

TIG 焊工艺对 LD10 铝合金接头气孔的影响

李艳军¹, 康 举¹, 吴爱萍¹, 赵 刚², 高彦军², 邹贵生¹

(1. 清华大学 先进成形制造教育部重点实验室, 北京 100084; 2. 首都航天机械公司, 北京 100076)

摘 要: LD10 铝合金是国内航天运载器推进剂贮箱的主要应用材料, 通常采用钨极氩弧焊(TIG 焊)。气孔是铝合金熔焊接头中的常见缺陷, 文中对 5.5 mm 厚的 LD10 铝合金进行了 4 种不同工艺条件的 TIG 焊接, 对比研究了 4 种工艺接头的气孔问题。结果表明, LD10 铝合金采用 TIG 焊时, 容易产生气孔, 其中两面三层焊接头 X 射线检测出的不合格焊缝相对较多; 对于合格焊缝中的微气孔而言, 两面三层焊较少, 其次是两面两层焊和单面两层焊, 单面单层焊最多, 它们的气孔率分别为 0.90%、2.28%、2.53%、3.28%。焊缝气孔较多时, 在接头横向拉伸试验中裂纹容易从气孔启裂。

关键词: LD10 铝合金; 钨极氩弧焊; 气孔

中图分类号: TG 442 文献标识码: A 文章编号: 0253-360X(2014)04-0037-04

0 序 言

LD10 铝合金是 Al-Cu-Mg-Si 系锻铝中最典型的合金, 具有比强度高、比刚度大和低温性能好等特点^[1], 在多种大型运载火箭和固体导弹的液氢、液氧推进剂贮箱上获得了成功应用^[2]。

LD10 铝合金的焊接方法包括钨极氩弧焊^[3](TIG 焊)、电子束焊^[4]和搅拌摩擦焊^[5]等。LD10 铝合金采用 TIG 焊时, 气孔是接头最常见的缺陷, 其对合金性能具有很多有害影响, 如减小合金有效截面、造成应力集中、成为疲劳裂纹源、降低合金气密性和塑性及耐腐蚀性。氢是铝及其合金熔焊时产生气孔的主要原因。弧柱气氛中的水分、焊接材料以及基体金属表面氧化膜所吸附的水分都是焊缝气孔中氢的重要来源^[6]。早期研究表明, 只有采用两面三层焊这种多层焊、弱焊接工艺时接头的塑性才能达到应用要求^[7]。但在近期的焊接实践中发现, 单面焊加盖面焊(单面两层焊)的焊接接头也可以达到应用要求。阐明不同焊接工艺接头的冶金特点对于可靠应用新工艺具有重要意义。气孔作为接头的常见缺陷, 对接头性能有不可忽视的影响, 因此有必要对不同工艺接头的气孔问题进行比较研究。

1 试验方法

试验材料为航天领域中广泛应用的 LD10 铝合

金($2A14$), 属可热处理强化的变形铝合金, 其化学成分如表 1 所示。板厚 5.5 mm, 板材的热处理状态为 T6, 热处理机制为固溶处理($495 \sim 505\text{ }^{\circ}\text{C}$, 1 h + 淬火)及人工时效($155 \sim 165\text{ }^{\circ}\text{C}$, 4 ~ 15 h)。焊丝采用 BJ-380, 其化学成分如表 2 所示。

表 1 LD10 化学成分(质量分数, %)

Table 1 Chemical compositions of LD10 Al alloy

Si	Fe	Cu	Mn	Mg	Zn	Ti	Ni	Al
0.6 ~ 1.2	0.70	3.9 ~ 4.8	0.4 ~ 1.0	0.4 ~ 1.0	0.3	0.15	0.10	余量

表 2 BJ-380 焊丝化学成分(质量分数, %)

Table 2 Chemical compositions of BJ-380 welding wire

Cu	Ti	Zr	Si	Al
4.1 ~ 4.8	0.12 ~ 0.32	0.23 ~ 0.35	1.3 ~ 1.7	余量

图 1 为 4 种焊接工艺的示意图, 需要注意的是: (1) 两面两层焊和两面三层焊在背面施焊前需要去除背面余高; (2) 单面两层焊不开坡口, 且第一层焊不填丝; (3) 焊前对待焊区进行打磨去除氧化层, 垂直板材轧制方向焊接; (4) 单面单层焊、单面两层焊以及两面两层焊第一层焊采用机器自动焊, 两面两层焊第二层焊和两面三层焊采用手工 TIG 焊; (5) 多层焊时后续焊道是等试件冷却到室温后进行, 即层间温度控制在室温, 焊接工艺参数如表 3 所示。

