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Investigation on Current Enhanced CO₂ Laser Welding of Aluminum

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Abstract By using of the magnetohydrodynamic effect of electrical current, a new aspect of CO₂ laser beam welding of aluminum with an electrical current technique was reported. A DC power source was used to supply current to the weld pool. One pole of the source was connected with a tungsten electrode which was set in front of the weld pool and the other with the work piece in the rear of the weld pool. In so doing a closed electrical circuit was built. When the electrical current flows in the weld pool, a magnetic field is induced and electromagnetic forces are generated in it, which change the fluid flow and the heat exchange condition of the weld pool. So far the experimental results have shown that the weld depth and area increase and the weld seam becomes more slender when the current is up to a certain value, e.g. 200 A. In the experimental conditions, the weld depth increases maximum nearly by 32% and the weld area nearly by 20%, but the weld width decreases maximum nearly by 28%.

Key words laser techniques; laser welding; current enhanced; magnetohydrodynamic effect
Steel materials are much better, while liquid aluminum has good fluidity and low surface tension. In laser welding processes, the molten pool experiences intense oscillation, which can easily lead to edge defects like tapering at the weld seam or discontinuity in weld seam formation. Severe cases may also result in sudden closure of small holes in the weld, forming large cavities in the weld seam with a morphology similar to缩孔, or plasma jet from the liquid metal blown out from the molten pool at the weld seam, forming voids.

High-power laser diode improvement and the use of shorter wave-length lasers have greatly improved the laser weldability of aluminum. The use of a filling material has effectively prevented weld metal cracking and improved joint strength. Double-beam laser welding technology improves the stability of the welding process and the weld seam formation.

It was recently found that there is an inherent current of several amperes in the weld pool of laser welding. By applying an external magnetic field within the welding zone, one can influence the fluidity of the molten pool. Therefore, one can use an external magnetic field to improve the stability and welding quality of the weld seam.

Experimental Method and Conditions

![Diagram of the experimental setup for laser beam welding with an external current](image)

Fig. 1: Schema of the experimental setup for laser beam welding with an external current

3

3.1

When $D = 3$ mm, $V = 2$ m/min, and $D = 3$ mm, $V = 2$ m/min, the weld bead formation at a weld speed of 2 m/min and $D = 3$ mm is compared. (a) Without current; (b) with a current of 200 A.

![Comparison of weld bead formation at 2 m/min and D = 3 mm](image)

Fig. 2: Comparison of weld bead formation at 2 m/min and $D = 3$ mm. (a) Without current; (b) with a current of 200 A.

When $D = 3$ mm, $V = 3$ m/min, and $D = 3$ mm, the weld bead formation at a weld speed of 3 m/min and $D = 3$ mm is compared. (a) Without current; (b) with a current of 250 A.

![Comparison of weld bead formation at 3 m/min and D = 3 mm](image)

Fig. 3: Comparison of weld bead formation at 3 m/min and $D = 3$ mm. (a) Without current; (b) with a current of 250 A.
没有外加电流的常规激光焊接焊缝深度约为
宽度约为
采用的辅助电流后
厚试板完全焊透
焊缝宽度则减小至
44
左右
相当于焊接深度增加约
宽度减小约
深宽比增加
电流大小与电极位置的影响
当钨电极接电源的正极
焊接速度为
时
焊缝深度
宽度和面积随外加电流大小的变化如
图
所示
从中发现以下现象
焊缝宽度随着电流的增加而减小
而焊缝深度和面积在电流较小时并无明显变化
然而一旦电流增加到某一值后
焊缝深度和面积明显增大
当试板完全焊透后
焊缝面积先随着电流的进一步增加而有所增加
然后逐渐减小
这种趋势在
时表现得非常明显
在本实验条件下
当
时
试板完全焊透的临界电流为
焊缝面积在电流为
时达到最大值
然后随着电流的进一步增大
焊缝面积逐渐减小
当
时
由于试板完全焊透的临界电流增加至
而本实验所用的直流电源的最大输出电流只能达到
焊缝面积随电流进一步增大而减小的趋势在本实验中不能验证
图
外加电流对焊缝形貌的影响
电极的位置对实验结果有明显的影响
电极距焊接熔池越近
电流的影响越明显
试板完全焊透所需施加的电流值减小
如前所述
在本实验条件下
当
时
试板完全焊透的临界电流为
而当
时
临界电流降低至

当
时
没有采用外加电流和采用
临界外加电流时焊缝成型对比如图
所示

当
时
没有采用外加电流和采用
临界外加电流时焊缝成型对比如图
所示

电极极性的影响
在焊接速度为
时
改变钨电极的极性
实验结果如图
所示
可见
极性的改变对焊接结果没有影响

分析与讨论
上述结果显示
采用辅助电流对铝合金的激光焊接具有非常明显的影响
附加电流通过焊接熔池将产生电阻热
我们可能自然而然地认为电流的影响是由于其热效应
然而
本文实验所用铝合金为工业纯铝
其导电性能良好
在长度极为有限的焊接熔池内的电压降微乎其微
因此附加电流的引入所带来的附加热输入完全可以忽略不计
此外
从焊缝的成型来判断
即使附加电流带来电阻热
这种附加电阻热也只能使焊缝加宽
不可能使其变窄
我们认为附加电流对焊接结果的影响是由电流的磁流体动力学效应引起的
由电磁学的基本原理可知
在两根平行的导线中
通过同方向的电流时
则产生相互吸引力
当电流在一个导体中流过时
整个电流可以看成由许多平行的电流线组成
这些电流线间也将产生相互吸引力
如果该导体是流体
电磁吸收力的作用将使流体的截面收缩并在流体内产生压力
由于单位体积内的电磁力与电流密度


Fig. 6 Influence of the polarity ($V = 2 \text{ m/min}, D = 3 \text{ mm}$)

Fig. 7 Schematic diagram of the current density distribution in the weld pool

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