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Laser + MAG Hybrid Welding of T-Joints

Abstract: The article presents the possibilities of the hybrid welding (laser + MAG) of T-joints, discusses primary technological conditions of the HLAW process as well as discusses the possibilities of using the HLAW method when making various types of T-joints in various configurations of interface preparation, joint positioning and laser beam-MAG welding torch alignment.

Keywords: laser welding, HLAW, laser + MAG, hybrid welding, T-joints

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Introduction

The hybrid (laser + MAG) method is one of the variants of the HLAW (**H**ybrid **L**aser **A**rc **W**elding) process characterised by a number of advantages not available when using the component processes of the method separately. The recent years have seen the intense research and technological development of the method in different variants as well as its increasing popularity in industrial applications. Presently, the method is applied when welding joints having thicknesses restricted between several and between ten and twenty millimetres, made of various structural steel grades used in the shipbuilding industry, power engineering, automotive industry etc. [1-24].

Technological Conditions of the HLAW (Laser + MAG) Process

The efficiency and stability of the process as well as the quality of joints made using the hybrid (laser + MAG) method depend on the appropriate adjustment and correlation of the entire set of parameters of both heat sources used in the above-named method, i.e. electric arc and laser. The most important of these parameters include the filler metal wire feeding rate, arc voltage and current, laser radiation power as well as the position and diameter of the laser beam and its geometric parameters (the so-called beam caustic). Another important aspect is the position of both heat sources in relation to the direction of welding, i.e. determining whether during the melting of sheet edges, arc precedes or follows the laser beam. The parameters of welding arc and the size of the laser-triggered plasma cloud over the weld pool are also affected by the type of a shielding gas. The MAG torch nozzle diameter and the shielding gas flow rate should be adjusted to the size and shape of the weld pool formed as a result of the simultaneous effect of both heat sources.

In addition to the adjustment and correlation of the above-presented primary parameters of arc and laser in the hybrid method, another crucial aspect is the position of the MAG welding torch and of the laser beam in relation to each other as well as in relation to the edge of the interface and the surface of the sheets making up a joint. The position-related possibilities are primarily

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determined by the design of the hybrid head and the kinematics of the manipulator on which the hybrid weld is positioned during welding. Examples of various hybrid welding stations are presented in Figure 1. The manipulator can be a simple single-axle transport system, gantry system (Fig. 1a, b), robot station or the combination of the above-named systems, e.g. a robot mounted on guide bars (Fig. 1c and d) or a versatile robot station featuring a tilt-and-turn table (Fig. 1e).

The HLAW method is usually used when welding butt joints, where the process of welding involves the single-run penetration of the unscarred interface of sheets having the same thickness and the uninterrupted formation of the weld root. The laser beam and the MAG welding torch are positioned in one plane perpendicular to the surface of the sheets being welded (Fig. 2a). The above-named process can be performed using a manipulator enabling the stable movement in one horizontal axis (e.g. Y-axis, Fig. 3) and the adjustment of a height at which the head is positioned over a joint being welded (Z-axis) as well as a standard hybrid head in which the laser beam axis and that of the MAG welding torch are in one plane (Fig. 3).

