Spot-resistant welding process of profiled wire for precise filtration screens – experiments and modelling

Marcin Kwiecień[1], Mateusz Kopyściański[1],
Krzysztof Muszka[1], Janusz Majta[1]

[1] AGH University of Science and Technology, Faculty of Metals Engineering and Industrial Computer Science, 30 Mickiewicza Ave, 30-059 Krakow, Poland
mkwiecie@agh.edu.pl, kopyscianski@agh.edu.pl,
muszka@agh.edu.pl, majta@agh.edu.pl

Keywords: Profiled wire, filtration screen, FE modelling, Spot-resistant welding

1. Introduction

Industrial filtration screens are widely used in various applications for separation purposes. Very often they have to be able to separate particles of a size about 20–40 micrometres what means that the gap between the profiled wire has to be smaller than that. This in turn, requires a very precise control of the manufacturing process. Screens are made of stainless steel (austenitic, ferritic or duplex). The manufacturing process involves wire rod rolling then cold drawing/rolling into a trapezoidal cross--section shape [1]. Then, screens are made by spot-resistant welding process of screen profiles – they can be either flat or cylindrical. Finally, the screens are made by formatting of the final shape by bending/rolling/ and welding of the final screen (conical baskets etc) [2]. In order to meet the final in-use properties (tight dimensional tolerances, strength and wear resistance) the interrelationships between process parameters and material parameters of the used steel grades have to be well understood. One of the most important steps of screen manufacturing is spot-resistant welding process. Its parameters (current, force, wire feed rate) play crucial role in the achievement of the final quality of the screen. If the current or force are not precisely selected, joint area may be too weak or then screen may not meet the dimensional tolerances. Spot-resistant welding process parameters may also influence on the level of residual stresses that build up in the screen. The results of the welding process can be also predicted based on the numerical modelling of the welding process [3]. In presented work, three different welding cases have been simulated using Abaqus Standard software. Effect of welding parameters on temperature distribution was studied and confronted with experimental data.

2. Experimental and modelling

For the calculations of the welding process flat screen made with thin profile wires shown in Figure 2a has been chosen. For the analysis of the effect of welding process a single weld point was used for calculations. In the paper the influence of the current parameters on the temperature distribution in the weld zone and the heat affected zone was taken into consideration. The process parameters were adopted according to the data gathered in Table 1.

The simulation was carried out using the thermal-electrical module. Boundary conditions for the welding process were assumed. For the calculations the heat transfer coefficient and electrical conductivity (both as a function of temperature) were assigned. Both were assumed between the copper

The publication is co-financed from the state budget under the programme
of the Minister of Education and Science called “Excellent Science” project no. DNK/SP/548041/2022

Doskonała Nauka
Ministry of Education and Science Republic of Poland
Republic of Poland

electrodes and 304L steel as well as between 304L steel and 304L. The electrical potential at the bottom surface of the bottom electrode was assumed to be zero in order to direct the current flow accordingly. The initial temperature of all elements was also assumed to be equal to the ambient temperature (20°C).

Table 1. Welding parameters of the profile wires and the mechanical properties of the welded joints.

Name	Tested joints	Material	Welding parameters			Breaking strenght		Shear strength	
			Current [kA]	Time [ms]	Force [kg]	[N]		[N]	
1A	18sb/q55	AISI 304L	0,23	60	42	1 915	1 581	1 522	1 821
1B			0,4	80		1 367	1 553	1 581	1 483
1C			0,77	20		2 387	4 804	1 553	1 452

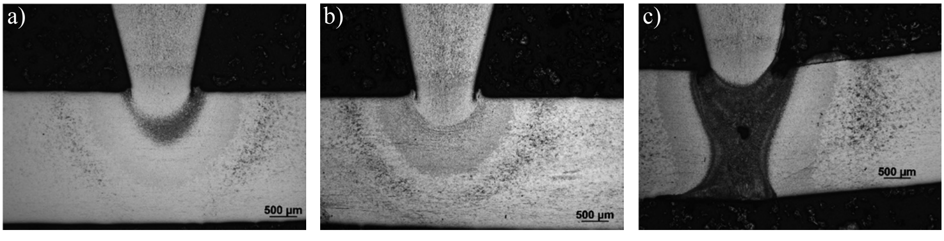

Figure 1. Macroscopy characterization of the joints of specimen for samples 1A (a), 1B (b), and 1C (c).

The mechanical properties of the tested welds show that the highest strength was obtained in the case of sample 1C. This is due to the very high temperature which was reached what caused phase transformation of the austenitic structure to martensitic ones. In the 1A and 1B the mechanical properties were lower and reached about 1500 MPa. The macroscopy characterization of the joints shows that in the 1A and 1B specimen the temperature did not affect the structure changes while in the 1C it can be observed that changes in the microstructure occurred due to the very high increase of the temperature.

