镁合金 AZ31B的激光 -TIG复合热源缝焊工艺

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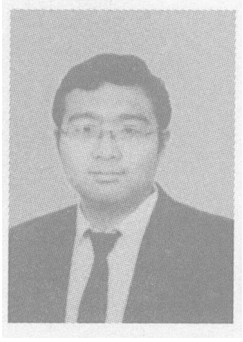

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摘 要：以 AZ31B变形镁合金为主要对象，研究了其激光 -TIG复合热源缝焊工艺特点，探讨了缝焊表面成形、缝焊熔深的影响因素以及缝焊缝的抗剪强度变化规律。结果表明，激光 -TIG复合缝焊的焊缝为明显的“图钉型”形貌，上部分为 TIG电弧焊接成形，下部分为典型的激光焊接成形。镁合金复合热源缝焊具有焊接速度高、焊缝成形美观、焊接参数范围较宽等特点，接头抗剪强度较高，是一种优良的焊接方式。

关键词：镁合金；激光 -钨极氩弧；复合热源缝焊；抗剪强度
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0 序 言

当前汽车焊接制造的特点与关键技术是焊接新工艺、新材料、新方法在汽车制造中的应用与高强轻金属材料的焊接问题。镁合金具有比重轻、比强度高、回收性好等优点，在汽车领域拥有广阔前景。为了减轻车身重量[1]，在汽车的框架和底板等结构件中，缝焊缝数量很多。当前汽车工业上主要采用激光缝焊的方式。激光焊接具有焊接速度高，焊接变形小，热影响区窄，焊缝美观等优点，但对于高反射金属(镁、铝、铜及其合金)激光能量利用率很低，随着焊接厚度的增加，对激光器功率的要求也越高，从而使激光的应用受到限制。激光与电弧复合热源焊接在继承激光焊接优点的同时在很大程度上又弥补了单独激光焊接的不足，可以起到提高能量利用率、增大熔深、降低焊接缺陷的效果，是一种高效的焊接方式，复合热源焊接作为一种新的焊接方法也越来越多的应用于制造领域。

文中针对目前应用较广的变形镁合金 AZ31B，研究了变形镁合金 YAG激光 -TIG复合热源缝焊工艺特点，探讨了缝焊表面成形的影响因素、各工艺参数对缝焊熔深的影响规律以及缝焊缝的抗剪强度变化。

