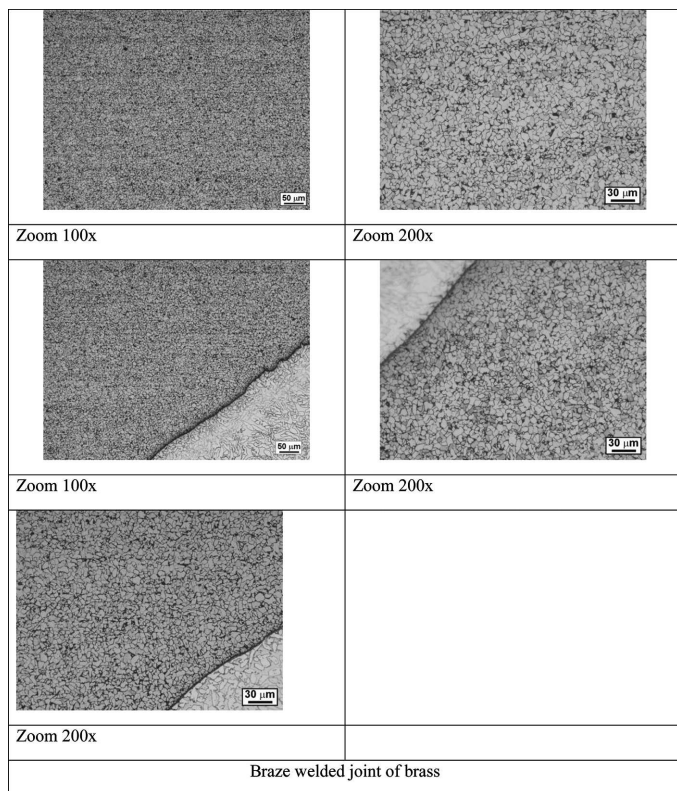
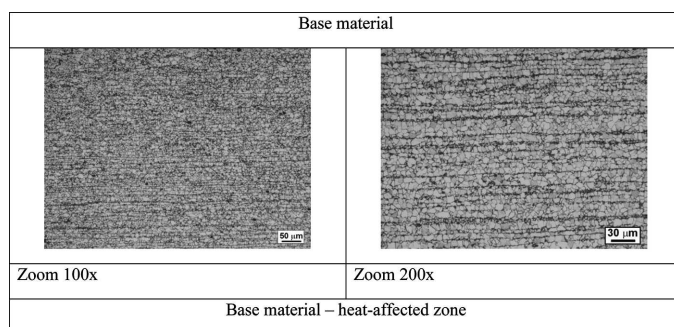
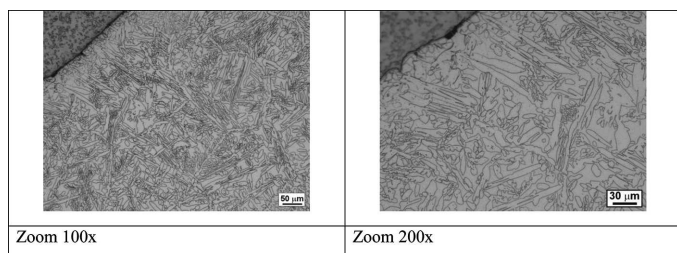
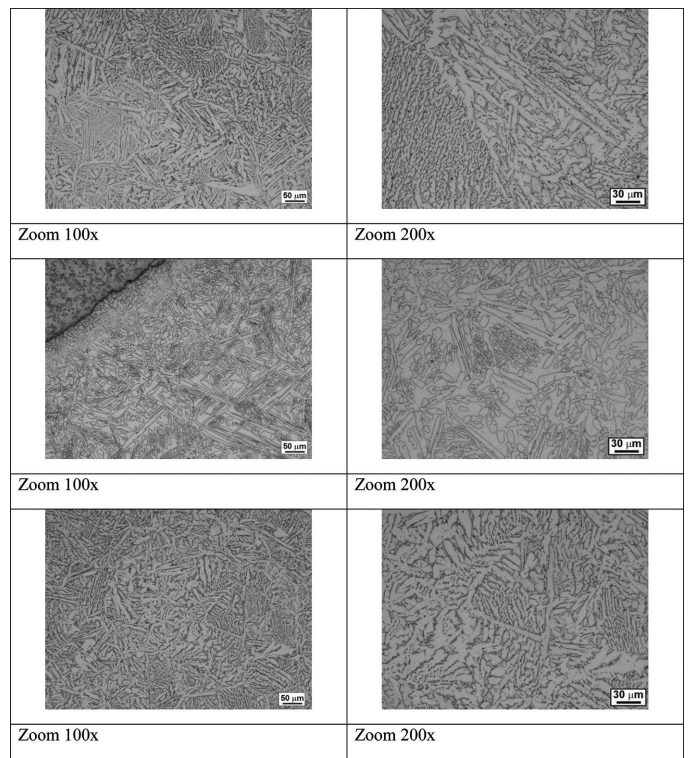
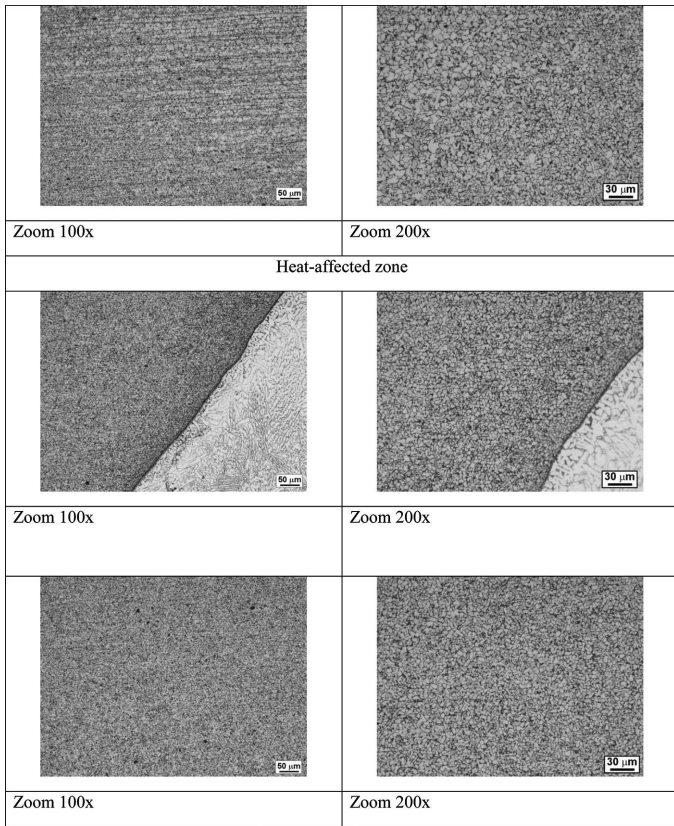