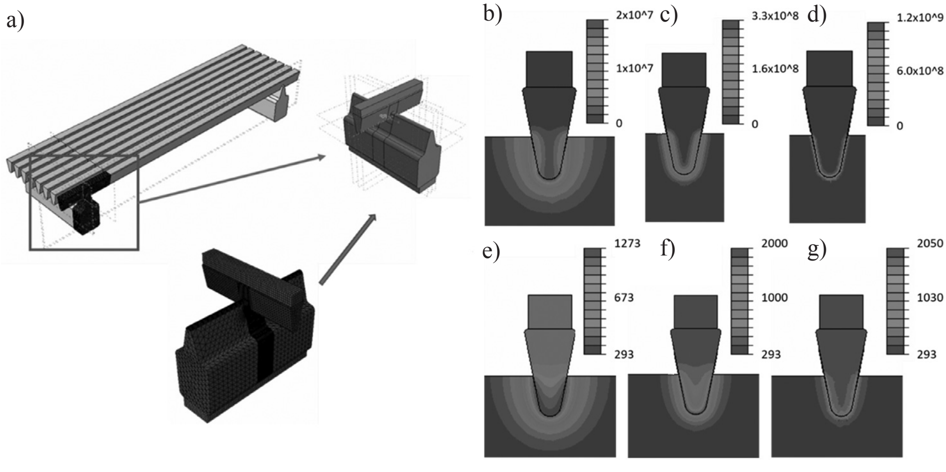

Figure 2. Spot welding model developed in Abaqus Standard (a). Heat flux distribution (J/K·m^2) within the weld for samples 1A (b), 1B (c), and 1C (d). Temperature distribution (K) within the weld for samples 1A (e), 1B (f), and 1C (g).

The modelling results in the form of heat flux distribution in the last welding time step are summarised in Figure 2(b–d). It can be seen that the welding parameters (current and welding time) have a crucial impact on the obtained results. When the smallest welding current (0.23 kA) is used, the maximum heat flux values are the smallest and did not exceed $2 \cdot 10^7$ J/K·m^2. In this case, however, the longest welding time was used, which is reflected in the heat flux distribution map. Here, the area of the heat affected zone is the largest.

The results of the temperature distribution in the weld area (in Kelvin) are shown in Figure 2(e-g). When the smallest welding current was used, the maximum temperature did not exceed 1273 K, while when a welding current of 0.4 kA was used, the maximum temperature reached 2000 K – that is, above the liquidus temperature (1773 K) – Figure 2(f). The use of a short welding time (20 ms) and the highest current (0.77 kA) increased the temperature to a maximum value of 2050 K – Figure 2 (g).

3. Summary

The simulations carried out were qualitatively compared with the results of the microstructure observations. The similar shape and size of the remelted zone and the heat affected zone indicate the correctness of the obtained results. The shape of the flash was not reflected in the results – due to the fact that, at this stage, the model is only developed in the thermal range – the thermo-mechanical model is not included – which does not allow, for example, the pressure force during welding to be taken into account. However, for temperature distribution calculations, such a limitation does not significantly affect the results. Based on the obtained results, the following relationships can be drawn between the process parameters and the obtained heat flux, temperature and HAZ distributions:

- as the welding current increases, the maximum temperature in the weld area increases,
- as the welding time increases, the area of the melted zone and the HAZ increases,

Therefore, the optimization of the flat screens welding process should be based on the principle of the correct choice of both current and welding time, so as to optimize the area of the remelted zone but not to overheat the joint, which can lead to defects and the generation of residual stresses.

The use of too short a welding time – even with a high welding current – may not produce a sufficiently large melted zone and lead to the formation of joints with insufficient mechanical properties.

References

1. Kwiecień M., Majta J., Rumiński M., Kawałko J., Muszka K.: *Surface quality and mechanical properties in drawn stainless steel profile wires caused by process parameters*. Key Engineering Materials, 926, 2022, 980–991.
2. Muszka K., Kwiecień M., Perzyński K., Majta J., Madej Ł.: *Metal forming driven surface engineering of thin profile wires for high precision industrial filtration screens*. CIRP Annals Manufacturing Technology, 72, 2022, 265–268.
3. Nielsen C.V., Martins P.A.F., Zhang W., Bay N.: *Numerical methods in simulation of resistance welding*. [in:] COUPLED VI: proceedings of the VI International Conference on Computational Methods for Coupled Problems in Science and Engineering, 322–333, CIMNE.
4. Neid H.A.: *The Finite Element Modeling of the Resistance Spot Welding Process*, Welding Journal, 63, 1984, 123–132.

Acknowledgements. The support from the National Centre for Research and Development, Poland through the grant NCBiR POIR.01.01.01-00-0961/19.