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1 试验方法与装置

1.1 试验设备

采用复合热源焊接设备为 IWS -500YAG固体脉冲激光器加旁轴式 TIG氩弧焊机，试验所采用的热源如图 1所示。

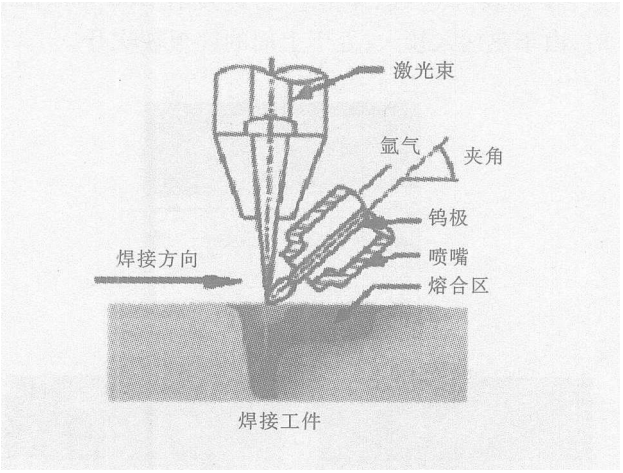


图 1 激光-TIG复合热源示意图
Fig. 1 Principle of laser-TIG hybrid welding

1.2 试验材料的选择

试验采用尺寸为 100 mm × 30 mm × 1.6 mm的变形镁合金 AZ31B板材。焊前采用丙酮去除油脂，干燥后分别用砂布和钢刷去除氧化膜。

1.3 接头形式

选用全搭接形式(over-lap)即缝焊，如图 2所示。

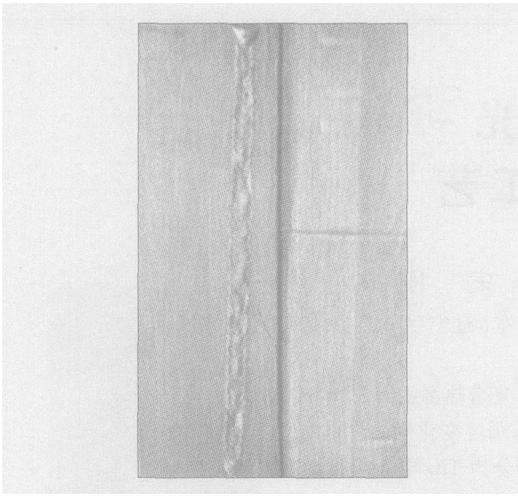


图 2 接头形式

Fig. 2 Joint geometry

2 试验结果与分析

2.1 焊接速度对缝焊表面成形的影响

在复合热源焊接过程中 TIG 焊接电流不变(100 A),焊接速度 v介于 600~2000 mm/min之间,焊接速度过大会产生激光与电弧分离现象,造成焊接熔深不够;焊接速度过低易产生烧穿、分层现象。图 3是焊接速度的变化对焊缝表面成形的影响,从图中可以看出,采用激光 -TIG 复合热源焊接镁合金,焊缝表面连续、平稳。当速度在 700 mm/min时,由于热输入较大,处于上面的镁板被吹开。

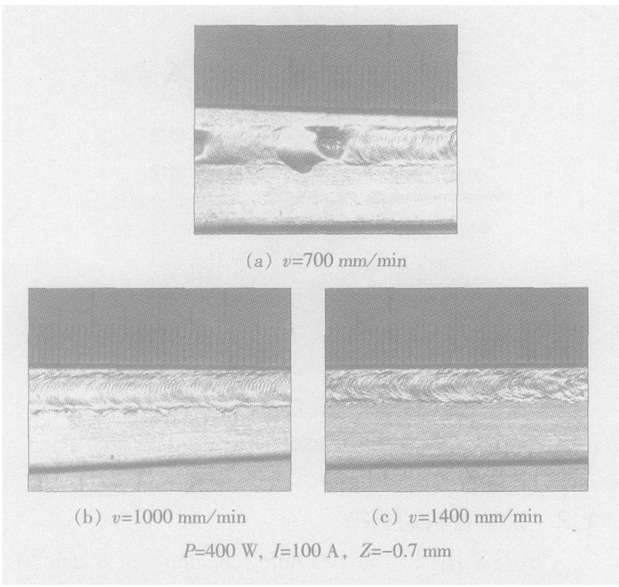


图 3 不同焊接速度的焊缝表面成形

Fig. 3 Weld appearances at different speed

试验发现,其它参数(激光功率 P、离焦量 Z)以及板厚一定的条件下当焊接速度超过 1 400 mm/min时,焊缝表面出现激光束单独走过的痕迹,激光与电弧没有完全复合上,这说明激光与电弧的复合也需要一定的条件。

2.2 工艺参数对缝焊熔深、熔宽的影响

2.2.1 焊接速度对缝焊熔深的影响

图 4为同样焊接电流(100 A)不同速度下焊缝横截面,从图中可以看出,焊缝为明显的“图钉型”形貌,这也反映了激光 -TIG 复合缝焊的焊缝成形特点。焊缝上部分为 TIG 电弧焊接成形,而焊缝下部分为典型的激光焊接成形。由图中可以看出缝焊的熔深主要依靠于激光的熔透能力,在复合热源缝焊工艺中,激光的能量得到充分的吸收,激光产生的的小孔继续向下层板材深处扩展,甚至穿透下层板材,从而实现缝焊过程。