Fig. 3. A macroscopic specimen of a sample nr 3

Example microstructures of braze welded joint 3 are shown underneath.





Specimen nr 4

Thickness of a base material 3 mm
 Prepared materials: V bevelled
 Made by TIG (141) method with argon applied from the root side in order to form it
 Parameters:
 Current intensity: 48 [A]
 Alternating current (AC)

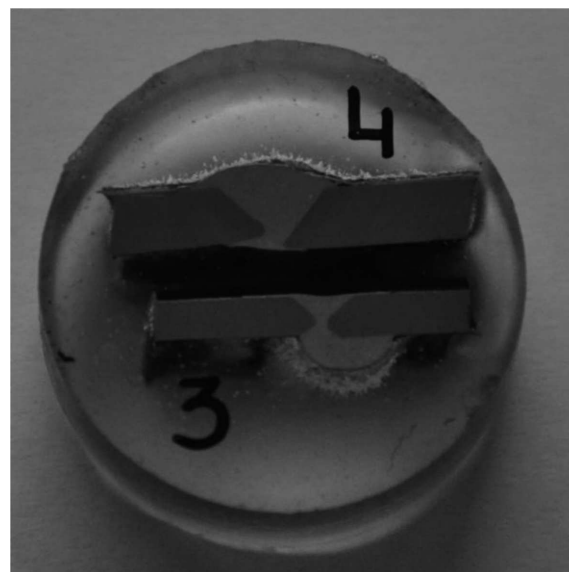
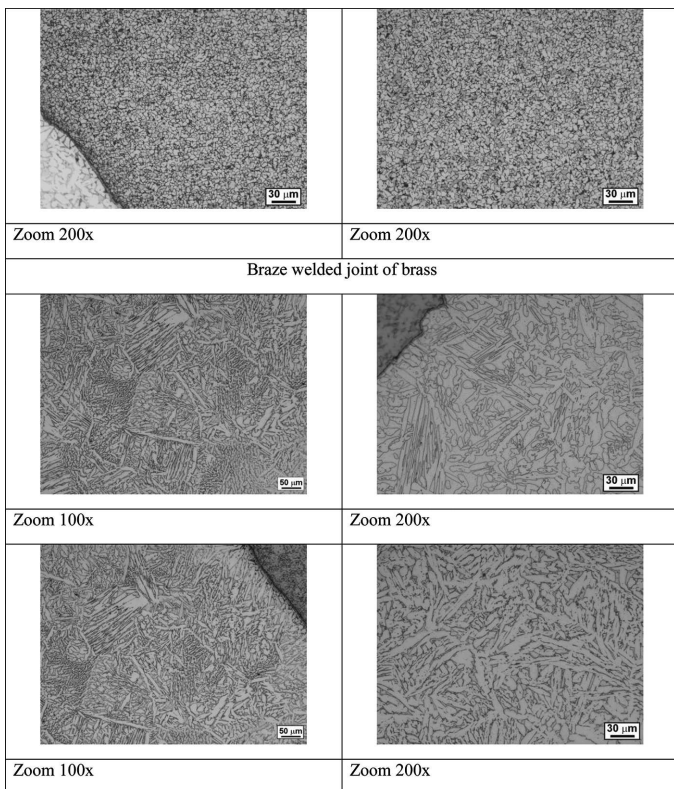
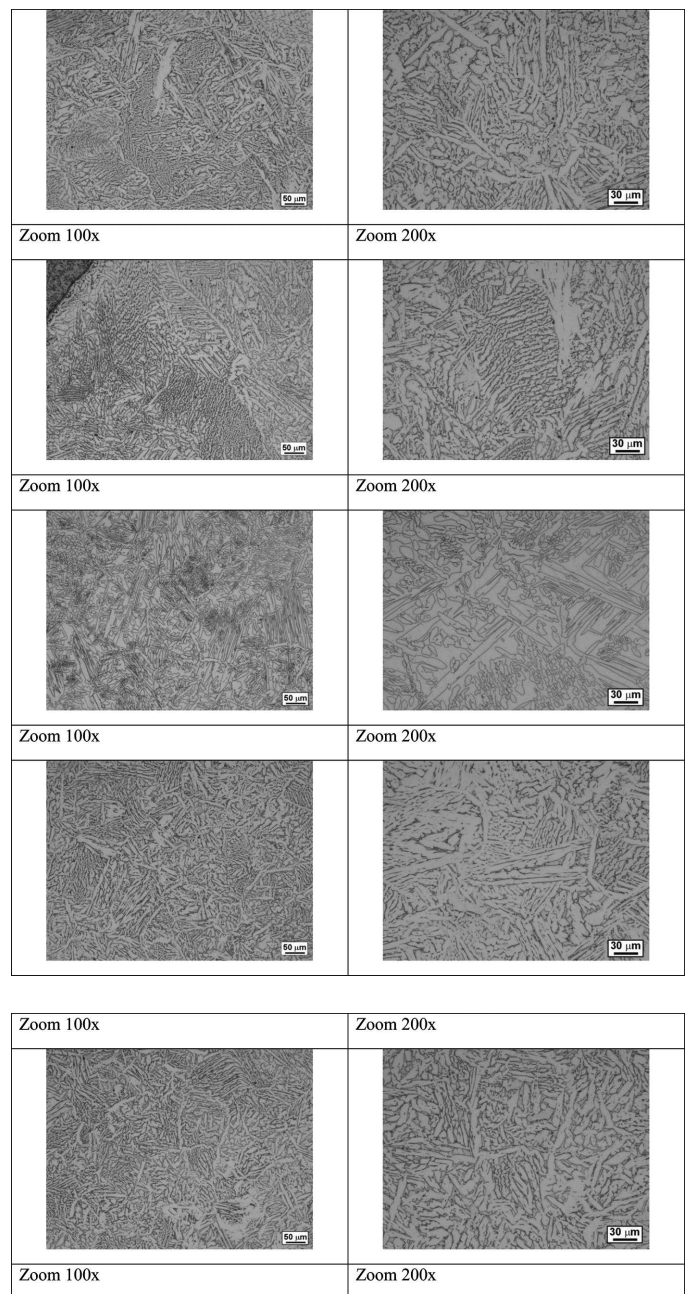
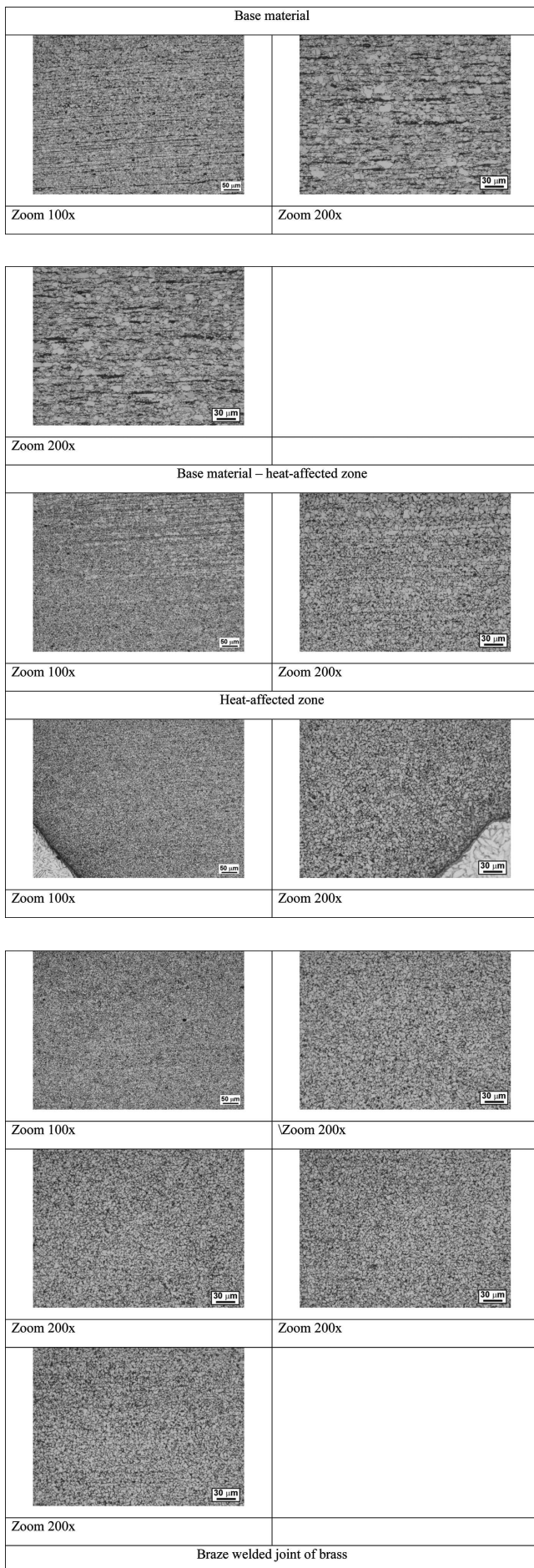


Fig. 4. A macroscopic specimen of a sample nr 4

Example microstructures of braze welded joint 4 are shown underneath.