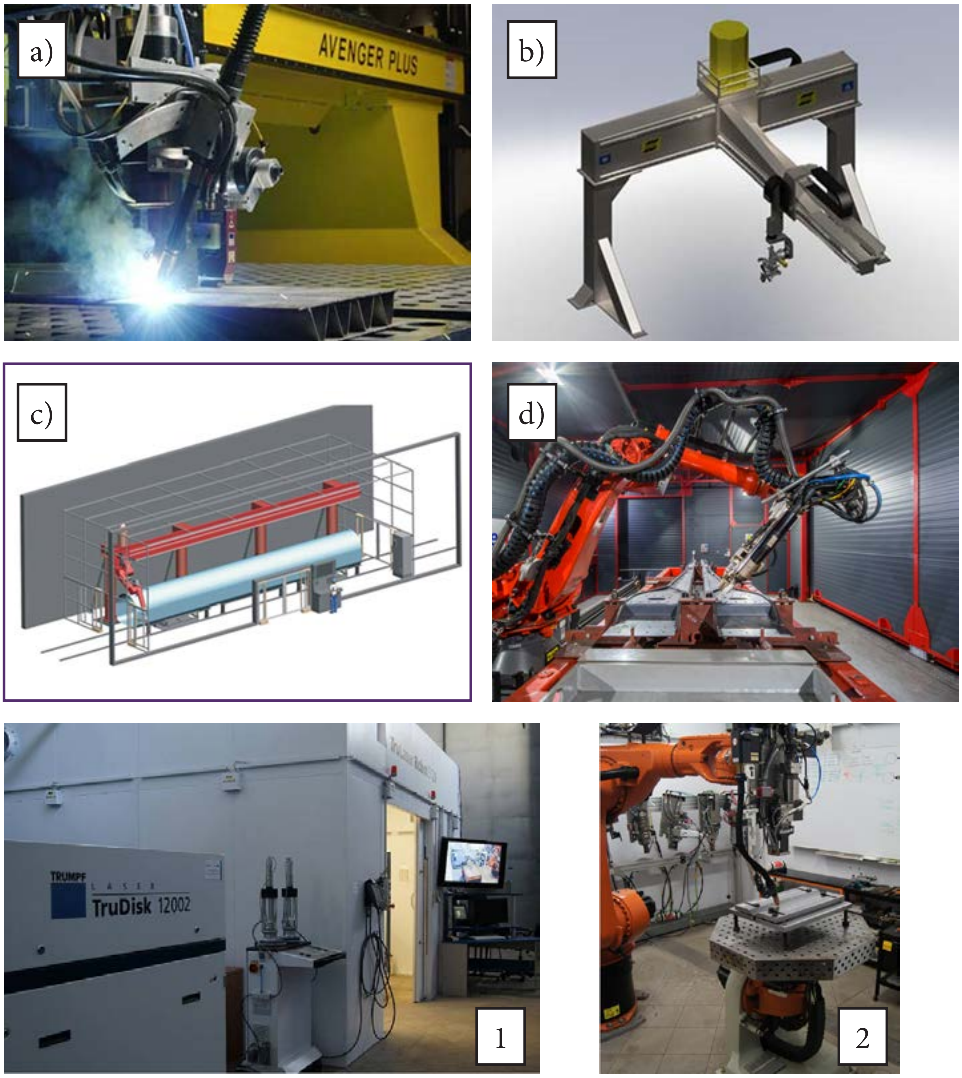

Fig. 1. Exemplary laser+MAG hybrid welding stations:
a, b) HLAW station modules (ESAB) [18],
c) station for the welding of large-sized closed sections (REIS) [10],
d) robot station for the welding of car chassis elements [11],
e) versatile HLAW station at Instytut Spawalnictwa, Gliwice:
1: station with a TruDisk 12002 laser and protective cabin, 2: inside the cabin – robot with the hybrid head and the tilt-and-turn table