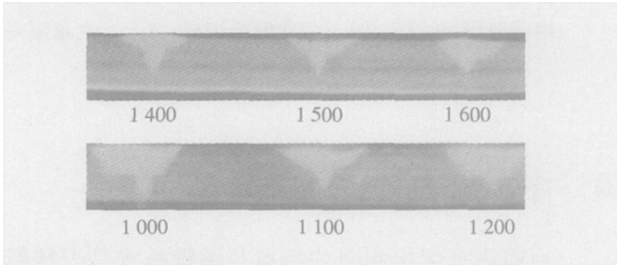


图 4 不同焊接速度(mm/min)下的焊缝截面

Fig. 4 Bead cross section at different welding speed

熔深对复合热源缝焊的意义很大。在缝焊过程中两层板间易产生气孔,气孔的存在严重影响焊缝力学性能,试验发现当上下两层板材完全焊透时,焊缝气孔的数量大大减少,这是因为熔深越大,说明激光的小孔效应越显著,小孔向下扩展的越深,气体就在小孔挤压下越远离于上下两层结合处,而当完全焊透时,熔深达到最大,这种效应最为显著,从而得到高质量的焊接过程。

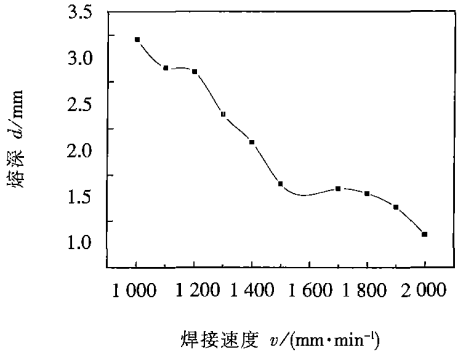
图 5为焊接速度对缝焊熔深的影响规律,从图中看出缝焊缝熔深随速度的降低而增大,当 TIG 焊电流为 100 A时,焊接速度小于 1 300 mm/min两个板能够良好连接,在速度小于 1 000 mm/min下层板能被完全焊透。

2.2.2 激光离焦量 Z 对熔深的影响

离焦量即激光焦点相对于被焊工件表面的位置,是一个对焊缝成形非常敏感的参数,很小的出入就会造成缝焊熔深的较大差异。

图 6为缝焊两个 1.6 mm厚度板材时不同离焦量对焊缝熔深的影响。从图中可以看出当离焦量在 -0.8 mm时,激光能量作用充分,此时产生的小孔效应使这一过程属于激光深熔;当离焦量超过 -1.2 mm后,激光能量增大熔深的作用不明显,说明此时

已属于热导焊过程。因此,焊接过程中,离焦量的调整很重要,一般激光焦点处在焊接试样板厚的四分之一为最佳。



P=400 W, I=100 A, D=2.4 mm, Z=-0.8 mm

图 5　焊接速度对熔深的影响

Fig. 5　Influence of welding speed on weld penetration

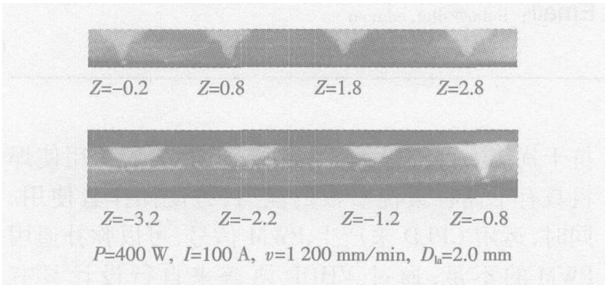
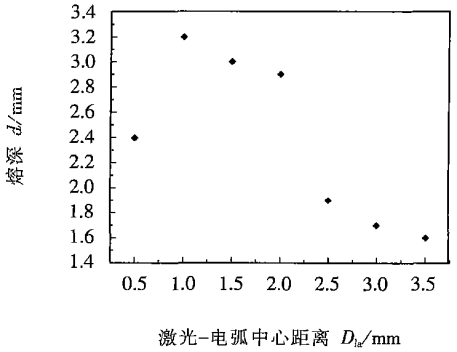