Specimen nr 5

Thickness of a base material 3 mm
 Prepared materials: V bevelled
 Made by TIG (141) method with argon applied from the root side in order to form it
 Parameters:
 Current intensity: 52 [A]
 Alternating current (AC)

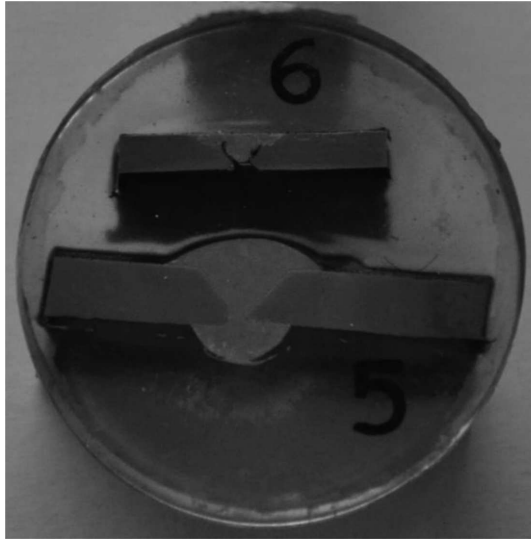
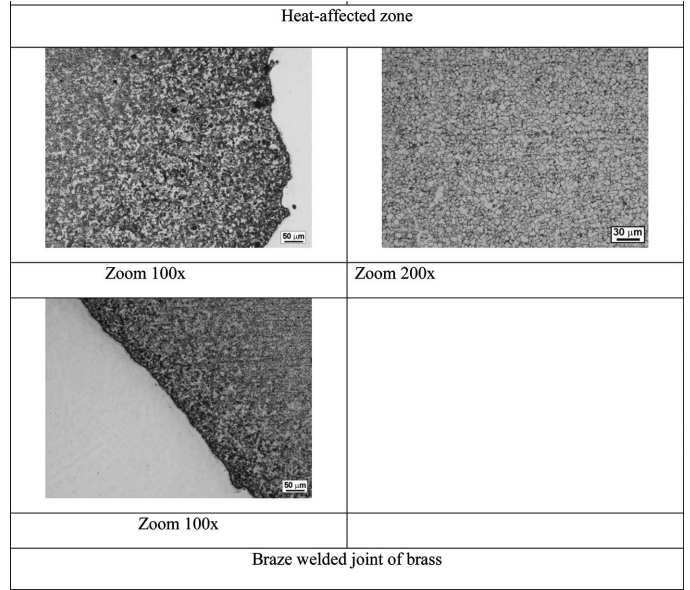
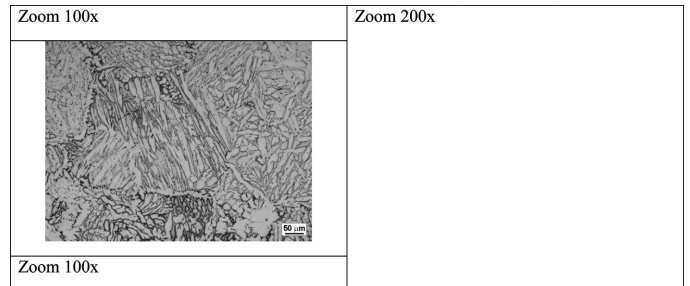
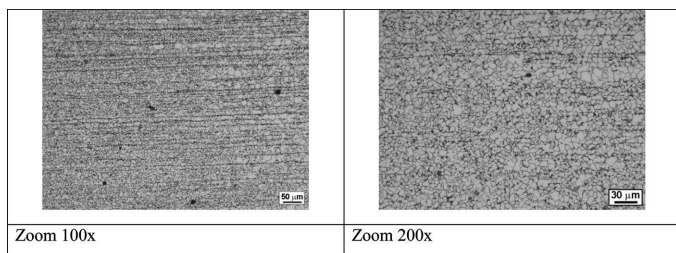
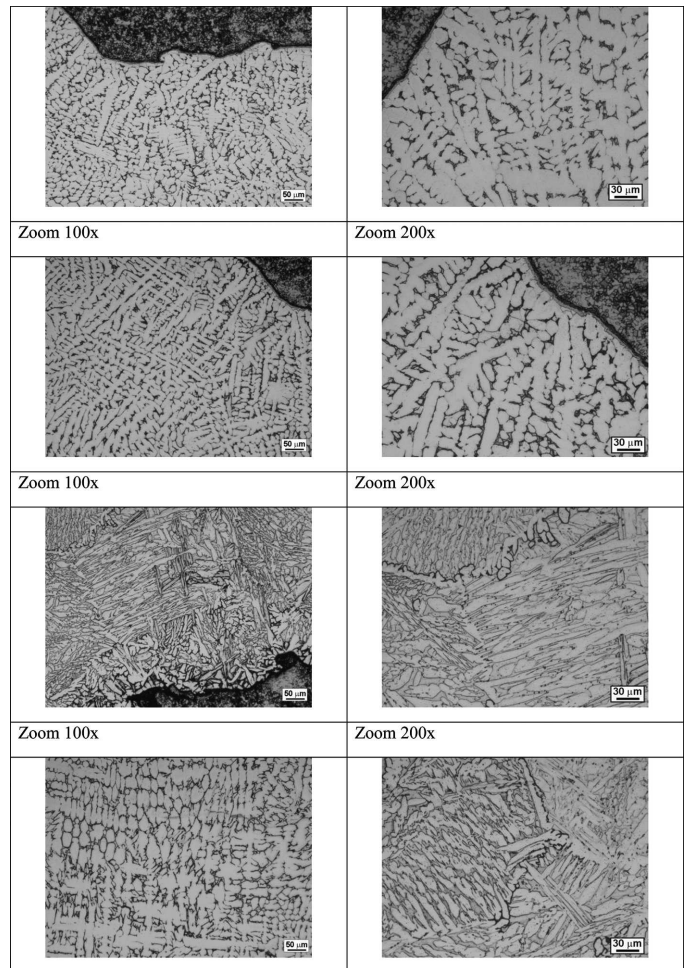
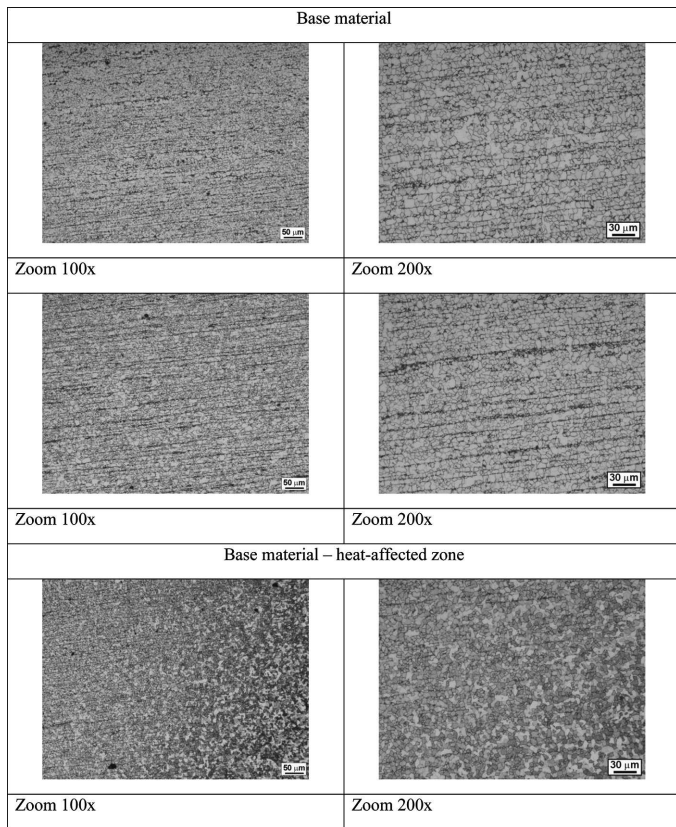