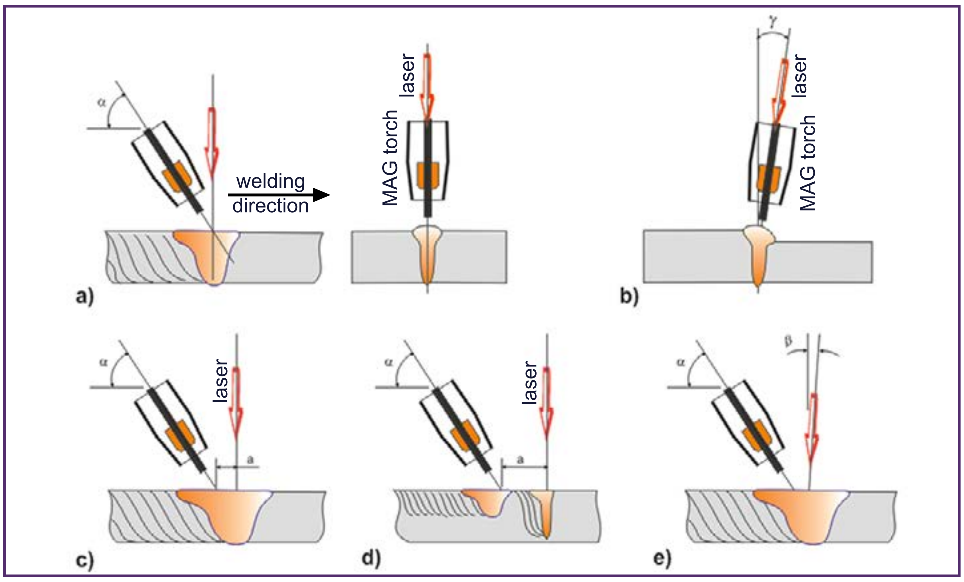

Fig. 2. Examples of the positioning of the MAG torch and the laser beam (in relation to each other) in the hybrid method

Fig. 3. Head used in the HLAW method: 1: laser head, 2: MAG welding torch, 3: optical fibre connection, 4: filler metal wire feeder module, 5: camera monitoring the laser beam position

Such a head should also provide the possibility of adjusting the MAG welding torch at a specific angle in relation to the surfaces of sheets subjected to welding (angle α according to Fig. 2a) and the precise adjustment of a very important HLAW process parameter, i.e. the distance between the electrode wire tip and the laser beam axis (Fig. 2c and d), affecting the size of the weld pool and the stability of the process. If the above-named distance is excessively long, the hybrid process turns into the so-called combined process [4], where two separate weld pools (Fig. 2d), not affecting each other in a synergic manner, are formed.

The above-presented types of heads are offered by companies manufacturing HLAW heads and modules or complete hybrid welding stations. It is also possible to individually build such heads, (Fig. 4), particularly in cases where standard laser welding heads have appropriate fixing planes enabling the mounting of an additional module with a MAG welding torch.

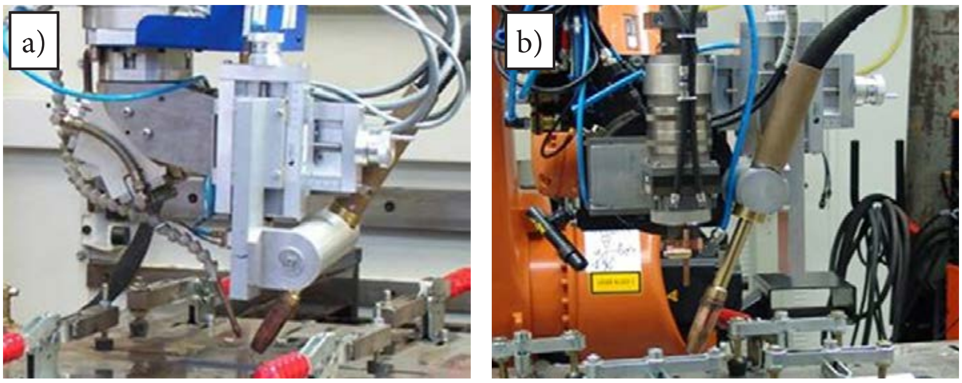

Fig. 4. Hybrid welds made at Instytut Spawalnictwa in Gliwice, based on standard CO_2 laser welding heads (a) and YAG laser heads (b)

Because of the possibility (particularly when welding materials characterised by the low absorption of laser radiation) of the reflection of laser radiation and its partial return to the optical system of the head and optical fibre, it is favourable if either the entire head-manipulator system or the laser beam alone could be deflected from the perpendicular by a slight angle (angle β according to Fig. 2e) so that reflected radiation would not return to the optical system damaging the optics of the head or the optical fibre. When welding butt joints made of sheets/plates having different thicknesses, it could also be favourable to incline the entire beam-MAG torch system by a slight angle (angle γ according to Fig.2b) in relation to the joint axis.

Welding of T-Joints using the Laser +MAG Method

T-joints are frequently welded using the MAG method. However, to ensure the appropriate strength of joints, it is often necessary to make multi-run fillet welds (Fig. 5a), the cross-section of which could provide the required strength of a joint. The welding of T-joints is often connected with the bevelling of the edge of one of the sheets/plates (1/2V or 1/2U joint) and the making of multilayer butt welds (Fig. 5b).

