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Direction of the Rolling of Plates Made of Steel Grade 0H18N9 versus Welding Distortions

Abstract: The article presents the results of tests concerning the effect of the direction of the rolling of plates made in steel 0H18N9 on welding distortions. The research-related analysis was concerned with the rolling direction in relation to the longer edge of specimens. The specimens were welded using the MAG method involving the use of pulsed arc. The acquisition of surface flatness-related data was performed using a GOM ATOS 5M blue light scanner. The analysis of the results revealed that the mean surface flatness of the specimens was similar in relation to all of the rolling directions related to analysis. However, the direction of distortions parallel and perpendicular to the weld varied depending on the direction of rolling.

Keywords: welding distortions, rolling direction effect, MAG welding

DOI: *10.17729/ebis.2020.6/5*

Introduction

The obtainment of sheets or plates having a specific thickness entails the application of the rolling process providing a sheet/plate with a specific thickness [1]. After rolling, metals are characterised by the anisotropy of mechanical properties, i.e. varying mechanical properties in relation to the direction of rolling. The anisotropy of plates may directly affect other technological processes such as cutting, welding or bending [2]. The awareness of the effect of post-roll anisotropy on many mechanical properties inspired, among other things, works [3–4].

Presently, many research works are based on modelling involving systems using the Finite Element Method (FEM). The above-named method is approximate and requires certain simplifications, including, among other things, ignoring stresses generated in previous technological processes [6].

Works [7–11] are concerned with the assessment of the effect of welding process parameters on welding distortions. However, attention should be paid to the method used in the validation of simulation results based on an actual experiment. Taking into account the effect of a random variable described in article [12] it is also necessary to investigate the effect of rolling directions and specific welding parameters on welding distortions.

Testing methodology

The analysis of the effect of a rolling direction on welding distortions involved the preparation of 9 standard specimens made of 5 mm thick stainless steel 0H18N9. Specimens consistent

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with the PN-EN ISO 15614-1:2017-08 standard and having dimensions of 150 mm×350 mm had been laser cut out of a plate in accordance with the following specification: a set of 3 specimens, the longer edge of which was parallel to the direction of rolling, a set of 3 specimens, the longer edge of which was perpendicular to the direction of rolling and a set of 3 specimens, the longer edge of which was at an angle of 45° in relation to the direction of rolling. Figure 1 presents the schematic diagram concerning the arrangement of the specimens on the plate.

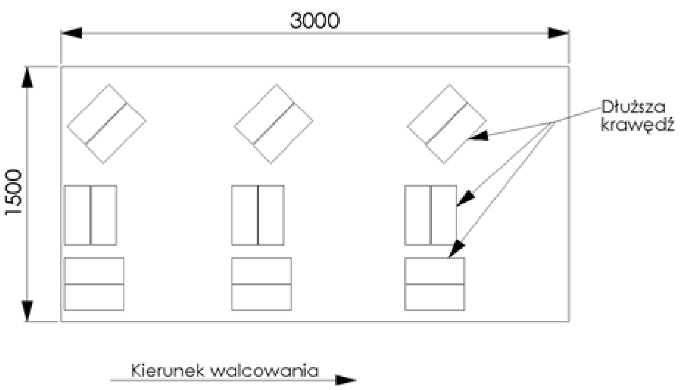

Fig. 1. Arrangement of the specimens on the plate surface

The geometry of the groove presented in Figure 2 was prepared using the machining process.

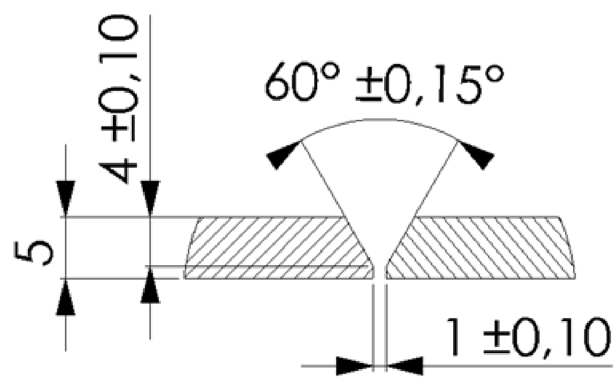

Fig. 1. Arrangement of Fig. 2. Schematic diagram of the joint of the specimen with characteristic dimensions the specimens on the plate surface

In order to ensure the proper starting and finishing of the welding process, the tests also involved the welding of plates (30 mm x 30 mm) to both sides of the specimens. Before welding, the specimens were degreased using acetone. The weld groove was not provided with any tack welds.