Fig. 5. A macroscopic specimen of a sample nr 5



Example microstructures of braze welded joint 5 are shown underneath.



Specimen nr 6

Thickness of a base material 2 mm
 Prepared materials: V bevelled
 Made by TIG (141) method with argon applied from the root side in order to form it
 Parameters:
 Current intensity: 48 [A]
 Alternating current (AC)

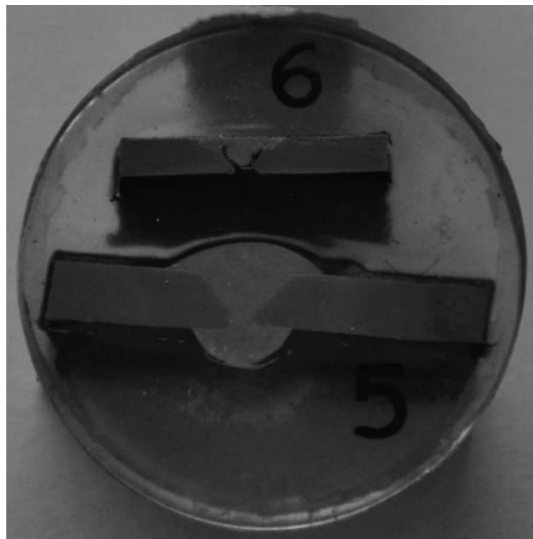
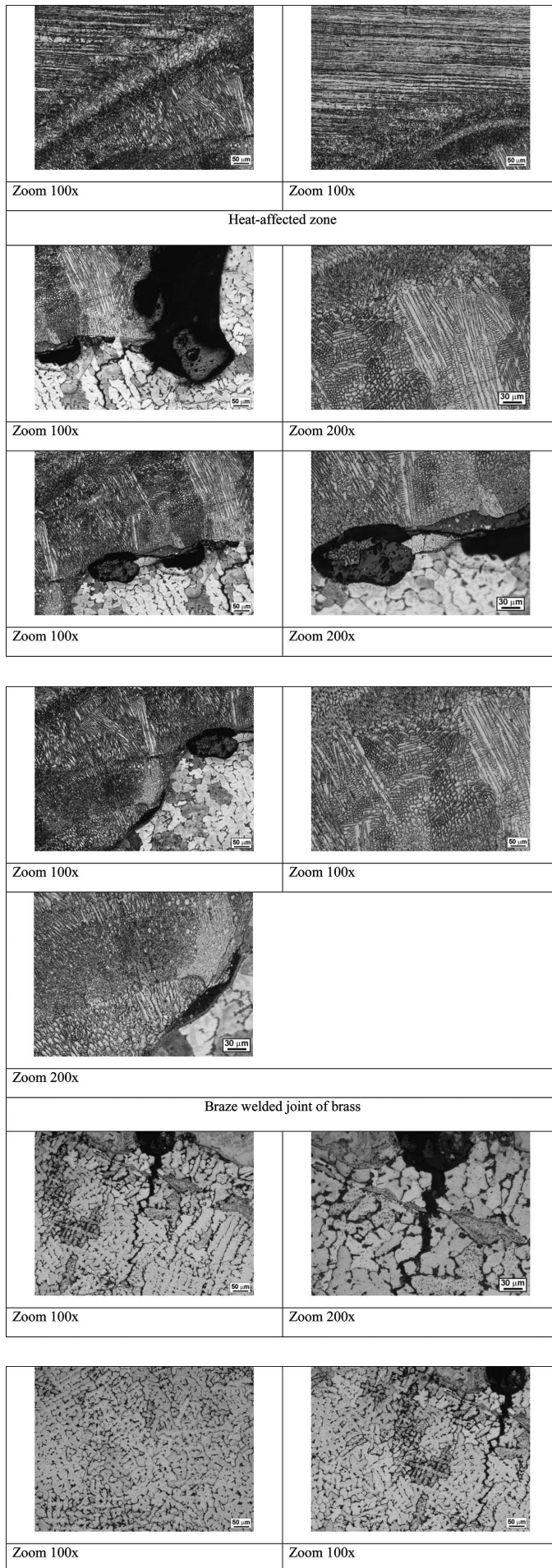
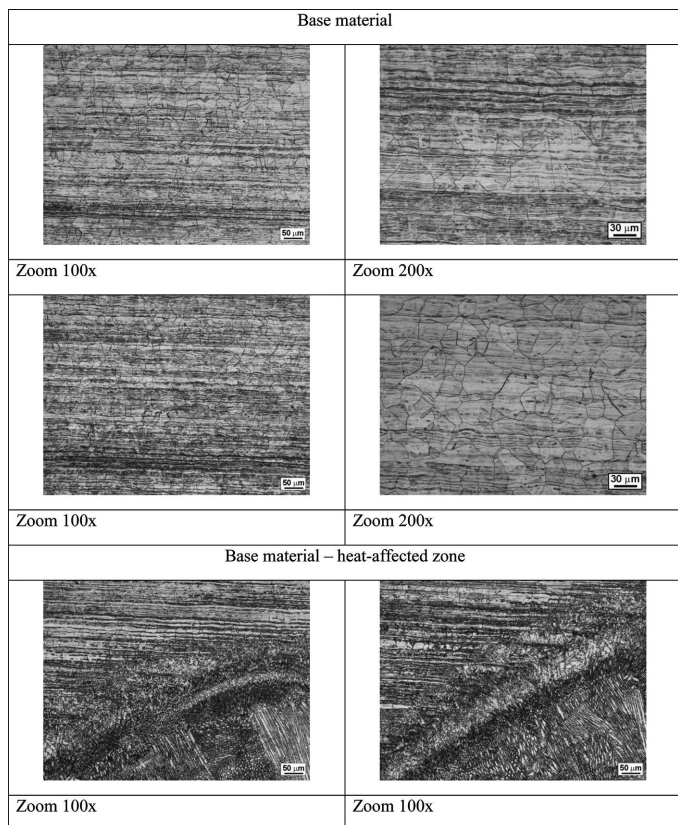


