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Review

Hybrid laser arc welding: State-of-art review

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ABSTRACT

Hybrid laser arc welding simultaneously utilizes the arc welding and the laser welding, in a common interaction zone. The synergic effects of laser beam and eclectic arc in the same weld pool results in an increase of welding speed and penetration depth along with the enhancement of gap bridging capability and process stability. This paper presents the current status of this hybrid technique in terms of research, developments and applications. Effort is made to present a comprehensive technical know-how about this process through a systematic review of research articles, industrial catalogues, technical notes, etc. In the introductory part of the review, an overview of the hybrid laser arc welding is presented, including operation principle, process requirements, historical developments, benefits and drawbacks of the process. This is followed by a detailed discussion on control parameters those govern the performance of hybrid laser arc welding process. Thereafter, a report of improvements of performance and weld qualities achieved by using hybrid welding process is presented based on review of several research papers. The succeeding sections furnish the examples of industrial applications and the concluding remarks.

Contents

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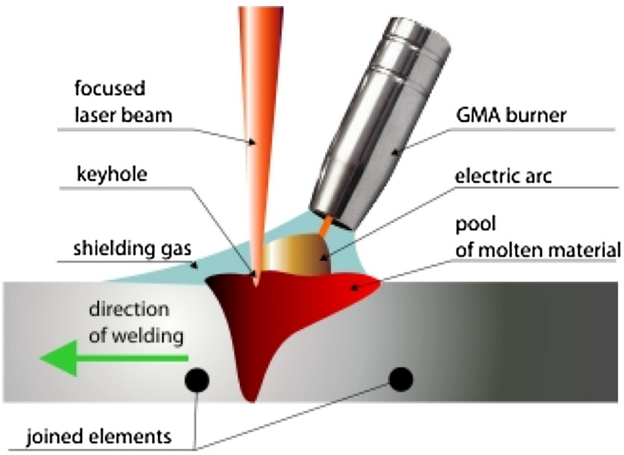

Fig. 1. Scheme of hybrid laser arc welding process.

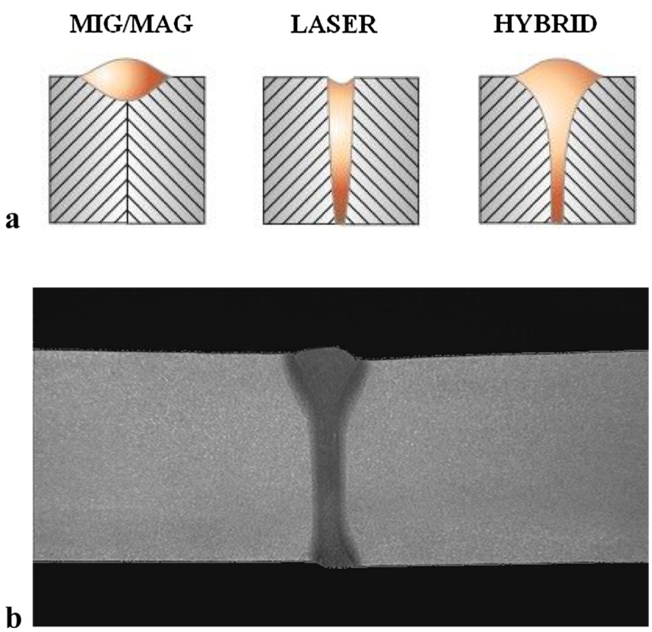

Fig. 2. Patterns of formation of weld beads during arc welding, laser welding and hybrid laser arc welding, respectively, and (b) sectional view of a weld bead of a hybrid laser arc welded specimen.

1. Introduction

In hybrid laser arc welding process, the laser beam and the electric arc interact in a common weld pool (Fig. 1) and their synergic effect is utilized to produce a deep and narrow weld with increased production rate [1,2]. Laser welding has gained reputation due to its ability to produce narrow and deep weld pool, as the laser beam can be focused on a very small area. The tight focus of the beam allows higher welding speed, which in turn reduces the heat input and the chances of thermal distortion in welded parts [3]. However, laser welding systems are costlier and electrical efficiency is very poor for most of the laser systems used for welding. Laser welding has poor gap bridging ability, and thus it requires high precession in workpiece fit-up and edge preparations. Laser welding is also very difficult for highly reflective materials like aluminium, copper, gold, etc. Contrary to this, arc welding processes have excellent gap bridging ability, high electrical efficiency and they can efficiently weld the materials having high reflectivity [4]. Arc welding systems are much cheaper than the laser welding systems of equivalent capacity [5]. However, low energy density during arc welding makes the process slower, which induces high heat input at weld zone and result in thermal distortion of welded part. Laser welding and arc welding, when applied in the same weld pool, the hybridization effect compensates the drawbacks of both the processes and compliments their advantages [6].

There are two different approaches of using laser along with electric arc for welding. The first approach is referred as laser assisted arc welding process, where the laser is used only to preheat the metals, which are to be welded by the arc welding process [7]. In this process a low power laser source is commonly used to augment the arc welding process and, therefore, improvements in weld penetration and the welding speed is not significant. In second approach, a high power laser beam is used to perform a deep penetration welding. This is a penetration mode welding process characterized by formation of key hole at the joint [8,9]. In this process, the synergic action of a laser beam having high energy density and an electric arc having high energy efficiency is used for welding [10]. This process is known as arc augmented laser welding process, most commonly known as hybrid laser arc welding process [11]. The dynamic interaction of laser irradiation, electric arc and the filler droplet govern the formation of shape and size of the weld bead and the strength of the weld [12]. Hybrid weld beads have two distinctive fusion zones, namely upper zone (arc) and lower zone (laser) [13,14]. The bead geometry of upper zone resembles a semi hemispherical 'cup' shape. The lower zone looks like a 'finger', clearly illustrating the laser keyhole effect (Fig. 2) [15,16]. In hybrid laser arc welding process, the laser beam is used as the primary heat source which interacts in the same weld pool created by a secondary heat source, i.e., the arc, generated during an electing arc welding process [17,18]. The use of secondary heat source compensates the requirement of high power laser source, which drastically reduce the cost of the set-up [5,19].

The hybrid laser arc welding process is introduced in late 1970s by Prof. W. M. Steen [11] and co-researchers, and the process is termed as "arc-augmented laser welding". The results of their research showed the clear advantages of combining a laser beam and an electric arc for welding. The hybridization effect shows a remarkable increase of welding speed, penetration depth and process stability. After the successful demonstration of this technique, further research and development on laser arc hybrid welding experienced a slow growth due lack of availability of high power, reliable laser source, required human skills, and incomplete knowledge of the process [20]. The development of reliable high power industrial lasers in late 1980s [21], catch the attention of the

Fig. 3. Integrated hybrid laser arc welding head developed by Fronius.