The test, performed by means of method 135, involved the use of the M12 Inoxline C2 gas mixture (Messer) and filler metal wire (ø12 mm) grade 316LSi (heat number 264664-62023). The torch position was perpendicular to the specimen surface. The welding power source was a Lorch S5 Speed Pulse welding machine. The torch was moved by a numerically controlled device. The specimens were welded without the use of fixing elements or clamps. The root was shielded by argon 4.9. Figure 3 presents the test rig.

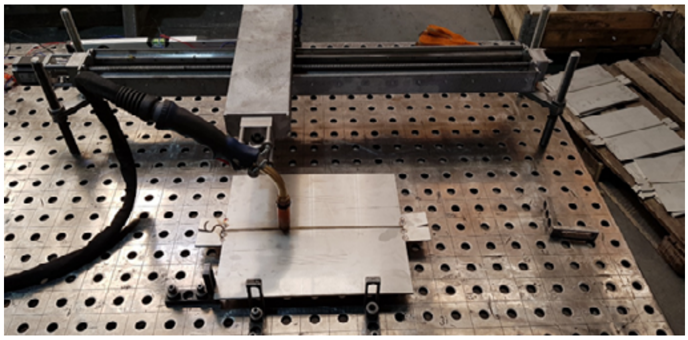

Fig. 3. Test rig

The joints were made using pulsed arc characterised by parameters presented in Table 1. The linear energy of the process was identified on the basis of work [13], using the following formula:

$$E_{śr} = \bar{\lambda}_s \frac{I_{av.}U_{av.}}{v}$$

where (λ_s) – pulsed arc power factor, I_{av} – mean current value, U_{av} – mean voltage value and v – travel rate.

Figure 4 contains a diagram presenting changes of mean current-voltage parameters during the welding process. Figure 5 presents momentary values of mean current-voltage parameters. The current-voltage parameters were measured using the feedback readout of the Lorch S5 Speed Pulse welding machine.

The distortion of the specimens was measured using a GOM Atos 5M blue light scanner. The scanning process was performed after providing the specimens with appropriate markers.

Table 1. Welding process (135) parameters

Adjusted current	Mean current	Adjusted voltage	Mean voltage	Filler metal wire feeding rate	Travel rate	Pulsed arc power factor	Mean calculated linear energy
A	A	V	V	m/min	m/min	-	kJ/mm
125	115.2	19.5	20.6	3.25	0.22	1.27	0.822

Figure 6 presents the measurement station and a specimen with markers.

Measurement results

The specimens were subjected to processing using the GOM Inspect Suite 2020 software programme. The acquisition of surface flatness deviations from the mesh of measurement nodes was performed in accordance with the PN-EN ISO 13920:2000 standard. Table 2 presents results concerning the effect of the direction of rolling on welding distortions.

Figures 7, 8 and 9 present exemplary results related to the measurement of distortions in the GOM Inspect Suite 2020 software programme.

Analysis of results

The tests results concerning the effect of the rolling direction on welding distortions revealed that the surface flatness deviation determined on the basis of the PN-EN ISO 13920 was similar in relation to the rolling directions subjected to analysis. The lowest mean flatness deviation value was obtained in relation

Table 2. Analysis concerning the effect of the rolling direction on welding distortions – results

Factor	Parallel direction	Perpendicular direction	Direction 45°
-	mm	mm	mm
Flatness deviation Specimen 1	4.94	5.49	6.00
Flatness deviation Specimen 2	1.97	4.27	5.14
Flatness deviation Specimen 3	4.23	4.70	3.43
Mean flatness deviation	3.71	4.82	4.86
Range	2.97	1.22	2.57