Fig. 6. A macroscopic specimen of a sample nr 6

Example microstructures of braze welded joint 6 are shown underneath.



Macroscopic examinations showed welding discrepancies in case of braze welded joints.

Specimen 1, 2,

Welding discrepancies are as follows:

- considerable edge displacements
- too much argon applied from the root side can be a possible reason of lack of full filling of a welding groove
- bubbles

Specimen 3

There are the following discrepancies:

- considerable edge displacements
- too little argon applied from the root side can be a possible reason of an excessive flow out from the root side
- concaved face of braze weld

Specimen 4

There is a following discrepancy:

- considerable edge displacements

Specimen 5

There are the following discrepancies:

- considerable edge displacements
- too little argon applied from the root side can be a possible reason of an excessive flow out from the root side
- excessive face reinforcement of braze weld

Specimen 6

There are the following discrepancies:

- lack of a filling of a welding groove
- discrepancies of a shape and size (a flat face of the braze weld)

Microscopic examinations for specimen 1-5 showed in the base material fine grained ferrite-pearlite microstructure with pearlite distributed in the bands.

In the heat-affected zones of examined steel (specimen 1-5) fine grained ferrite-pearlite microstructure was observed without any visible bands. Moreover, in the area of the face of braze welded joint 1 (which is pointed in the picture of a macroscopic specimen) a microstructure of needle-like ferrite was observed.

Two phase brass microstructure was observed in the joint. Both microstructures consisting of an irregular phase mixture α (light areas) and phase β (dark areas) were noticeable, as well as the areas of two phase microstructures showing the features of Widmannstätten microstructure were revealed.

Microscopic examinations of specimen nr 6 showed that the base material is characterised by the microstructure highly deformed austenite. Heat-affected zone in the area of fusion had a dendrite structure, and numerous welding discrepancies were observed. In case of the above joint, cracks spreading on the boundaries of grains of α phase were revealed from the zone of the fusion line into the centre of the joint. In the joint, two phase brass microstructure was observed. It consists of a mixture of α phase (light areas) and β phase (dark areas)

6. Hardness measurement

Hardness measurement for the braze welded joints of specimen 1-6 was made by Vicker's method by means of Future-Tech FV-700 hardness testing machine using a load of 5 kG (49,03 N) of the indenter. Due to the thickness of the pipe's wall hardness distribution was made only to one row of

stamps making measurements in the centre of the wall's thickness. Obtained measurements are presented as the graphs in the charts 7-12. A measurement of microhardness for braze welded joints of specimen 1-6 was made by the microhardness testing machine Future-Tech FM-7 with a load of 100g. The results of microhardness measurements are shown as the graphs in the charts 13-18. A microhardness measurement in the examined elements was made along the joint section within 1 mm from the edge of the specimen, in the area of the face and the root.