The laser-only welding of T-joints with full penetration (Fig. 5c) requires the precise preparation of a joint with a gap close to zero and entails a risk of the incompletely filled groove, usually constituting an unacceptable structural notch. The position of the laser beam excessively close to perpendicular in relation to the horizontally positioned sheet/plate might reduce the beam power, where part of the beam affects the vertical sheet and partially melts the above-named sheet above the interface (Fig. 5c).

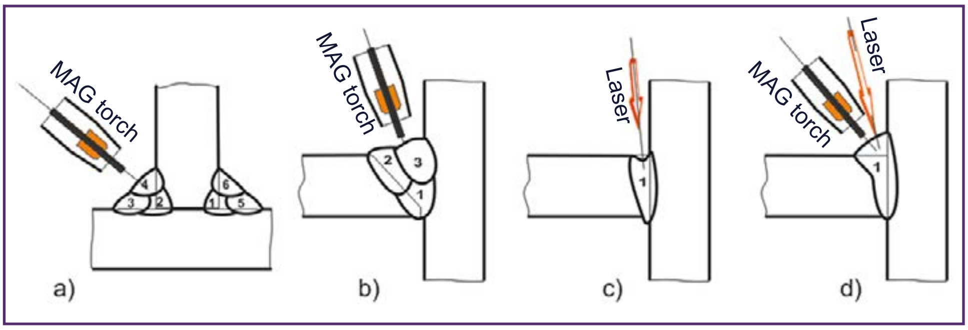

Fig. 5. Examples of T-joints made using various methods

The HLAW method can be successfully used when welding T-joints and enables the obtainment of welds characterised by geometry and shapes not available when using the component processes of the method separately. The laser + MAG method enables the making of fillet welds with a significant and precisely adjusted penetration depth (Fig. 6b) as well as of unique, in terms of shapes and geometry, butt welds in T-joints (Fig. 5d).

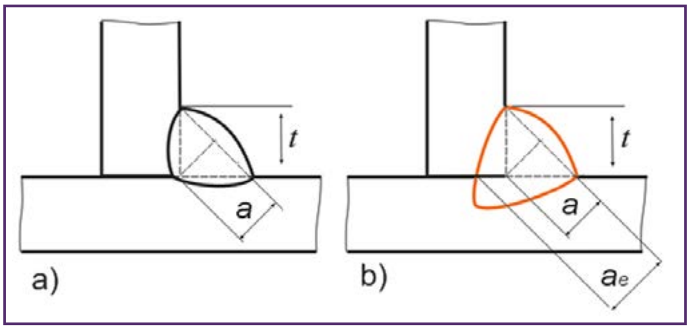

Fig. 6. Examples of fillet welds having various geometry: a) classical weld made using the MAG method, b) fillet weld with deep penetration made using the HLAW method; a_e – effective thickness of the fillet weld affecting the strength of a joint

A simple method applied when making T-joints using a standard hybrid head and a manipulator enabling the movement in one axis only is welding in the flat position (Fig. 7). When welding large-sized structures, the above-named positioning of joints constitutes an additional operation requiring the use of large-sized positioners enabling the precise positioning of large-sized structures (Fig. 8).

