Influence of the resistive-pulse welding parameters of nickel super-alloys on selected properties of the connection

Wpływ parametrów spawania opornościowo-impulsowego superstopów niklu na wybrane właściwości połączenia

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DOI: https://doi.org/10.17814/mechanik.2017.11.180

Microstructure and mechanical tests of welds of thin sheets made from nickel-based super-alloys (Haynes 230 and Hastelloy X) were presented. The welds were made using the resistive-pulse micro-welding method using the WS 7000S device. The micro-hardness of the joints was measured with a Matsuzawa Vickers MX 100 hardness tester at 100 G (0.98 N). Metallographic observations of the prepared micro-sections were performed using the Nikon Eclipse MA200 optical microscope at various magnifications. The metallographic microstructure studies were supplemented by linear analysis of the chemical composition, for which the OXFORD X-MAX electron microscope was applied.
KEYWORDS: micro-welding, surface engineering, microstructure, micro-hardness

Resistive-pulse welding [1, 2, 4], called micro-welding (as a result of the impact on bonded materials), is characterized by the fact that high-energy discharge in the short term produces a local rise in a temperature above the solidus line. Due to the physical phenomena accompanying the bonding process, the welded material is connected indirectly between the sealing and welding. Micro-welding is used where, due to the small size of the bonding (or micro-gripping) area, traditional techniques would be ineffective. Resistive-pulse welding is suitable for a much wider range of repairs than traditional regeneration methods [5–16]. This technique has gained a lot of popularity. Although the micro-seam yields in terms of the quality of classic weld, due to its negligible thermal impact on the substrate material, ease of processing, and the applicability of the components for quick and relatively easy repair of the components, is valid in many different cases – e.g. in repairing local damage to the dies, injection molds or cutting edges. The commercially available micro-welding devices have impulse parameters indicating the possibility of producing thin sheet metal connections made of Ni-based super-alloys. In literature, the results of investigations of such connections are increasingly found [17–28].

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Research equipment and subject of study

The resistive-pulse micro-welding was performed using a WS 7000S welding machine from SST France & Vision Lasertechnik. The device generates pulses with an average frequency of 5000 Hz. Analyses of preliminary results have allowed to determine the conditions of micro-welding of thin sheets made of Hastelloy X and Haynes 230 super-alloys.

The following settings have been made:

- welding current intensity in the range of 50÷70% of power (maximum 7000 A),
- welding time 10 ms,
- pulse form – continuous,
- working cycle – welding cycle, many pulses.

The chemical composition of the tested super-alloys is shown in tables I and II.

Fig. 1. Pulse micro-welding device WS 7000S

TABLE I. Chemical composition of Hastelloy X super-alloy

Element	Content, %
Ni	47
Cr	22
Fe	18
Mo	9
Co	1.5
W	0.6
C	0.1
Mn	1.0
Si	1.0
B	0.008

TABLE II. Chemical composition of Haynes 230 super-alloy

Element	Content, %	
	minimum	maximum
Ni	47	65
Cr	20	24
W	13	15
Mo	1.0	3
Co	–	5
Al	0.2	0.5
La	0.005	0.005
Mn	0.3	1
C	0.05	0.15
Si	0.25	0.75

Metallographic microstructure of a joint

In order to carry out the metallographic examination of the joint, the specimens were cut off and included in the resin and then prepared for metallographic deposition.

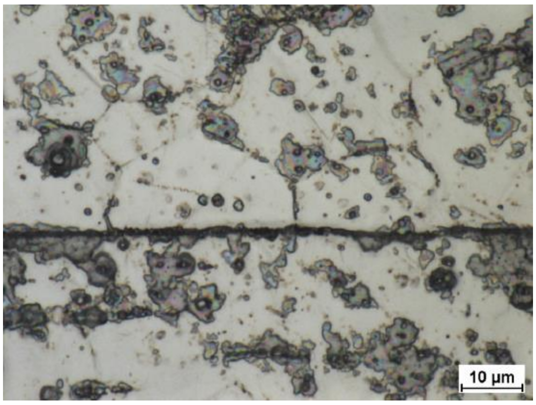

Fig. 2. Microstructure of the joint made at current value of 50% (magnification 1000×)

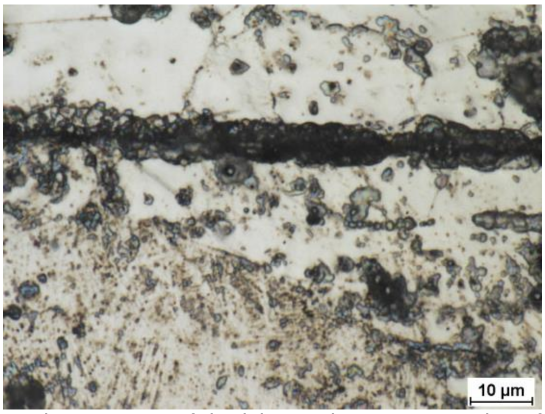

Fig. 3. Microstructure of the joint made at current value of 60% (magnification 1000×)

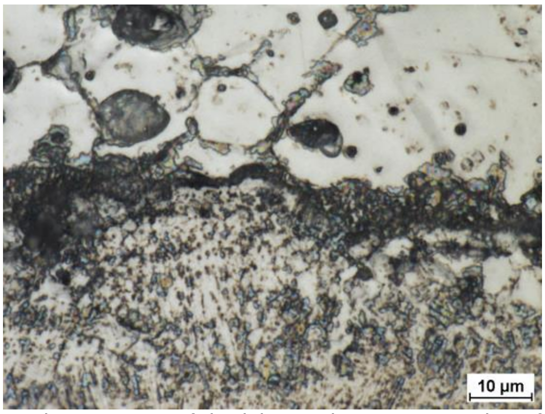

Fig. 4. Microstructure of the joint made at current value of 70% (magnification 1000×)

Samples were etched by means of electrolysis. Exemplary photographs of metallographic microstructures (observed on the Nikon Eclipse MA200 optical microscope with NIS 4.20 image analysis system) are shown in figs. 2–4.