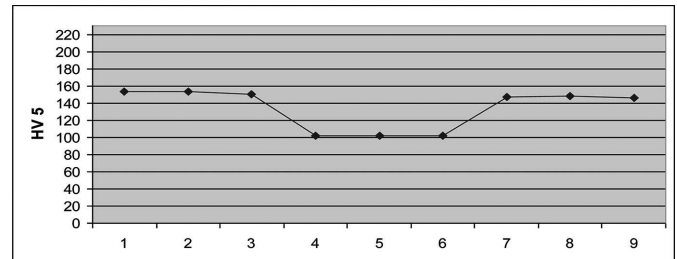


Fig. 7. Hardness distribution of an examined braze welded joint 1

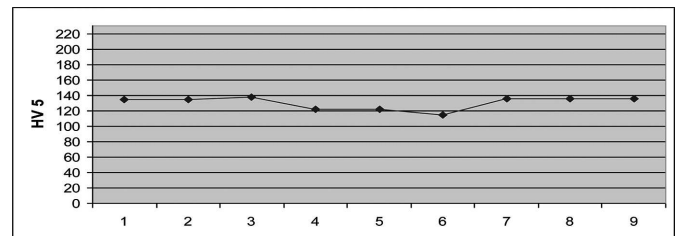


Fig. 8. Hardness distribution of an examined braze welded joint 2

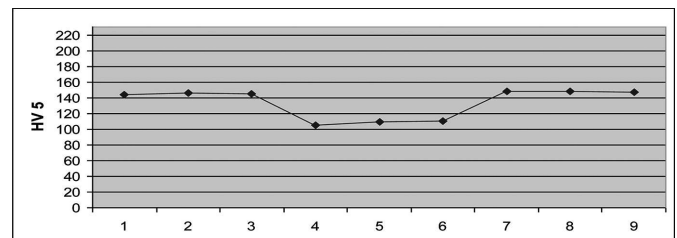


Fig. 9. Hardness distribution of an examined braze welded joint 3

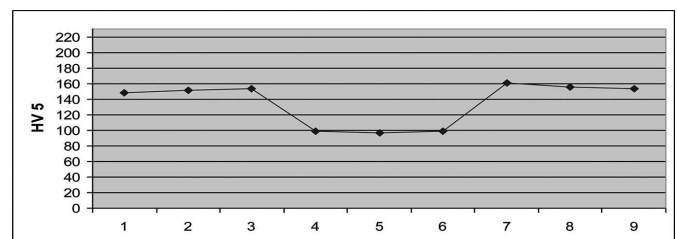


Fig. 10. Hardness distribution of an examined braze welded joint 4

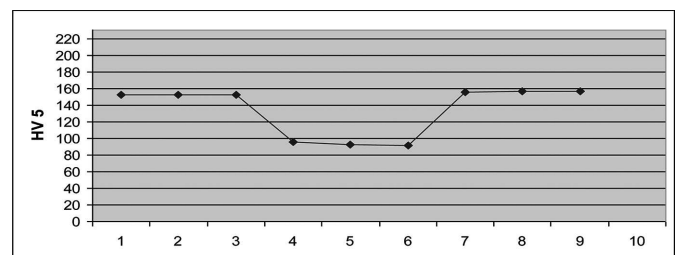


Fig. 11. Hardness distribution of an examined braze welded joint 5

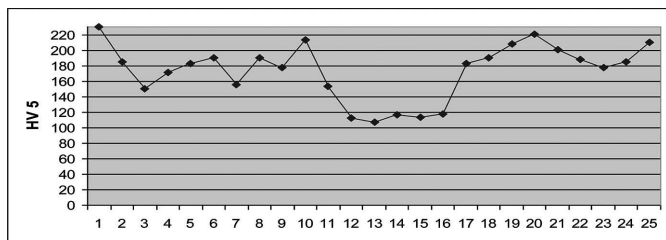


Fig. 12. Hardness distribution of an examined braze welded joint 6

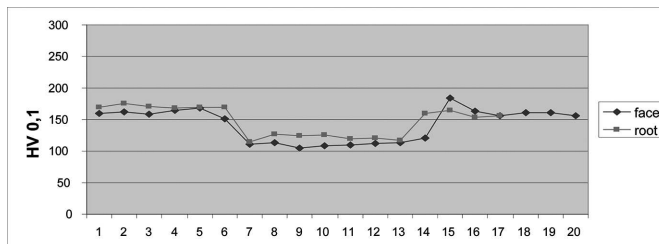


Fig. 17. Microhardness distribution of an examined braze welded joint 5

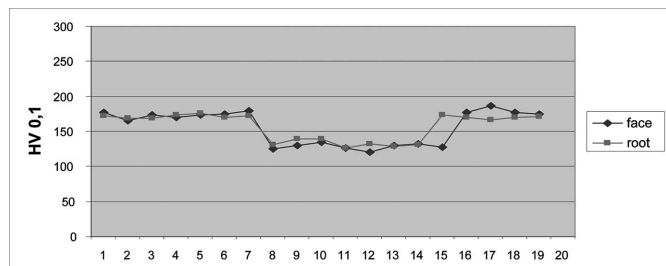


Fig. 13. Microhardness distribution of an examined braze welded joint 1

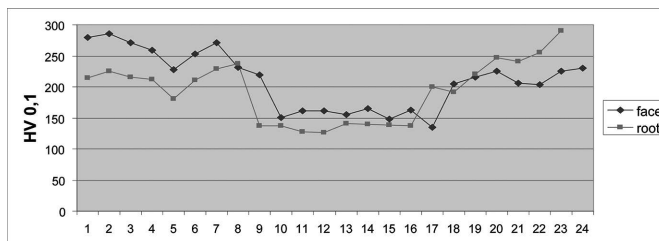


Fig. 18. Microhardness distribution of an examined braze welded joint 6

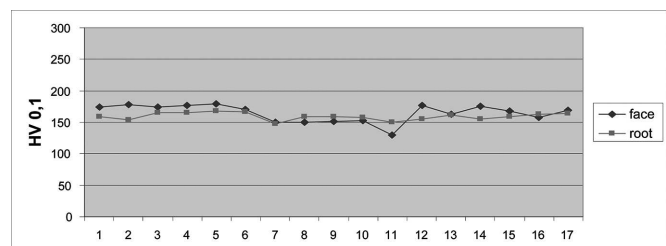


Fig. 14. Microhardness distribution of an examined braze welded joint 2

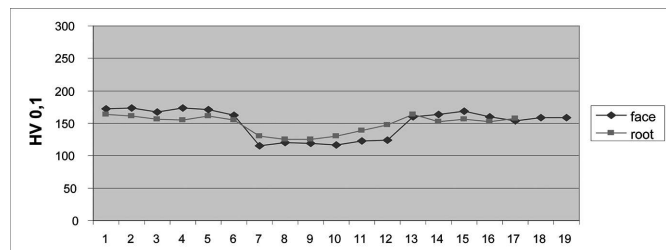


Fig. 15. Microhardness distribution of an examined braze welded joint 3

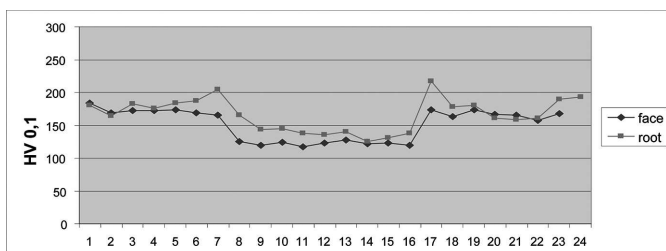


Fig. 16. Microhardness distribution of an examined braze welded joint 4

7. Static tensile test

The results of the static tensile test of braze welded joints are presented in the Table 1.

TABLE 1

The results of the static tensile test of braze welded joints

Specimen number	R _m MPa
1	294
2	180
3	304
4	268
5	201
6	113

All the specimen were broken in the area of braze welded joint. Macroscopic pictures of specimen after a static tensile test are presented in the photos 19-24.

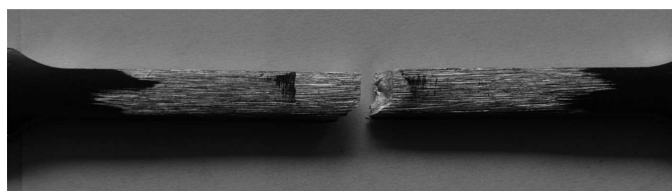


Fig. 19. A specimen nr 1 after a static tensile test

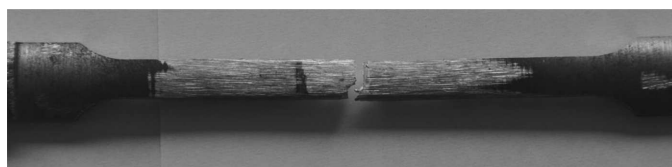