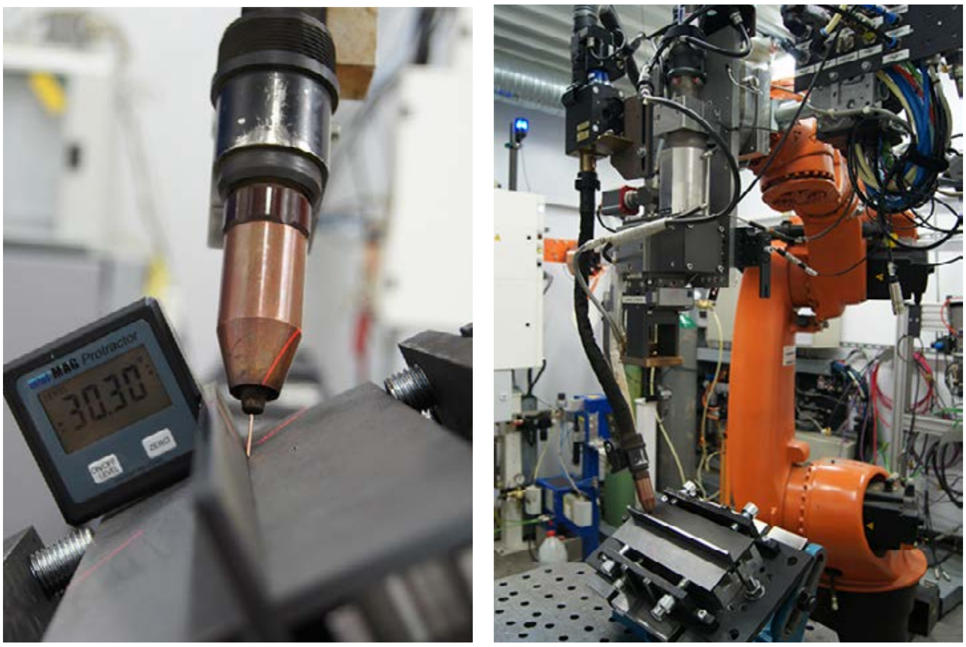

Fig. 7. Making of T-joints in the flat position using the HLAW method


Fig. 8. Exemplary positioners used when welding large-sized structures

Depending on the thickness of sheets/plates being welded, laser power and the MAG torch nozzle diameter, when performing the single-sided welding of joints in the flat position it is possible to obtain single-layer fillet welds with deep penetration (Fig. 9a) or butt welds (Fig. 9b). When performing the double-sided welding, it is possible to obtain two-layer butt welds (Fig. 9c) or fillet welds (Fig. 9d).

If the manipulator, on which the welding head is mounted enables the precise inclination of the head at a significant angle, one of the T-joint sheets/plates can be positioned horizontally (Fig. 10a). The above-presented variant is simpler as regards the positioning of a joint as it does not require the use of a special positioner. In addition, the above-named positioning of elements also enables the simultaneous double-sided welding of joints in the horizontal position (Fig. 10b) making it possible to increase the process efficiency, use a low power laser, simplify the making of a structure and to reduce welding stresses and strains in joints.

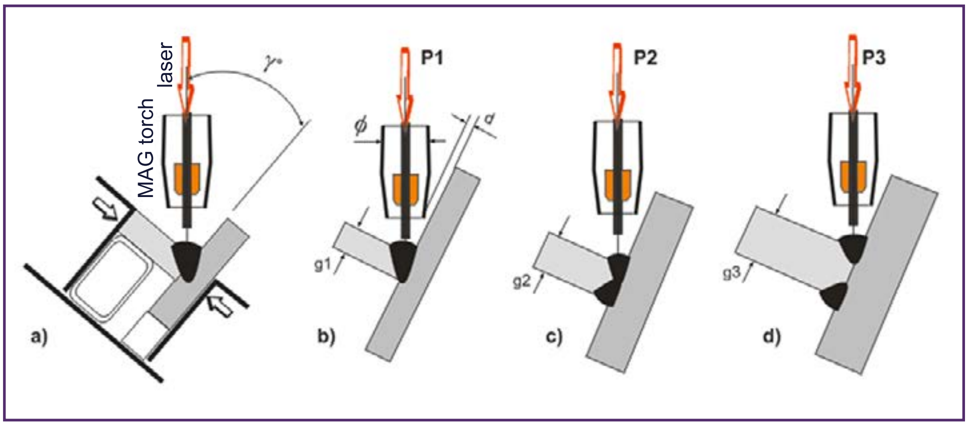

Fig. 9. Exemplary butt joints made using the HLAW method: g1, g2, g3 – sheet/plate thicknesses; φ- nozzle diameter; d – distance between the nozzle and the sheet/plate edge; P1, P2, P3 – laser power

