Hybrid laser welding of fillet joints – case study

Background

Reduction of distortion is one of the most difficult challenges in welding technology. Thermal expansion and plastic flow of the material subjected to localised heating and cooling during welding, results in residual stress and distortion. Distortions are particularly severe in the shipbuilding industry, where large components with a relatively low thickness are welded. In Fig.1 an example of a ship hull with visible distortions is shown. This deteriorates the performance and aesthetic appearance of the vessel. It also leads to increase in production cost through rectification.

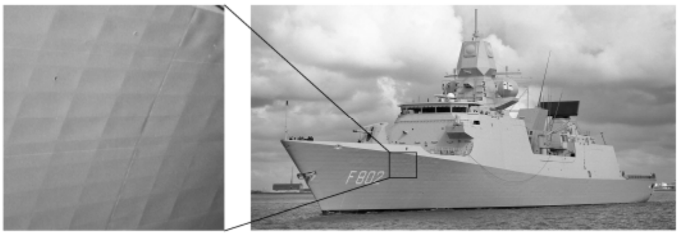

Fig.1: *Welding distortion in a ship hull (van der Aa, 2007)*

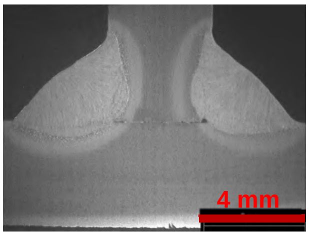

Fig.2: *Double sided GMAW fillet joint*

Fillet welds are one of the most common types of joints used in shipbuilding. Currently the majority of fillet welds are made using gas metal arc welding (GMAW), where a consumable electrode is applied in the form of filler wire. An example of a double sided fillet joint welded by GMAW is shown in Fig.2. Note the joint strength is determined by the size of the weld; however global distortion is directly proportional to the applied heat and hence to the amount deposited material.

Compared to GMAW the highly focused energy of a laser enables a specific thickness to be welded with a fraction of the energy. As shown in Fig.3a the same joint could be welded from just one side when using laser welding. However, difficulties with adding a filler metal and poor tolerance to fit-up of laser welding make the process prone to defects. The best compromise is achieved by hybrid laser welding, where a laser beam and an arc source, such as GMAW, are combined together. In this configuration the laser provides deep penetration whilst the arc source broadens the top of the melt pool and provides filler metal, which improves the weld profile, chemistry of the fusion zone and fit-up tolerance.

Since hybrid laser welding consists of two independent heat sources, the process flexibility enables almost independent control of the weld profile and depth of penetration. As shown in Fig.3b and Fig.3c the depth of penetration can be tailored according to the requirements. Compared to the GMAW weld, the strength of the hybrid weld is improved by deeper penetration, which allows for a reduction of the amount of deposited material. Even a complete joint in a single pass can be achieved, as shown in Fig.4d. This has a great impact on improvement of productivity and reduction of distortion.

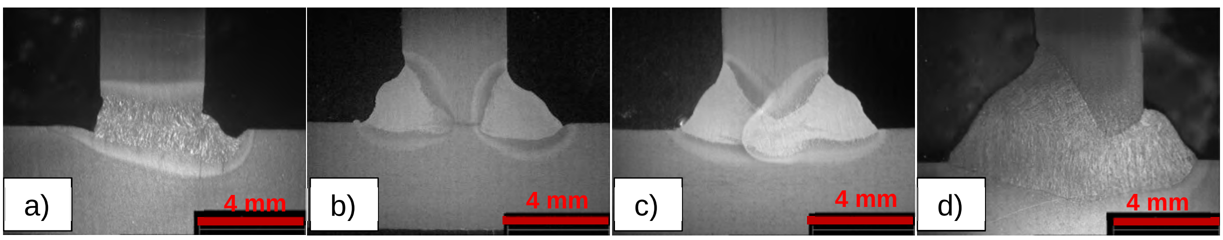

Fig.3: *Fillet joints;* ***a)*** *fully penetrated laser weld;* ***b)*** *double sided shallow penetration hybrid weld;* ***c)*** *double sided deep penetration hybrid weld;* ***d)*** *fully penetrated hybrid weld*

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Project scope

In this project the effect of welding parameters and the possibility of controlling the weld profile of fully penetrated hybrid laser/GMAW fillet welds were investigated. The flexibility of hybrid welding requires understanding and control of many parameters, in order to achieve a desired weld profile. As shown in Fig.4 the distribution of molten metal changes with laser power and wire feed rate. The reinforcement at the rear side increases with increasing laser power, whilst the reinforcement at the front side decreases. This is also shown in Fig.5. The effect of arc power is more complex, because an increase of wire deposition increases the arc electromagnetic force. Note that the arc energy increases with increasing the wire feed rate in synergic GMAW. In general, the reinforcement increases at both sides with increasing the wire deposition.