Fig. 20. A specimen nr 2 after a static tensile test

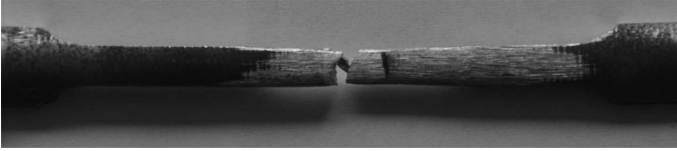


Fig. 21. A specimen nr 3 after a static tensile test

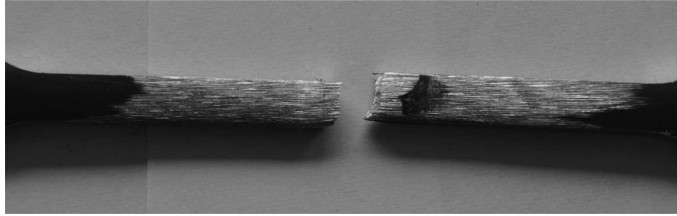


Fig. 22. A specimen nr 4 after a static tensile test

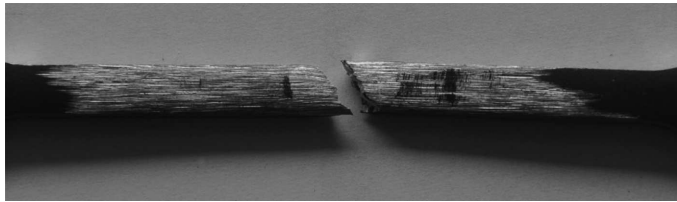


Fig. 23. A specimen nr 5 after a static tensile test

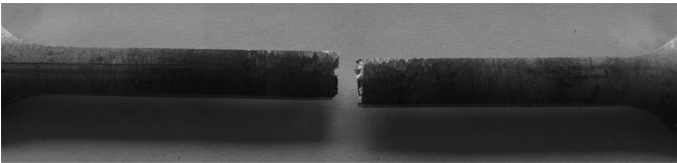


Fig. 24. A specimen nr 6 after a static tensile test

8. Summary

Examinations of braze welded joint showed numerous discrepancies such as: bubbles, incomplete fusion, edges dislocations as well as an excessive flow out from the root side.

The reason of the occurrence of discrepancies is probably an imprecise preparation of the material before starting joining, particularly:

- an insufficient cleaning of the material, which probably causes bubbles between a braze weld and a base material,

- as well as a noticeable sticking of the braze weld to the material (lack of diffusing)
- an imprecise centring of the pipes, which causes an occurrence of a visible impermissible edge dislocation
- an excessive flow out from the root side caused by an imprecise centring of the pipes and too big distance between materials

Distance between materials should not exceed a thickness of a filler material.

Widmannstätten structure can also be observed due to a temporary, excessive cooling of the braze weld. There is not any influence on the durability of the joint in case of braze welding from the technological point of view. There are tensile tests, which were taken to prove it. The crack appeared in braze weld in each specimen.

Summing up, braze welding method can be used for the galvanized materials, which do not operate in the high temperature environment, as well as in high pressure e.g. fire protection systems, which in turn considerably reduce the costs of manufacture.

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