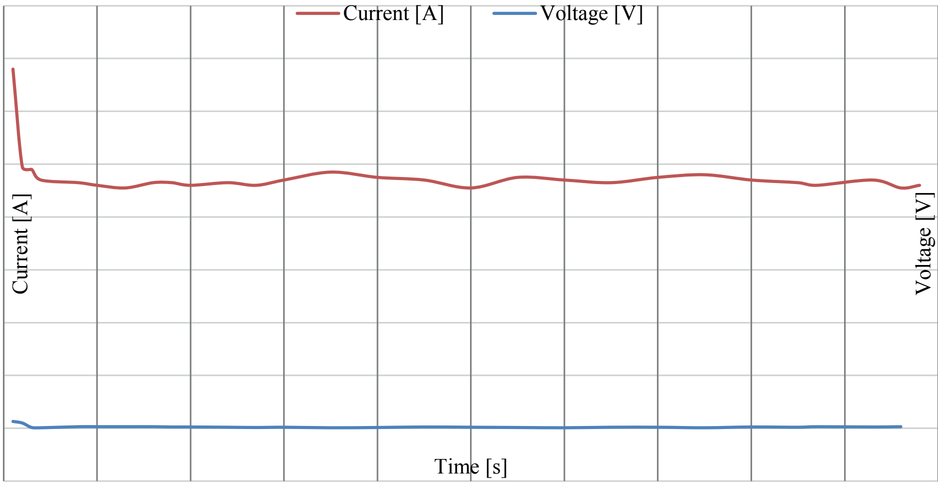

Fig. 4. Changes of mean current-voltage parameters during the welding process

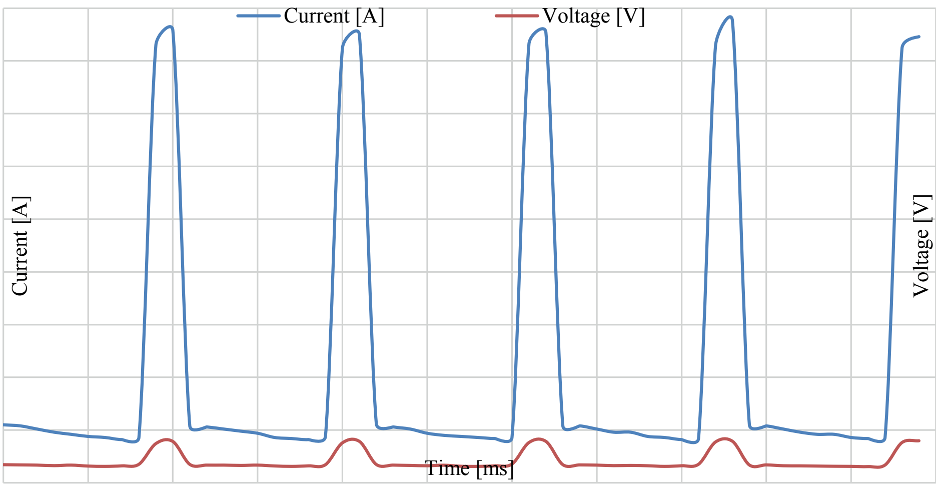

Fig. 5. Changes of momentary current-voltage parameters during the welding process

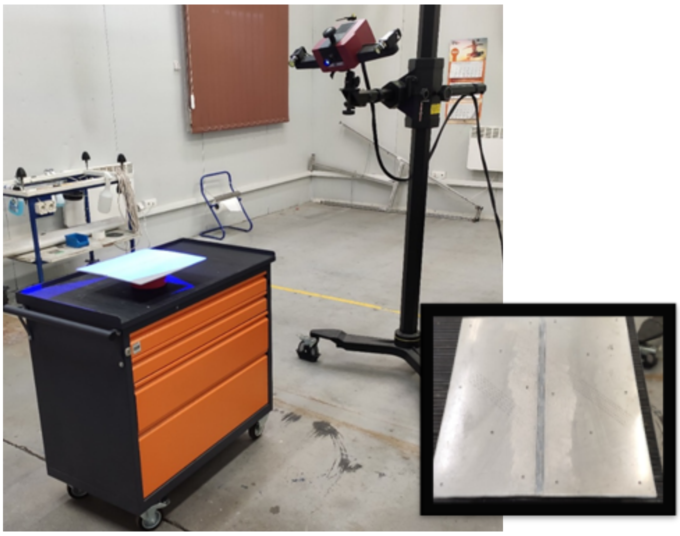

Fig. 6. Measurement station and the specimen with the markers

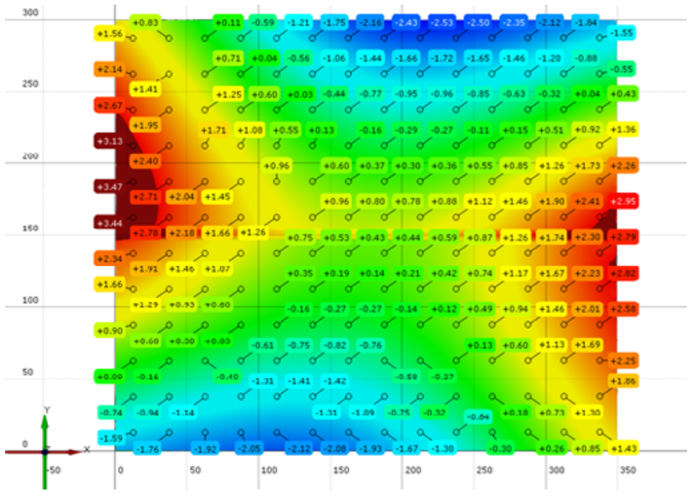

Fig. 7. Measurement results of the surface flatness deviation related to specimen 1, subjected to rolling at an angle of 45° in relation to the longer edge

to the specimens, the longer edge of which was parallel to the direction of rolling, constituting 76.34% of the maximum value. The mean flatness deviation values related to the specimens, the longer edge of which was perpendicular to the rolling direction or at an angle of 45° in relation to the rolling direction were similar.

