Zeszyty Naukowe Politechniki Częstochowskiej
Budownictwo
ISSN 0526-5916

Zeszyty Naukowe Politechniki Częstochowskiej nr 26 (2020), 114-119
DOI: 10.17512/znb.2020.1.17

The effect of the resistance spot welding current on weld quality and joint strength

Judyta Niemiro-Maźniak[1]

ABSTRACT:
Thin-walled area elements are becoming increasingly popular and necessary in construction and various other industries. This trend is also accompanied by the need for development and research into joining methods that will ensure that the structures have an appropriate ratio of their load capacity to their weight. A commonly used method for joining thin metal elements is resistance welding, using the natural electrical resistance property of metals. The study examined the impact of the resistance welding current value on the quality and load capacity of the RSW weld. Lap joints with a single weld, using alternative current flow values during welding, were made. The joints were subjected to a static tensile test. Load capacities of the analyzed joints and force-displacement graphs were obtained. A numerical analysis of joints with different weld diameters was also carried out. Plastic deformation graphs were obtained in the cross-section through the center of the weld and the distribution of plastic deformations throughout the sample. As the weld diameter increases, the load capacity of the joint increases and the plastic deformation decreases. However, the use of excessive current flow may cause molten metal splash and reduce the strength of the joint.

KEYWORDS:
resistance welding; thin-walled constructions; RSW joint

1. Introduction

In construction and other industries, there is growing interest in thin-walled constructions. It is primarily influenced by the lightness of such constructions, easy assembly and shorter implementation time. A very important aspect when designing thin-walled structures is the connection method that ensures a high load-bearing capacity of the structure in relation to its weight. One of the commonly used methods for obtaining permanent metal connections is resistance welding. It is an efficient and economic method of joining metals using their electrical resistance. The most widely used form of resistance welding is spot resistance welding (RSW) [1, 2]. Resistance welding testing of various metals with the same metallographic composition, as well as metals with different mechanical properties, including aluminium and steel is increasingly being carried out [3]. Spot welding can be performed manually, automatically or using a spot welding machine [4, 5]. The quality of connections (welds) is greatly influenced by properly selected welding parameters.

The study carried out experimental research on the impact of the resistance welding current on the weld quality and joint load capacity. The current flow rate determines the size of the weld nugget, which further affects the distribution of deformation in the joint and the load capacity of the joint. A numerical analysis of joints with different weld diameters was performed and the graph of plastic deformation distribution in the joint was presented.

[1] Czestochowa University of Technology, Faculty of Civil Engineering, ul. Akademicka 3, 42-218 Częstochowa, e-mail: j.niemiro-mazniak@pcz.pl, orcid id: 0000-0001-6808-7067

2. Resistance spot welding

2.1. The resistance spot welding process

Resistance spot welding is a process where the welded elements are pressed together with a certain force by means of electrodes. Then, an electric current of the appropriate intensity is passed through these elements. On the contact surface, heat is generated and a liquid weld nugget is formed, which then cools to form a uniform metallic connection. The weld nugget cools down under the electrode pressure [6]. The resistance spot welding process is shown in Figure 1.

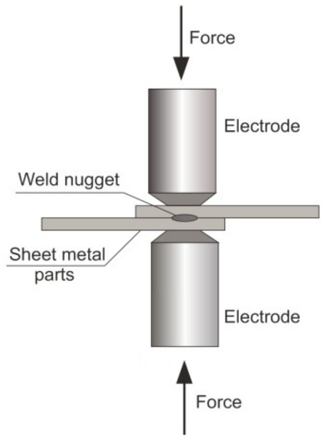

Fig. 1. Resistance welding process

The heat generated during the flow of electricity is determined on the basis of Joule-Lenz's law (1). The amount of heat generated is directly proportional to the square of the current intensity *I*, welding zone resistance *R* and current flow time *t*:

$$Q = \int_0^t I^2(t) \cdot R(t) \cdot dt \tag{1}$$

2.2. Welding parameters

The basic parameters of resistance spot welding (RSW) are current intensity, welding current flow time, dimensions, material and electrodes pressure force. Parameters are selected depending on the type of materials being joined, their thickness, shape and dimensions. One of the most important parameters of resistance welding is the value of current intensity [6], which determines the quality of welding. Too low a current during welding, despite the long flow time, makes welding difficult. It is caused by intensive heat dissipation through welded elements and cooling of electrodes with water. The resulting weld nugget is too small or sticking is observed. Too much current leads to the rapid formation of a liquid weld nugget. It then grows to the outer surfaces of the welded elements and is followed by the splash of liquid metal. This weld splash has a major relationship to the value of the welding current. Joints in which liquid metal splash occurs have lower strength [7], and during their formation the electrodes wear out more quickly. The magnitude of the current intensity is selected so that the size of the weld nugget ensures the formation of a joint with adequate strength. It reaches its maximum size when the power supply is turned off. The desired nugget diameter can be obtained by matching the welding current to the welding time.

3. Experimental research

3.1. Experimental research – samples

Experimental studies were carried out on thin-walled components with the dimensions 25x100 mm, cut from steel sheets of 0.8 mm thick DC01. Resistance spot welding was carried out on a resistance welding machine. Six lap joints were made with a single RSW weld, differing in the amount of weld current flow. The geometry of the joints is shown in Figure 2. Joints 1 and 2 were made assuming optimal welding parameters obtained in [8] (control samples). The welding current for these samples averaged 6.8 kA. Welding of joints 3 and 4 was carried out with a 10% reduction in weld current flow compared to joints 1 and 2, while joints 5 and 6 had a 10% increase in weld current flow compared to joints 1 and 2. The joints were subjected to a uniaxial tensile test on a strength machine at a test speed of 2 mm/min.

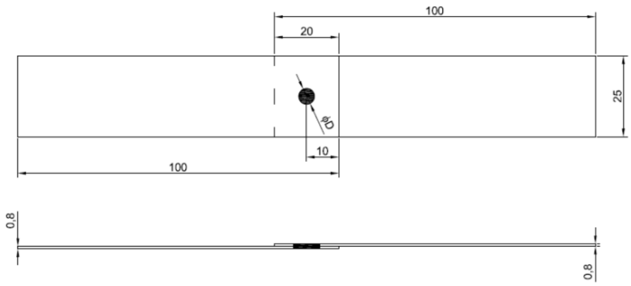

Fig. 2. Geometry of RSW joints

The welding time for all samples was kept the same at 11 periods. The down force was 700 daN.

3.2. Results

As a result of the shearing test of the joints, maximum values of forces, which were transferred through the analyzed RSW joints were obtained. Table 1 summarizes the results from the tensile test. The average tensile load capacity of joints 1 and 2 (control samples) was 4.8 kN. Joints made using a 10% reduction in current compared to joints 1 and 2 – 4.37 kN. Joints made using a 10% increase in current in relation to joints 1 and 2-5.13 kN. The displacement – force diagrams are shown in Figure 3.

The largest diameter of welds was obtained for joints 5 and 6, while the smallest for joints 2 and 3. The structure of welds in the joints was subjected to microstructural analysis and showed no defects or cracks.

Table 1
Shear test results of RSW joints

RSW joint number	Maximum force [kN]	The average force [kN]
RSW joint 1	4.78	4.8
RSW joint 2	4.82	
RSW joint 3	4.34	4.37
RSW joint 4	4.4	
RSW joint 5	5.1	5.13
RSW joint 6	5.16	