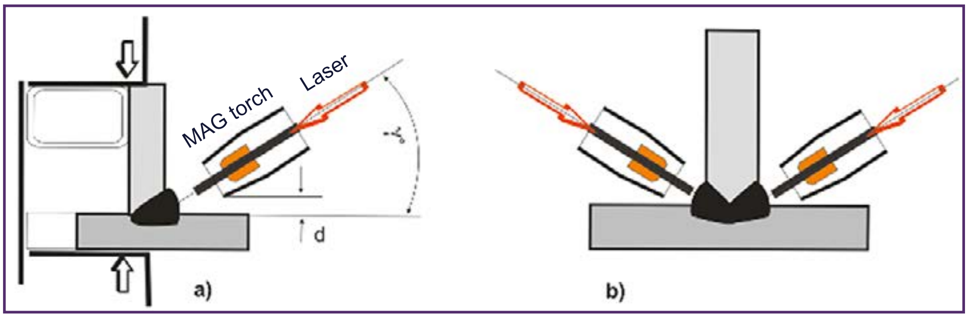

Fig. 10. Schemes of the single-sided (a) and double-sided (b) welding of T-joints performed using the HLAW method

An angle at which the laser beam strikes the sheet/plate surface determines the location of penetration or of the weld in a melting material (when welding both in the flat and horizontal position). The direction and shape of penetration in the material in relation to various angles at which the laser beam strikes the material are presented in Figure 11. During MAG welding, the shape of fillet and butt welds also depends on the angle at which the welding torch is positioned in relation to the joint.

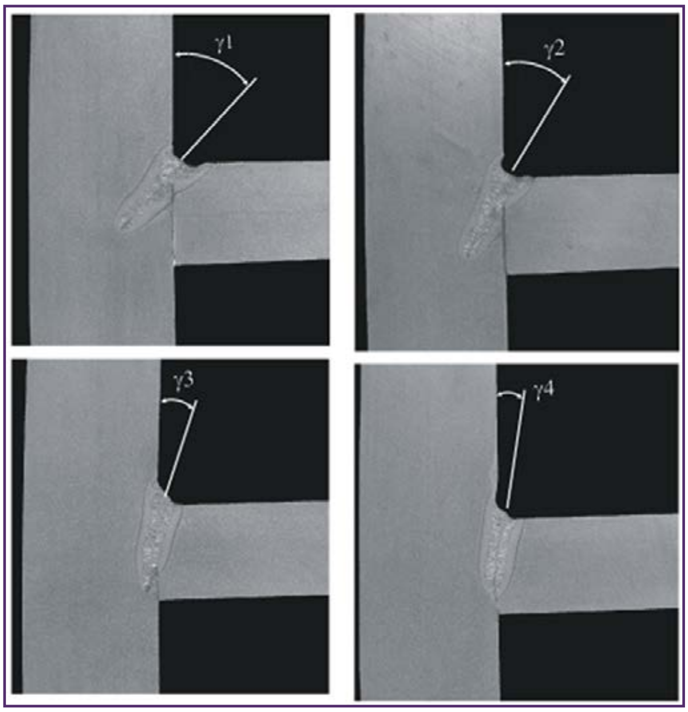

Fig. 11. Position of the weld (in a T-joint) made using laser only in relation to the laser beam angle of incidence; partially melted vertical sheet/plate of the joint resulting from the use of boundary angle $\gamma 4$

Due to the foregoing, when adjusting various angles of laser beam insertion in the material and of welding torch inclination used when performing MAG welding (Fig. 12a), it is possible to obtain welds of unique geometry and to make butt welds in T-joints having significant thicknesses (even between ten and twenty millimetres.

The performance of the above-named process requires the use of a special head enabling the positioning of the laser beam and of the MAG welding torch in various planes (independent of each other) (Fig. 12a) or the modification of the design of a standard hybrid head. An example of the above-named head developed by Instytut Spawalnictwa is presented in Figure 12b. If the size of a structure precludes the positioning of the joints of the structure in the horizontal position, the above-presented HLAW method can also be used in other positions (e.g. flat, horizontal overhead, vertical up position etc.). If the laser power is insufficient to make a butt weld with full penetration in a T-joint, it is possible to perform the double-sided welding of a joint. The hybrid method can be expertly combined with e.g. the MAG method, where both processes can be performed at the same time (Fig. 13).