图 6　激光离焦量 Z的变化对焊接熔深的影响

Fig. 6　Influence of laser focus position on weld penetration

2.2.3　激光斑点与电弧中心距离 D_{la}对熔深影响

复合热源缝焊过程中电弧使表面金属液化,增大了材料对激光的吸收率;另一方面激光改变了电弧热源特性,激光与电弧复合时,电弧被吸附到激光与材料的冲击点上,使电弧能量更加集中。随着电弧中心与激光斑点间的距离减小,焊缝的熔深明显增大,但当距离小到一定程度时,激光与电流间的增强作用减弱,熔深反而变小(图 7)。



P=400 W, I=100 A, v=1 100 mm/min, Z=-0.8 mm

图 7　D_{la}对焊缝熔深的影响

Fig. 7　Influence of D_{la} on weld penetration

2.2.4　TIG焊接电流对缝焊熔宽的影响

缝焊缝在上层板具有明显的 TIG电弧焊接成形特点,所以 TIG焊接电流对于焊缝熔宽的大小是一个很敏感的参数,图 8为它们之间的关系曲线。电流的增大对缝焊缝熔深有一定的影响,但并不像焊接速度等其它焊接参数对熔深影响那么显著。

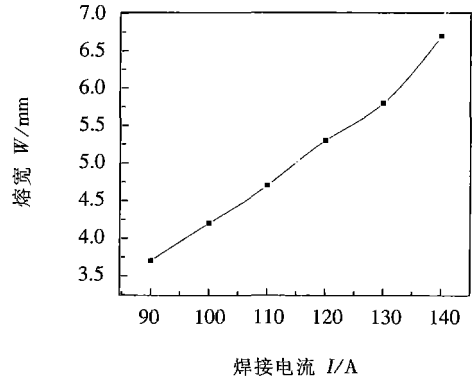


图 8　TIG焊接电流对熔宽的影响

Fig. 8　Influence of TIG welding current on weld width

3　缝焊缝的抗剪强度

复合热源缝焊缝剪切试样的制备如图 9所示[2],做剪切试验时,为了抵消偏心力矩,在夹头处各垫上一块与试样等厚的板。

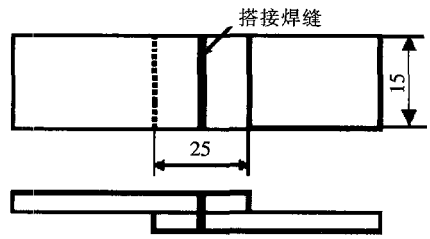


图 9　剪切试样

Fig. 9　Test specimen for tensile shear strength of lap welded joint

缝焊缝的抗剪强度测试结果如表 1所示,抗剪强度随着焊接速度的增加而逐渐减低:当焊接速度小于 1 100 mm /min时,抗剪强度达到母材抗拉强度的 62.1%;当速度在 900 mm /min时,抗剪强度与母材的抗拉强度百分比达到 80%以上,达到了该种接头的优良水准。这是因为复合热源缝焊熔深随着速度的减低而增大,从前面的分析可知熔深的增大会避免缝焊过程中气孔的产生,这样就使抗剪强度得到了相应的提高。

综上所述,复合热源缝焊镁合金是完全可行的。

表 1 复合热源缝焊缝抗剪强度

Table 1 Shearing strength of lap joints by laser TIG hybrid welding

焊接速度 v/(mm·min^{-1})	抗剪强度 τ/MPa	母材百分比 /%
900	193.3	80.1
1000	164.9	68.3
1100	149.8	62.1
1200	111.5	46.2

4 结 论

(1) 采用激光 -TIG 复合热源缝焊镁合金能够得到质量良好的焊缝并且焊接工艺参数范围较宽。

(2) 缝焊缝熔深是评定焊接质量的重要依据，熔深越大两层间的结合愈牢固。焊接速度、激光斑点与电弧中心距离、离焦量对缝焊熔深均有很大影响。

(3) 激光 -TIG 复合热源缝焊镁合金可以得到抗剪强度较高的焊接接头，是一种优良的焊接工艺。

参考文献：

[1] 彭 毅，郑大春. 激光加工在汽车工业生产中的应用 [J]. 新材料新工艺，2000 (7)：15-17.

