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Undercuts in Laser Arc Hybrid Welding

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Abstract

Undercuts are usually an imperfection in welding that either continuously or sporadically form, especially when welding at high speed. Efforts, usually lowering the welding speed or overfilling, are applied to avoid undercuts as they can significantly lower the fatigue properties of the welded workpiece. Undercut formation is complex and occurs by various means, mainly based on temperature and melt flow mechanisms. When having two power sources as in laser arc hybrid welding, the melt flow can be tailored to suppress undercut formation. This can be done e.g. by narrowing the width of the gouge or by optimum positioning of the power sources relative to each other. The present paper shows and explains the main reasons of various types of undercut formation. By following the herein generated guidelines, the critical welding speed during laser arc hybrid welding can be further increased, free of undercuts.

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Keywords: Undercut; Laser; Arc; Hybrid; Welding; Shapes; Mapping

1. Introduction

This study aims at creating a survey and at systematically categorizing different types and origins of the undercut weld imperfection in Laser Hybrid Arc Welding (LAHW), Bagger and Flemming (2005), with the leading arc configuration and using a 1 µm wavelength laser. Already reported undercuts in Laser Beam Welding (LBW) and Gas Metal Arc Welding (GMAW) found in literature are also here presented and categorized. Undercut reduces the mechanical properties of welds. If not kept to a minimum, undercut may severely reduce the fatigue properties of the entire welded construction Alam, et al (2010), Bell, et al (1989), Nguyen and Wahab (1998), Otegui, et al (1989).

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Figure 1 illustrates the LAHW process while Fig. 2 illustrates designations and imperfections of an LAHW weld, including undercuts. Welding standards, such as the one for LAHW (ISO/FDIS 12932), specifies typical tolerance limits for occurring undercuts but not how to prevent them. In order to prevent undercut formation in arc welding, the arc generated gouge needs to be filled, Mendez and Eagar (2003). A typical counter measure is to add more material to the process, overfilling the weld and forming a high reinforcement, neither esthetical nor cost-effective.

As welding speed has increased over the years, e.g. by LBW and LAHW, undercuts have become a more severe issue, Kaplan, et al (2007). In fusion welding the speed is often limited by the occurrence of undercuts, coupled with high power the speed can be further limited by other imperfections such as humping, Nguyen, et al (2006), Soderstrom and Mendez (2006). Undercut formation is generated by solidification (dependent on heat conduction) and melt flows, which is dependent on chemistry- and temperature-dependent viscosity and surface tension. Surface tension typically decreases with higher temperatures, negatively affecting adhesion to the solid metal, Mendez and Eagar (2003). Welding on mill scale is known to cause more/larger initial flaws and poorer fatigue behavior (usually due to undercuts), compared to having the mill scale removed, Nguyen and Wahab (1996a). The mill scale usually consists of Fe and FeO in the layer close to the base metal, accompanied by Fe_2O_3 and Fe_3O_4 in the upper layer, Legodi and de Waal (2007).

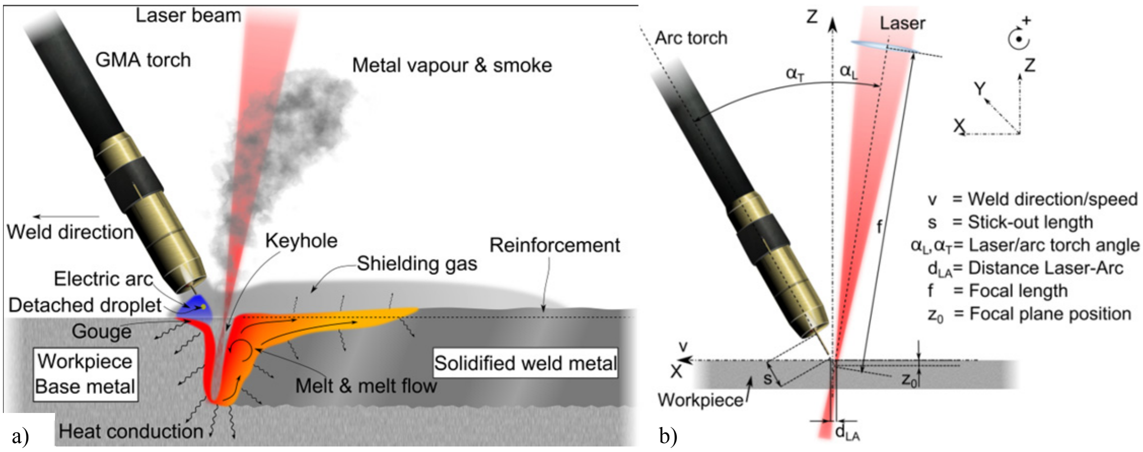

Fig. 1. (a) Illustration of laser arc hybrid welding; (b) geometrical setup.

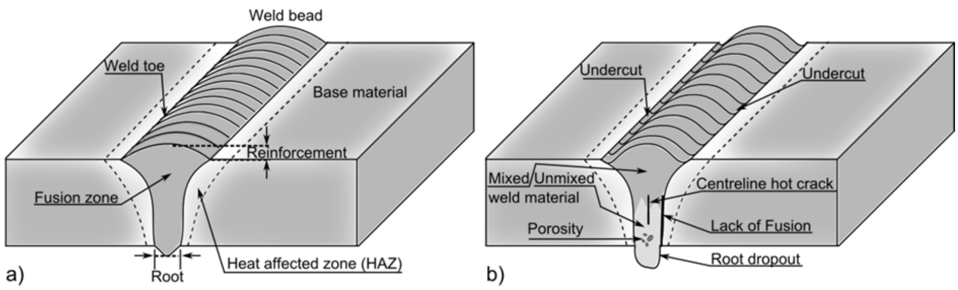

Fig. 2. LAHW crosscut (a) designations; (b) common weld imperfections.

1.1. Undercuts in Laser Beam Welding

Figure 3 shows illustrated LBW generated undercuts found in literature. Here, three different types of undercuts are presented where each has different formation causes. The curved undercut is increasingly formed at higher welding speeds (using the same line energy), Eriksson, et al (2011). Due to lowered wetting, where the temperature gradients between the melt and solid are believed to be the key, factor Pengfei, et al (2011). The rounded bottom