Investigations

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Welding Imperfections in T-joints of Thin-walled Elements Made Using Mechanised TIG Welding with Filler Metal Wire

Abstract: The article presents welding imperfections in TIG-welded T-joints of thin-walled elements made using filler metal wire. The study discusses both typical, i.e. specified in PN-EN ISO 6520-1:2009 and untypical imperfections, i.e. not classified in the standard mentioned above.

Keywords: TIG welding, welding imperfections, T-joints, filler metal wire, PN-EN ISO 6520-1:2009

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Tests of mechanised TIG welding performed using various parameter and filler metal wire feeding adjustment systems [1] revealed the presence of typical welding imperfections specified in PN-EN ISO 6520-1:2009 [2] and of untypical imperfections not classified in the standard mentioned above. The objective of this study was to present welding imperfections formed when making T-joints of thin sheets (1.0-2.0 mm thick) along with the reasons for their formation.

Examples of typical welding imperfections

Typical welding imperfections of T-joints made using mechanised TIG welding and a filler metal wire, specified in PN-EN ISO 6520-1:2009, are the following:

- excessive asymmetry of a fillet weld (imperfection no. 512 according to PN-EN ISO 6520-1:2009);
- irregular width (imperfection no. 513) – irregular weld width fluctuations;
- incomplete root penetration (imperfection no. 4021) in a T-joint (Fig. 1);

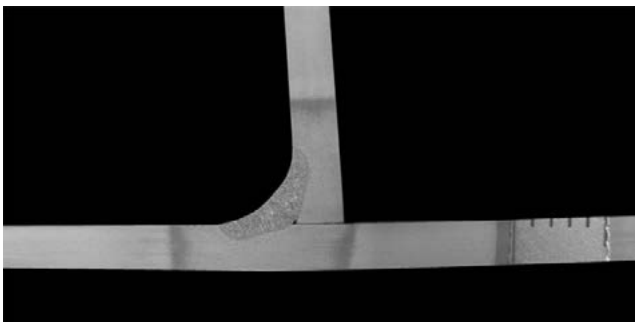

Fig. 1. Incomplete weld root penetration caused by a displacement of the filler metal wire axis in relation to the weld axis

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– deviation from the intended geometry of a fillet weld, also classified as incomplete root penetration (imperfection no. 4021). According to the definition provided in standard [2], this imperfection is present if one face (or both faces) of the root grove are not melted (Fig. 2 and 3).

Fig. 2. View of the weld face after the change of a stable process (regular weld face surface) into unstable, caused by filler metal wire feeding disturbances (areas of disturbances are marked with arrows)

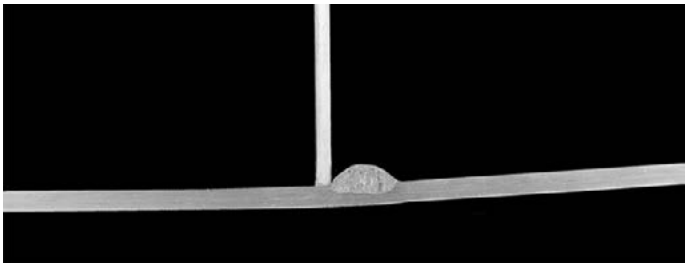

Fig. 3. Macrostructure of a T-joint with incomplete root penetration (4021) – lack of penetration into the vertical wall

During robotic welding tests, it was observed that the wire feeding was initially steady until the pulling of the reel with the wire, causing a rapid change of the filler metal wire feeding rate. This was due to an excessively long distance between the wire reel and the filler metal wire feeder (approximately 4 m) located on a welding robot arm as well as due to the slack of wire in the flexible hose armour. As a result, welding was accompanied by disturbed wire feeding, leading to the formation of weld shape and dimension-related welding imperfections presented in Figures 1-3.

The reasons for the asymmetry of fillet weld dimensions and for the lack of penetration in the weld root are deviations of the wire axis from the joint axis, excessive electrode extension and the twisting of the wire in filler metal wire feeding conduits. The reason for the deflection of the wire at its extension could be the excessive wear of the wire feeder brass conduit guide (replaceable terminal of the filler metal wire feeding conduit). In the event of excessive wire deflection following the long-term operation of a TIG welding torch, the (quickly wearing) wire guide should be replaced with a new one. During technological welding tests it was also determined that improper bead formation was caused by even slight deformations of thin sheets being joined and their displacement in relation to the axis of the weld being made.