[2] Moriaki Ono, Yukio Shinbo, Akihide Yoshitake. Development of laser arc hybrid welding[J]. NKK Technical Review，2002 86：8-12

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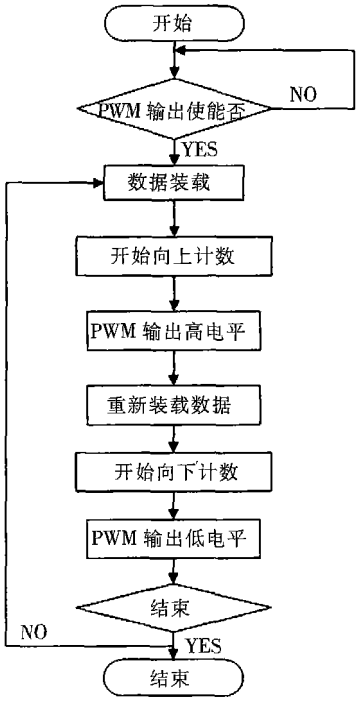

图 7 数字 PWM流程图

Fig. 7 Digital PWM diagram of CPLD

控制算法成为可能。焊机采用键盘输入及液晶显示，从而使参数预置和显示实时、清晰明了。DSP-MCU双机通信采用双口 RAM使通信的速度以及抗干扰能力得到极大的提高。X25045的运用使焊机具有了储存最优参数的能力，方便操作者使用。同时，运用 CPLD来产生 PWM信号，可以弥补通用 PWM的不足，通过 VHDL语言来自行设计具有 PWM功能的芯片，使系统的整体性能得到了加强。试验结果证明所设计的控制系统完全满足多功能数字化逆变焊机控制要求。

参考文献：

[1] Liu Jia, Lu Zhengyang, Yin Shuyan. The digitalization of welding inverter[J]. Transactions of the China Welding Institution，2002 23(1)：88-92
刘 嘉，卢振洋，殷树言，等. 电焊机的数字化 [J]. 焊接学报，2002 23(1)：88-92

[2] 公茂法，马宝甫，孙 晨. 单片机人机接口实例集 [M]. 北京：北京航空航天大学出版社，1998 63-65.

[3] 李朝青. PC机及单片机数据通信技术 [M]. 北京：北京航空航天大学出版社，2000 103-114.

[4] 宋万杰，罗 丰，吴顺君. CPLD技术及其应用 [M]. 西安：西安电子科技大学出版社，1999 83-107.

[5] 程杰斌，王华民，李劲松，等. 基于 CPLD的全数字脉宽调制器的设计 [J]. 电力电子技术，2003 37(3)：76-78

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Technology for Non-ferrous Materials, Lanzhou University of Technology, Lanzhou 730050, China). p17-20, 24

Abstract: A two-processing controlling digital inverter welding power system was designed based on digital signal processor (DSP) and micro-control unit (MCU) and its multi-functions were achieved. DSP (TMS320F240) was mainly used in sampling welding parameters and calculating control algorithm, whereas MCU (80C196KC) was used in implementing interfaces including keyboard, display and communication. Liquid crystal display is adopted for man-machine interaction. The key point of the design was the communication between DSP and MCU, therefore, a dual-port RAM (IDT7005) was adopted to ensure its reliability and rapidity. Complex programmable logic device was used to realize digital pulsed width modulation. The results indicates that fully digital controlling of multi-function welding machine was realized through DSP-MCU controlling system.