Examination of micro-hardness distribution in the joint zone

Micro-hardness tests according to Vicker's method were performed under the load of 100 G (0.98 N) for 15 s. The average results of micro-hardness measurements in the joint material and thermal transfer zone (SWC) are presented in table III, and distribution of micro-hardness in fig. 5.

TABLE III. Results of micro-hardness measurements

Pulsepowerlevel	Hastelloy XSWC, HV 0.1	JointHV 0.1	Haynes 230 SWC, HV 0.1
50%	232	278	260
60%	240	300	255
70%	239	290	253

Analysis of the micro-hardness distribution of the micro-joint and the hardness in the zone of thermal transfer indicates that the parameters of the process were chosen correctly. With respect to the hardness of the native material, there was an increase in the hardness of the joint area and in the zone of thermal transfer.

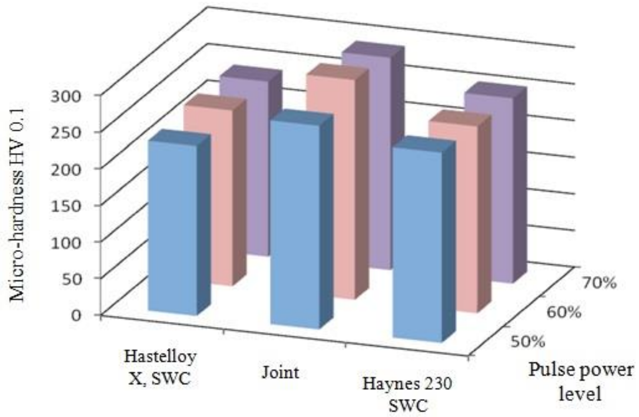

Fig. 5. Micro-hardness distribution in micro-welded joints of Hastelloy X and Haynes 230 super-alloys and heat transfer zones

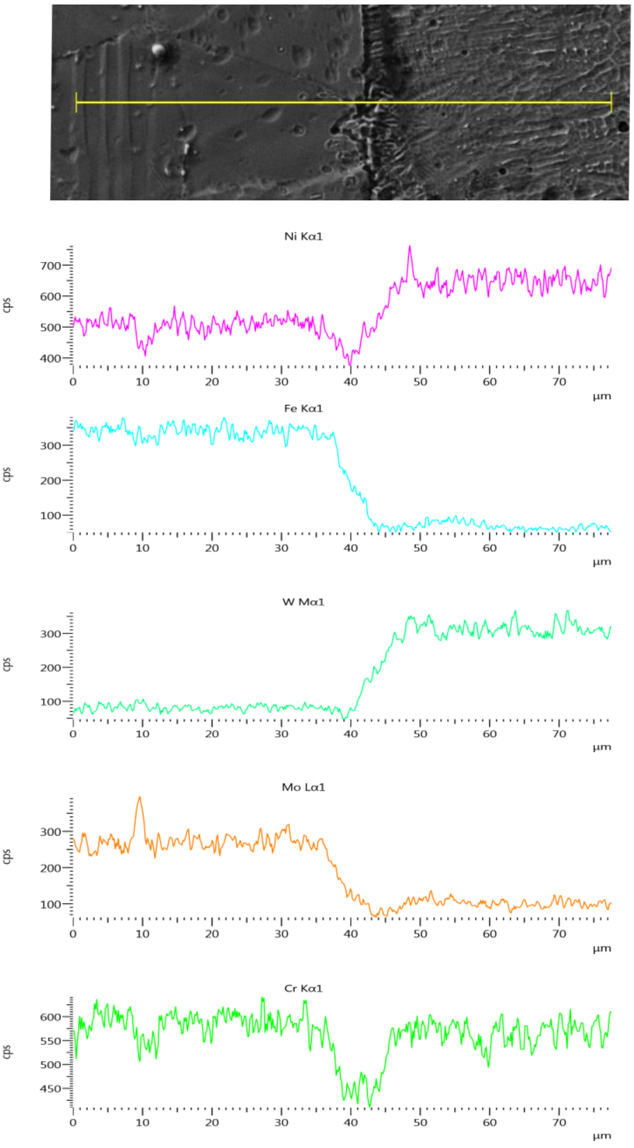

Fig. 6. Linear SEM analysis of chemical composition of welded joint of super-alloys Hastelloy X and Haynes 230

Linear analysis SEM of chemical composition

The metallographic microstructure study was supplemented by linear analysis of the chemical composition. As a result, the distribution of selected elements (fig. 6) in the area of the joint. The analysis was carried out using OXFORD X-MAX electron microscope.

In the presented micro-photograph and graphs, the left side corresponds to the Hastelloy X super-alloy, while the right – to Haynes 230.

Conclusions

The research has allowed for drawing the following conclusions:

- it is possible to obtain the correct joint, provided that high power parameters are used,
- micro-hardness tests for all samples confirmed the increase in hardness in the joint zone,
- no cracks in the area of the weld and the heat transfer zone,
- no modification was found in the joint – no diffusion of elements occurred.

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