Similar to other welding methods, a typical imperfection of fillet welds performed using mechanised TIG welding is also an insufficient or excessive thickness of the fillet weld (imperfection no. 5213 and 5214 respectively).

Examples of untypical welding imperfections

Untypical welding imperfections of T-joints made using mechanised TIG welding with a filler metal wire, not classified in PN-EN ISO 6520-1:2009, in group no. 5 "Imperfect shape and dimensions" and in group no. 6 "Miscellaneous imperfections", include the following:

– **fillet weld root concavity with the vertical element undercut** (in a T-joint) when welding in a horizontal position (Fig. 4). The reason for the concavity is an excessively long welding arc (overheating the vertical sheet) and overly low amount of filler metal.

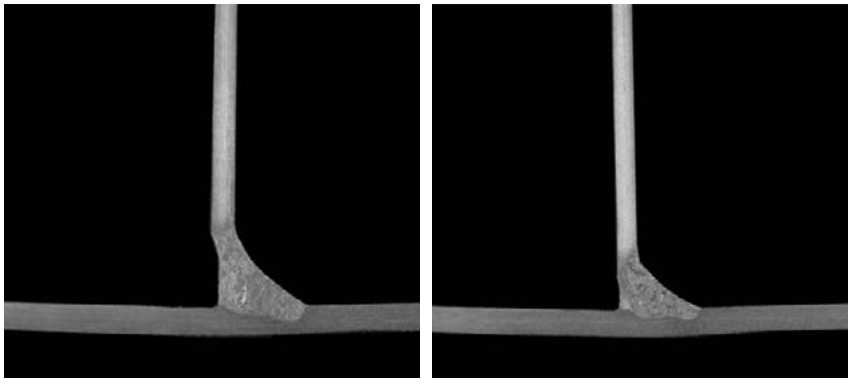

Fig. 4. Examples of fillet weld root concavity with the vertical element undercut

– **fillet weld root concavity with the horizontal element undercut** (in a T-joint) (Fig. 5);

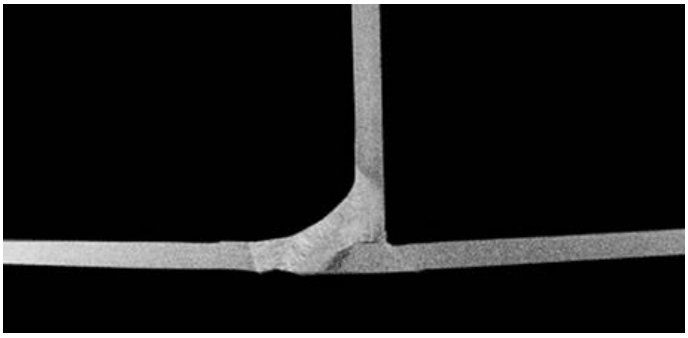

Fig. 5. Example of fillet weld root concavity with the horizontal element undercut in a T-joint

Fig. 6. Face (a) and root (b) of the fillet weld with irregular excessive melt-through of the element being welded and excess penetration beads

– **excessive melt-through of the vertical element being welded** in a T-joint with excessive penetration on the joint root side (Fig. 6, 7);

The excessive penetration on the root side of the T-joint with the fillet weld cannot be rated among the group of excessive penetration according to standard [2] as the standard defines excessive penetration (no. 504 and 5041-5043) exclusively for butt joints. As can be seen in Figure 7, this imperfection cannot be rated among weld overlaps referred to as "excess weld metal covering the base material surface without penetration".

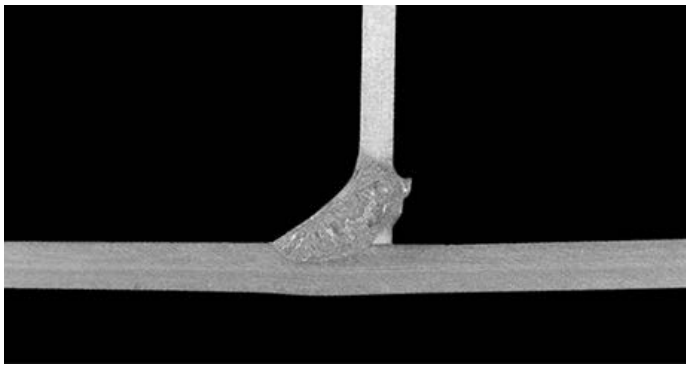

Fig. 7. Macrostructure of a T-joint with excessive melt-through of the vertical element being welded with excess penetration bead on the joint root side