Key words: pulsed width modulation; complex programmable logic device; digital signal processing; micro-control unit; digital welding power

Laser-TIG hybrid overlap welding process of AZ31B Mg alloy

CHI Ming-Sheng, LIU Li-Ming, SONG Gang (State Key Laboratory of Material Surface Modification by Laser, Ion and Electronic beams, Dalian University of Technology, Dalian 116024, China). p21-24

Abstract: Wrought magnesium alloy AZ31B was welded with laser-TIG (tungsten inert gas) hybrid overlap welding process and the surface appearance of the bead, the influencing factors of the penetration and shear strength were discussed. The results show that the bead evidently presents "pin shape" when welded by laser-TIG hybrid overlap welding. The top of bead is the typical shape when welded with TIG process, while the bottom of bead showed the typical shape of laser welding. It was a good way to weld magnesium alloy by using the laser-TIG hybrid welding with advantages high welding speed, aesthetic bead form, comparative wide welding parameters and high shear strength of joints.

Key words: AZ31B Magnesium alloy; hybrid overlap welding; shear strength; laser-tungsten inert gas welding

Numerical model of heat input from rotational tool during friction stir welding

WANG Da-yong, FENG Ji-cai, WANG Pan-feng (National Key Laboratory of Advanced Welding Production Technology, Harbin Institute of Technology, Harbin 150001, China). p25-28, 32

Abatract: This paper has established the numerical models of the heat generation from the shoulder, the cylinder-shape and the cone-shape pins (including pin-sideface and endface) during friction-stir welding. The effect of pin angle on the heat generation from the cone-shape pin has been analyzed. The results confirm that the heat generation from the shoulder and the cone-shape pin endface decreases, and the heat generation from the cone-shape pin sideface increases when pin angle increases. However, the general heat generation from the cone-shape pin decreases firstly, then increases rapidly with pin angle increasing.

Key words: friction-stir welding; heat input; numerical model

Effect of trace Zr on microstructures and properties of welded joint of Al-5.8Cu-0.3Mn alloy

LI Hui-zhong, ZHANG Xin-ming, CHEN Ming-an, LIU Ying, ZHOU Zhuo-ping (School of Materials Science and Engineering, Central South University, Changsha 410083, China). p29-32

Abstract: Al-5.8Cu-0.3Mn alloy was welded using 4047 solder wire with metal inert gas welding. Mechanical properties and microstructures of the welded joints and base metals were studied by means of optical microscope, transmission electron microscope and microhardness. The experimental results show that the tensile strength of base metal can be improved by 30 MPa and the tensile strength of the welded joint can be improved by 50 MPa. At the same time, the microstructures of recrystallization of the welded zone are fined due to addition of 0.21% Zr. The tensile strength of the welded joint of Al-5.8Cu-0.3Mn alloy is lower than that of the base metal. In the welded joint, the weld bead is the weakest area and the soften zone in the heat affected zone is the second weakest where the θ' phase particle became coarser.

Key words: Al-5.8Cu-0.3Mn alloy; welded joint; microstructure; tensile strength; properties

Influence of coaxial shielding gas flux on keyhole in Nd:YAG CW laser deep penetration welding

QIN Guo-liang, Lin Shang-yang (Harbin Welding Institute, Harbin 150080, China). p33-36

Abstract: The influence of coaxial shielding gas flux on keyhole was studied by processing the captured coaxial image of keyhole. The results show that the coaxial shielding gas has great influence on the upside of keyhole and its influence on keyhole bottom is weak. For more flux of coaxial shielding gas, the radial dimension of outer edge of keyhole increases but the radial dimension of inner edge of keyhole varies little. The distances from the centers of keyhole edges to that of laser spot decrease with increasing the flux of coaxial shielding gas, which indicates that the vertical axis of keyhole is nearer to that of laser beam. In general, coaxial shielding gas has little influence on keyhole.

Key words: solid laser; deep-penetration welding; keyhole; coaxial shielding gas; flux

Morphology processing image of aluminum alloy metal inert gas welding pool

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Abstract: Weld pool geometry is a crucial factor in determining welding quality and its feedback control is a fundamental requirement of automated welding. Therefore, a vision sensing system for taking and processing the image of metal inert gas (MIG) welding pool of aluminum alloy is developed. Clear images of the MIG welding pool are obtained by u-