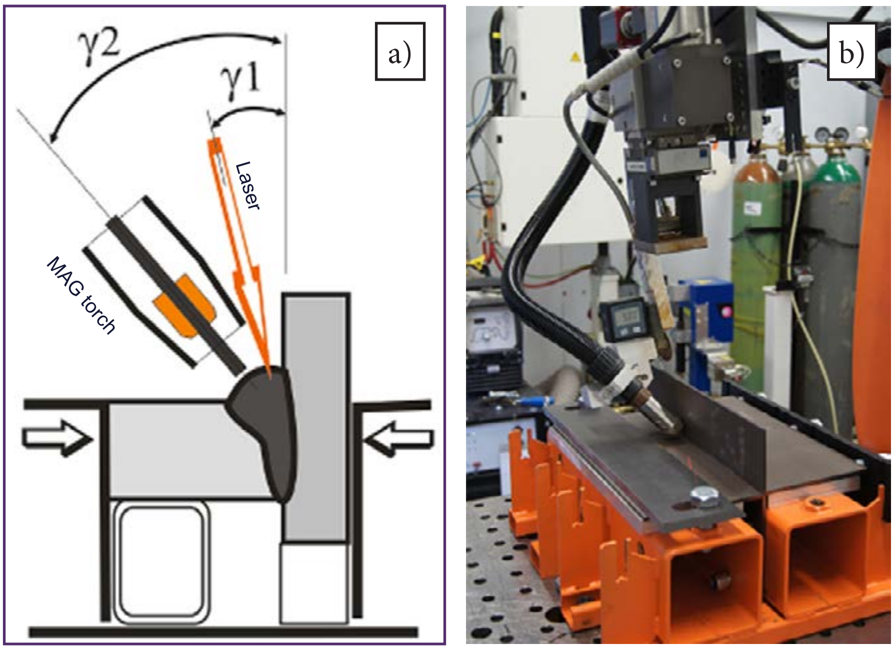

Fig. 12. Laser + MAG welding of T-joints involving the use of various laser beam and MAG torch angles of inclination in relation to the plane of the interface of sheets/plates (a); design and positioning of the head when welding T-joints using the hybrid welding station at Instytut Spawalnictwa (b)

Exemplary macrostructures of T-joints made using the HLAW method when welding T-joints made of sheets having various thicknesses and using various angles of the laser beam and MAG torch positioning in relation to the interface of sheets/plates are presented in Figure 14.