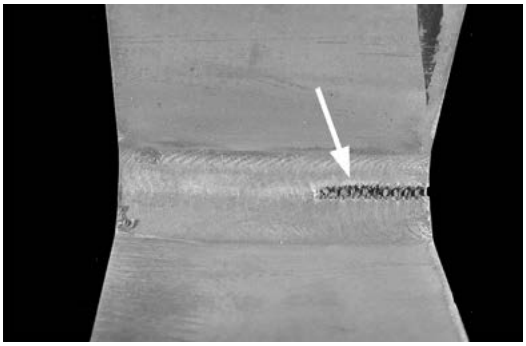

Fig. 8. Fillet weld face with a scratch after making approximately 5 cm of the joint (marked with the arrow)

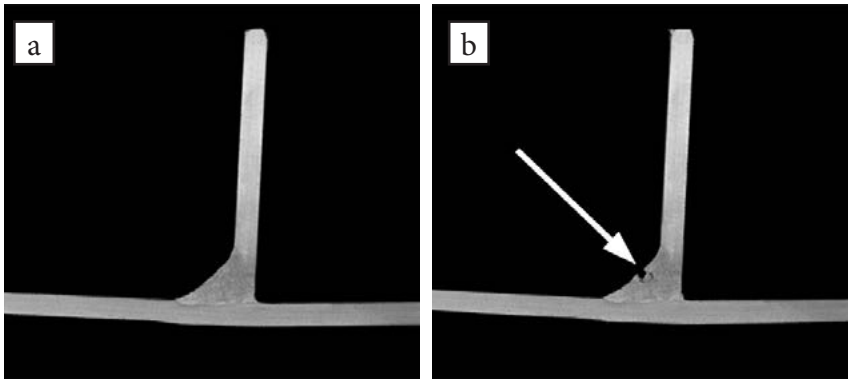

Fig. 9. T-joint macrostructure: a) initial section, b) section with the scratch in the weld face (marked with the arrow)

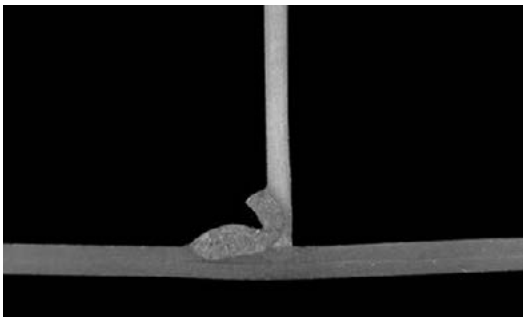

Fig. 10. Macrostructure of the T-joint with a deep scratch in the weld face

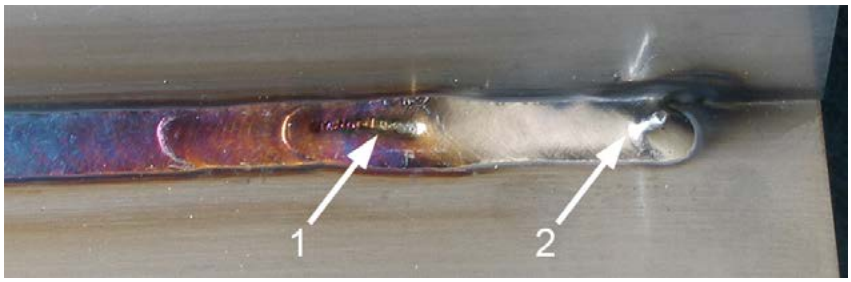

Fig. 11. Weld end during disturbances of steady filler metal wire feeding – visible scratch due to the immersing of the wire in the weld metal pool (1) and the wire adhesion at the weld end (2)

– **scratch (concavity) in solidified weld metal** due to the immersing of the wire in the weld pool liquid metal, melting of the wire in the pool and, at the same time, leaving a concavity in the solidified metal, on the weld face during disturbances of steady filler metal wire feeding (Fig. 8-12).
– **adhesion of wire** at the end of a welding process (Fig. 13). Similar to MIG/MAG, the reason for adhesion could be an improperly adjusted wire stop delay time during arc termination or the lack of this functionality in the filler metal wire feeding system, but also the deformation of a welded element at the terminal section of the joint, locally decreasing the distance between the filler metal wire guide terminal and the element being welded. The adhesion of wire is considered to be a significant imperfection in welded joints of thin-walled elements and could be rated among group no. 6 "Miscellaneous imperfections" of standard [2], yet it is not specified therein.