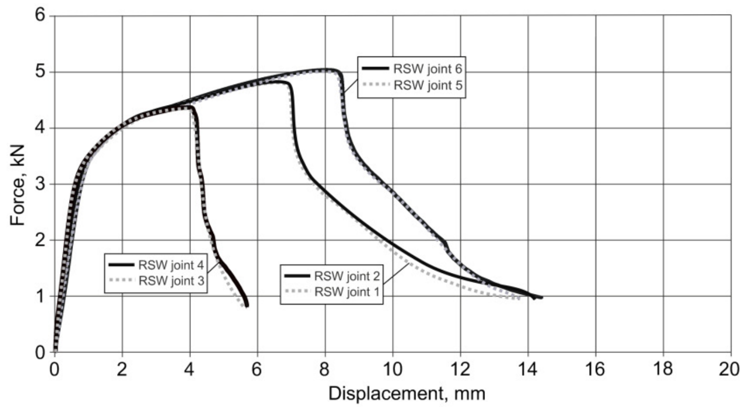

Fig. 3. Shear test results RSW joints – displacement-force diagrams

4. Numerical analysis

4.1. Numerical models

For the numerical analysis, models of lap joints consisting of a single weld with the same geometry as in the experimental studies were made (Fig. 4). The models differed in that the diameter of the welds; 3.5, 6 and 7 mm welds were adopted. The distribution of plastic deformations was observed in the joint cross-section depending on the given diameter. All models were made of 27-node 3D-solid elements. Boundary conditions and displacements were applied to the surface. The displacement value in all models was the same and amounted to 6 mm. The numerical analysis was carried out in a program using the Finite Element Method – ADINA.

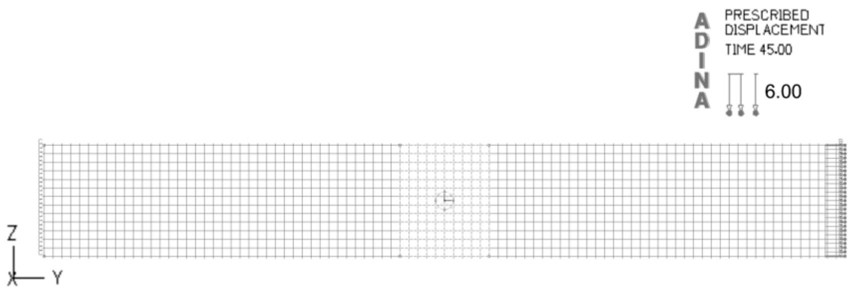

Fig. 4. Numerical model

4.2. Results

Figure 5 shows a graph of plastic deformation in the cross-section of joints with different weld diameters. In joints with a diameter of 5-7 mm, the maximum deformation shows the place of initiation of cracks at the edges of the weld. In this case, it can be predicted that the sample will be compromised by breaking the material near the weld. In a joint with a diameter of 3 mm, the maximum plastic deformation is in the middle of the weld. In this case, the weld may be truncated or the weld too small and the material will stick. Figure 6 shows the distribution of plastic stress throughout the joints.

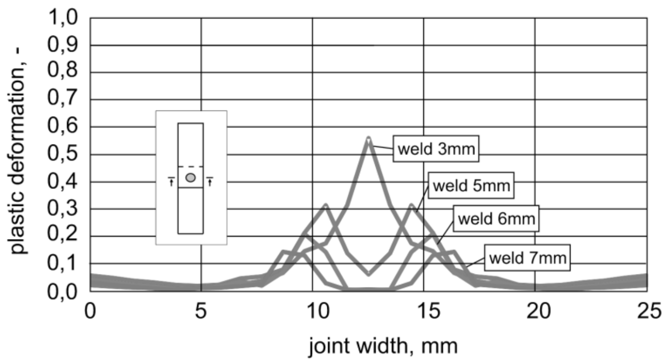

Fig. 5. Graph of plastic deformation in joints

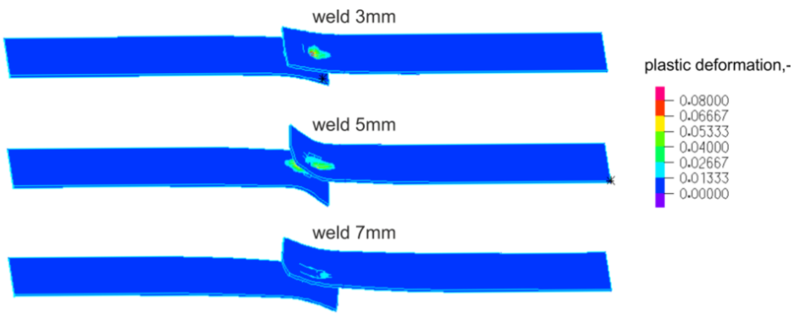

Fig. 6. Plastic deformation

5. Conclusions

The growing interest in thin-walled structures results in the need for further research that will grant higher load capacities and quality of the structure. The experimental tests carried out in the study provides the opportunity to observe the impact of the weld current flow on the load capacity of weld joints. The higher the value of weld current flow, the greater the weld. As the diameter of the weld increases, the joint has a higher load capacity and plastic deformation decreases. A reduction in the flow rate by 10% relative to the flow rate used in the control samples reduced the load capacity of the joints 9%. Increasing the flow rate by 10% relative to the flow rate used in the control samples increased the load capacity of the joints 7%. The obtained joints had the correct microstructure. With further increase of the current, excessive welds and splash of liquid metal could occur, resulting in reduced strength.