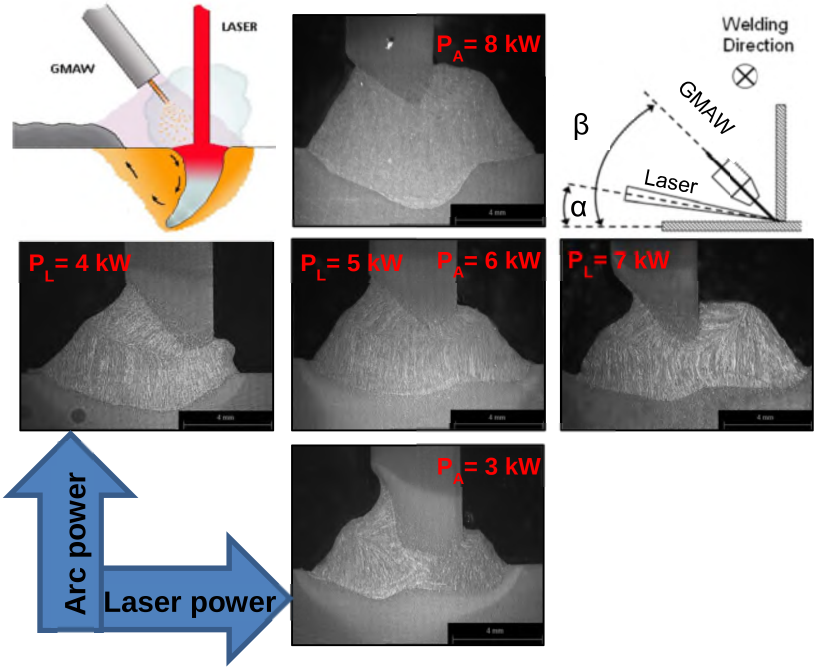

***Fig.4:** Effect of wire feed speed (arc power) and laser power on weld profile of hybrid laser/GMAW fillet welds*

Other parameters that were identified as having a significant effect on the metal distribution and weld profile in this joint configuration are: laser beam diameter, welding speed, inclination angle of laser beam, gap between the components and welding position. Understanding the net effect of all these parameters on the melt pool balance enabled us to achieve a stable process and to tailor the weld profile to a particular application.

Summary

In summary the project demonstrated the high flexibility of hybrid laser/GMAW welding, in terms of degree of control of the weld profile. For a given thickness the penetration and distribution of molten metal can be controlled by the laser source i.e. laser power, power density, inclination angle and welding speed. In addition to this the arc source determines the amount of deposited material and penetration in certain conditions.

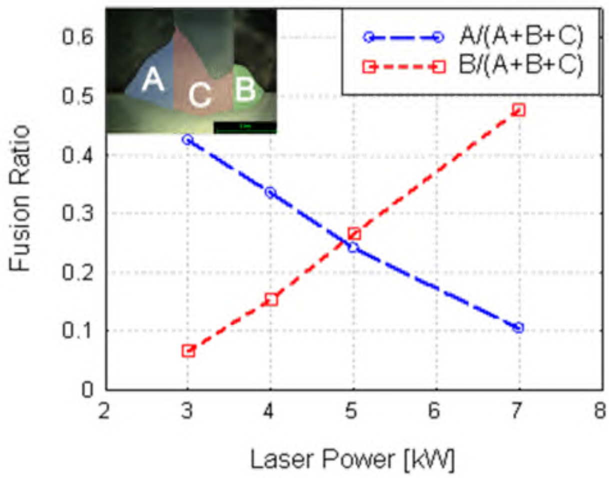

***Fig.5:** Effect of laser power on distribution of molten metal in hybrid laser/GMAW fillet joints*

Acknowledgement

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