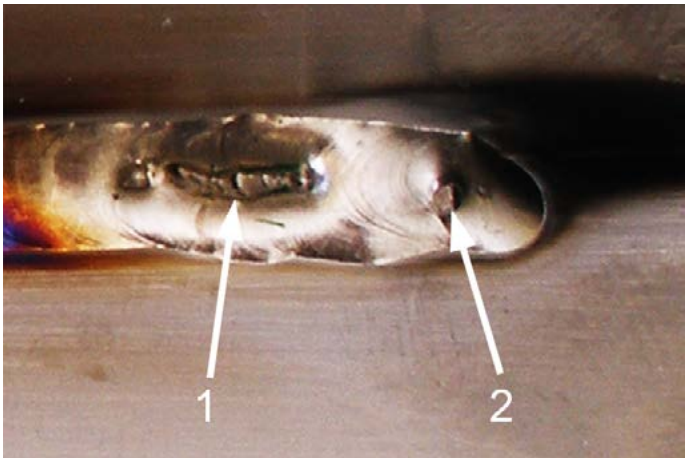

Fig. 12. Weld crater with a scratch (1) due to immersing the wire in the weld pool metal and the wire adhesion area (2) at the end of the weld

Some tested joints revealed the presence of welding imperfections specified in PN-EN ISO 6520-1:2009 and imperfections not classified in this standard. For instance, in the joint presented in Figure 14 there is incomplete root penetration (imperfection no. 4021), fillet weld root concavity with the vertical element undercut in the T-joint and the excessive melt-through of the horizontal element (as regards butt welds, in the standard this imperfection is designated with no. 5043, yet it is not classified for fillet welds).

Summary

The performed tests of mechanised TIG welding using various parameter adjustment and wire feeding systems have demonstrated that T-joints of thin sheets may contain typical welding imperfections specified in PN-EN ISO 6520-1:2009 and untypical imperfections not included in the standard mentioned above. Untypical imperfections of T-joints are the following:

– fillet weld root concavity with vertical or horizontal element undercut,
– excessive penetration on the root side of the T-joint with the fillet weld (excessive melt-through of the vertical element in the T-joint with excessive penetration on the root side of the joint),
– scratch in the solidified metal of the weld,

Fig. 13. Wire adhesion in the crater

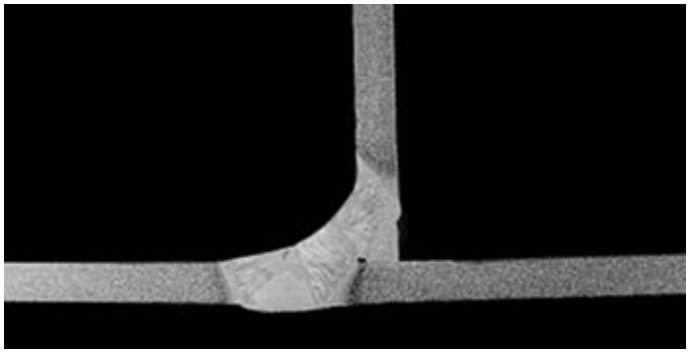

Fig. 14. Macrostructure of the T-joint with imperfections, i.e. incomplete root penetration, fillet weld root concavity with the vertical element undercut and the excessive melt-through of the horizontal element

– adhesion of the wire to the crater during welding completion.

Introducing the above imperfections into EN ISO 6520-1 would facilitate and unify the classification of welding imperfections which may appear in such welded joints of thin-walled elements.

References

[1] Turyk E., Grobosz W., Dudek S., Riabcew I.A.: *Technological Conditions of Mechanised TIG Welding using Various Systems Adjusting Current and Electrode Wire Feeding Parameters*. Biuletyn Instytutu Spawalnictwa, 2015 r., no. 5 http://dx.doi.org/10.17729/ebis.2015.5/2

[2] PN-EN ISO 6520-1:2009: Welding And Allied Processes - Classification Of Geometric Imperfections In Metallic Materials - Part 1: Fusion Welding

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