The numerical analysis showed the distribution of plastic deformations in the cross-section of the joint depending on the diameter. The maximum deformation initiating the crack site shifts to the periphery of the weld as the diameter increases. The smallest plastic deformations are observed for a joint with a weld diameter of 7 mm. The joint with the weld diameter of 3 mm obtained the largest deformation, where the maximum deformation can be observed in the very center of the joint. If the current is too low, the weld nugget may be too small and only sticking can be observed, resulting in poorly made joints.

References

[1] Eşme U., Application of Taguchi method for the optimization of resistance spot welding process, The Arabian Journal for Science and Engineering 2009, 34, 2B.

[2] Hou Z. et al., Finite element analysis for the mechanical features of resistance spot welding process, J. Mater. Process. Technol. 2007, 185, 160-165.

[3] Sun X., Stephens E.V., Khaleel M.A., Shao H., Kimchi M., Resistance spot welding of aluminum alloy to steel with transition material-from process to performance – Part I: Experimental study, Welding Journal 2004, 83(7), 197S-202S.

[4] Yang Y.S., Lee S.H., A study on the joining strength of laser spot welding for automotive applications, J. Mater. Process. Tech. 1999, 94, 151-156.

[5] Nong N. et al., Research on press joining technology for automotive metallic sheets, J. Mater. Process. Tech. 2003, 137, 159-163.

[6] Aslanlar S., The effect of nucleus size on mechanical properties in electrical resistance spot welding of sheets used in automotive industry, Material & Desing 2006, 27, 2, 125-131.

[7] Manladan S.M., Yusof F., Ramesh S., Fadzil M., Luo Z., Ao S., A review on resistance spot welding of aluminum alloys, The International Journal of Advanced Manufacturing Technology 2017, 90, 605-634.

[8] Lacki P., Niemiro-Maźniak J., A comparative analysis of the load capacity of riveted and resistant welded joints, Zeszyty Naukowe Politechniki Częstochowskiej 2019, seria Budownictwo 25, 126-130.

Wpływ natężenia prądu zgrzewania oporowego na jakość zgrzeiny i wytrzymałość złącza

STRESZCZENIE:
Elementy cienkościenne stanowią aspekt coraz bardziej popularny i potrzebny w budownictwie oraz różnych gałęziach przemysłu. Towarzyszy temu również potrzeba rozwoju oraz badań nad metodami, które będą zapewniać konstrukcjom odpowiedni stosunek nośności do ich masy. Powszechnie stosowaną metodą łączenia cienkich elementów metalowych jest zgrzewanie oporowe, wykorzystujące naturalną właściwość metali – oporność elektryczną. W pracy przeprowadzono badania wpływu wielkości natężenia prądu podczas zgrzewania oporowego na jakość i nośność zgrzeiny RSW. Wykonano po dwa złącza zakładkowe z pojedynczą zgrzeiną, różniące się wielkością natężenia przepływu prądu podczas zgrzewania. Złącza zostały poddane statycznej próbie rozciągania. Uzyskano nośności analizowanych złączy oraz wykresy siła-przemieszczenie. Przeprowadzono również analizę numeryczną złączy o różnej średnicy zgrzeiny. Uzyskano wykresy odkształceń plastycznych w przekroju przeprowadzonym przez środek zgrzeiny oraz rozkład odkształceń plastycznych na całej próbce. Wraz ze wzrostem średnicy zgrzeiny rośnie nośność złącza, a odkształcenia plastyczne maleją. Jednak zastosowanie zbyt dużego natężenia przepływu prądu może spowodować wyprysk ciekłego metalu i obniżyć wytrzymałość złącza.

SŁOWA KLUCZOWE:
zgrzewanie oporowe; konstrukcje cienkościenne; złącze RSW