Some attention should be paid to the range of results in relation to a given rolling direction. As regards the specimens, the longer edge of which was parallel to the rolling direction or at an angle of 45° in relation to the rolling direction, the value of the range was similar. In terms of the specimens, the longer edge of which was perpendicular to the rolling direction, the range difference was significant and constituted 41.08% of the maximum value. The above-presented observation indicated that the specimens, the longer edge of which was perpendicular to the rolling direction were characterised by the lower range in relation to the mean value of the surface flatness deviation. The foregoing reduced the risk of the misinterpretation of welding distortions.

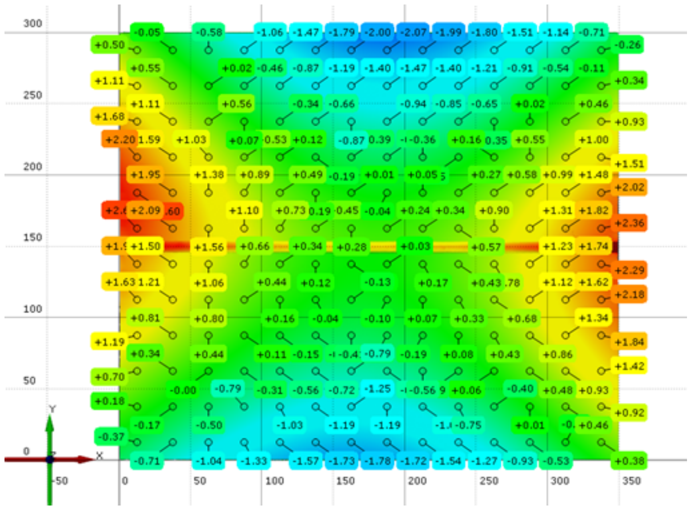

Fig. 8. Measurement results of the surface flatness deviation related to specimen 3, subjected to rolling performed perpendicularly in relation to the longer edge

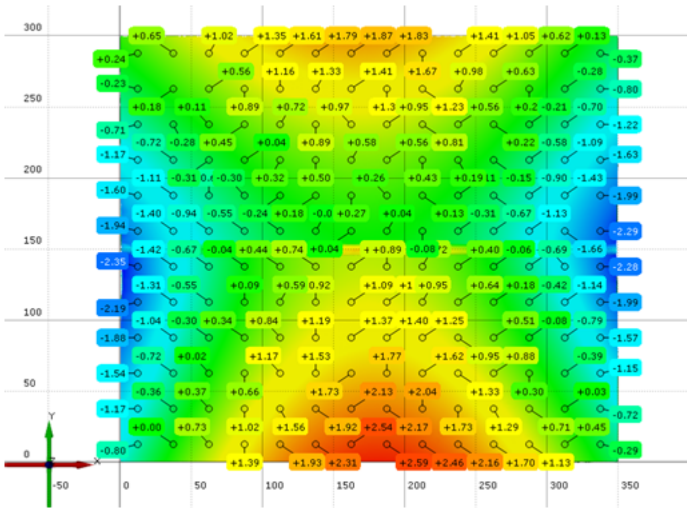

Fig. 9. Measurement results of the surface flatness deviation related to specimen 1, subjected to rolling performed in parallel to the longer edge

The comparative analysis of the exemplary distortion-related results presented in Figures 7, 8 and 9 revealed significant differences in terms of the correlation between welding distortions and the direction of rolling. As regards the specimens, the longer edge of which was at an angle of 45° in relation to the direction of rolling and the specimens, the longer edge of which was perpendicular to the direction of rolling it was possible to observe the convergence of distortions formed perpendicularly and in parallel to the weld axis. As regards the specimens, the longer edge of which was along the rolling direction, the sense of the deformations formed perpendicularly and in parallel to the weld axis was opposite in relation to the remaining rolling directions subjected to analysis. The foregoing indicated that the direction of distortions formed as a result of the thermal cycle effect also depended on the direction of rolling. As regards the specimens, the longer edge of which was at an angle of 45° in relation to the rolling direction it was possible to observe the shift of the minimum and maximum values of distortions in relation to the weld axis by an angle similar to that between the longer edge of the specimen and the direction of rolling.

Conclusions

The analysis concerning the effect of the rolling direction on welding distortions justified the formulation of the following concluding remarks.

1. The mean values of surface flatness deviation determined in accordance with PN-EN ISO 13920:2000 were similar in relation to all of the rolling directions subjected to analysis.
2. The rolling direction perpendicular to the longer edge of the specimens provided the smallest range in terms of welding distortions.
3. The direction of rolling directly affected the direction of welding distortions.

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