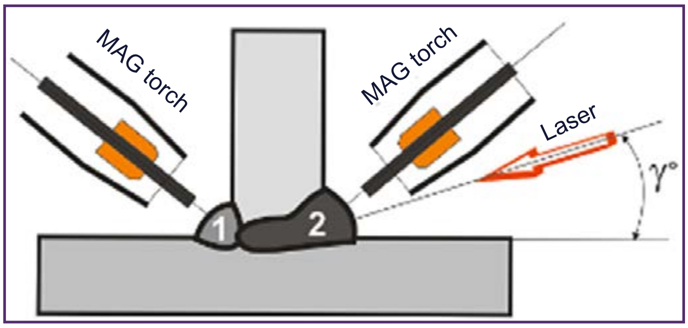

Fig. 13. Combination of the MAG and HLAW method when welding T-joints

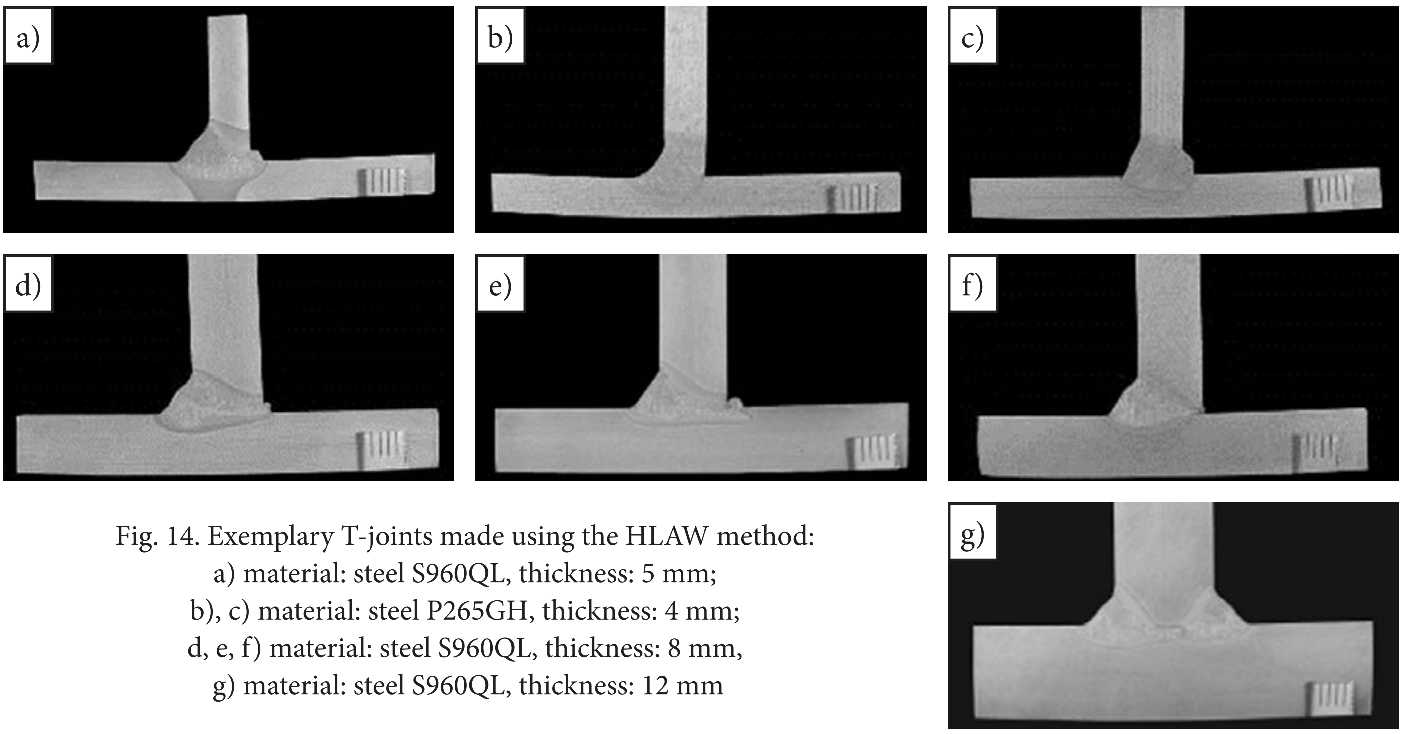

Fig. 14. Exemplary T-joints made using the HLAW method:
a) material: steel S960QL, thickness: 5 mm;
b), c) material: steel P265GH, thickness: 4 mm;
d, e, f) material: steel S960QL, thickness: 8 mm,
g) material: steel S960QL, thickness: 12 mm

Summary and Concluding Remarks

1. Components available on the market such as lasers, manipulators, robots and hybrid heads make it possible to create various hybrid welding (laser + MAG) stations used when welding structures containing T-joints.

2. Depending on laser power, laser beam parameters, manipulator possibilities and the hybrid head design, there are various manners in which the HLAW method can be used when welding T-joints. T-joints can be joined using fillet welds with deep penetration or butt welds replacing multi-run welds made using the MAG method. The welding of T-joints can be performed in the flat or horizontal position (PA and PB respectively); welds can be one or two-sided.

3. When welding T-joints using butt welds, without the scarfing of an edge of one of the sheets, the optimum manner enabling the obtainment of quality joints with full penetration involves the setting of various properly adjusted laser beam angles of incidence and MAG torch angles of inclination in relation to the plane of the interface between the sheets.

4. When welding T-joins, the replacement of multi-run welds made using the MAG method with single-run welds made using the HLAW method simplifies the making of structures, significantly increases process efficiency and reduces the consumption of filler metals.

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Program Badań Stosowanych

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