采用可防电弧辐射的多通道高精度快速信号采集系统测定焊接热循环, 热电偶为直径 0.5 mm 的镍铬-镍硅 K 型热电偶。焊接试验结束后进行 X 射线

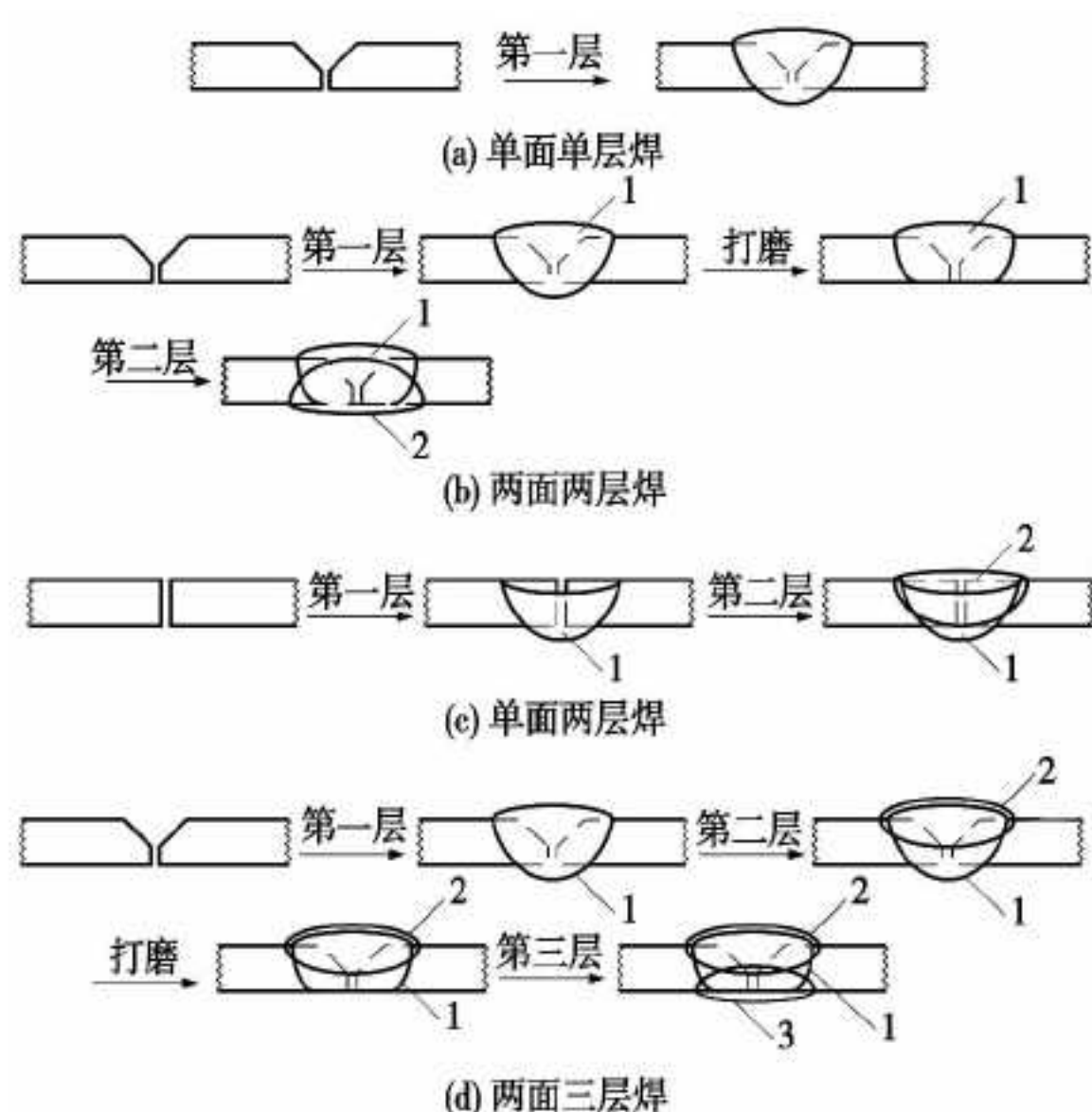


图 1 焊接工艺示意图

Fig. 1 Welding processes

表 3 TIG 焊工艺参数

Table 3 Welding parameters of TIG

保护气体 焊接速度 $v/(cm \cdot min^{-1})$ 热输入 $E/(J \cdot cm^{-1})$			
单面单层	氩气	14.2	22 309
单面两层	① 氩气	① 26.0	① 6 674
	② 氩气	② 15.0	② 27 864
两面两层	氩气	① 14.2	① 22 309
		② 7.1	② 26 273
两面三层	氩气	① 11.0	① 20 652
		② 11.0	② 20 154
		③ 10.0	③ 18 138

注:表中序号①②③分别对应第一、二、三层焊道

检测,然后在接头的典型部位截取焊缝的横截面制作金相试样,基于 Matlab 图形处理软件编程对焊缝的横截面金相照片进行图像处理(二值化、膨胀运算、腐蚀运算、开运算、面积提取等),计算气孔率(气孔率是指焊缝横截面上气孔所占面积的百分比),并统计不同尺寸范围的气孔占焊缝总面积比。

2 试验结果及分析

2.1 热循环测试结果

在焊接热源作用时,焊件上某点的温度随时间的变化过程称为焊接热循环。图 2 为单面两层焊、两面两层焊第二层和两面三层焊第一层焊缝中心的热循环曲线。由热循环测试结果可知,手工 TIG 焊的升温速率和降温速率均比自动焊小,从而其高温停留时间 t_H 和凝固区冷却时间 t_c 比自动焊长。表 4

为部分热循环特征参数。

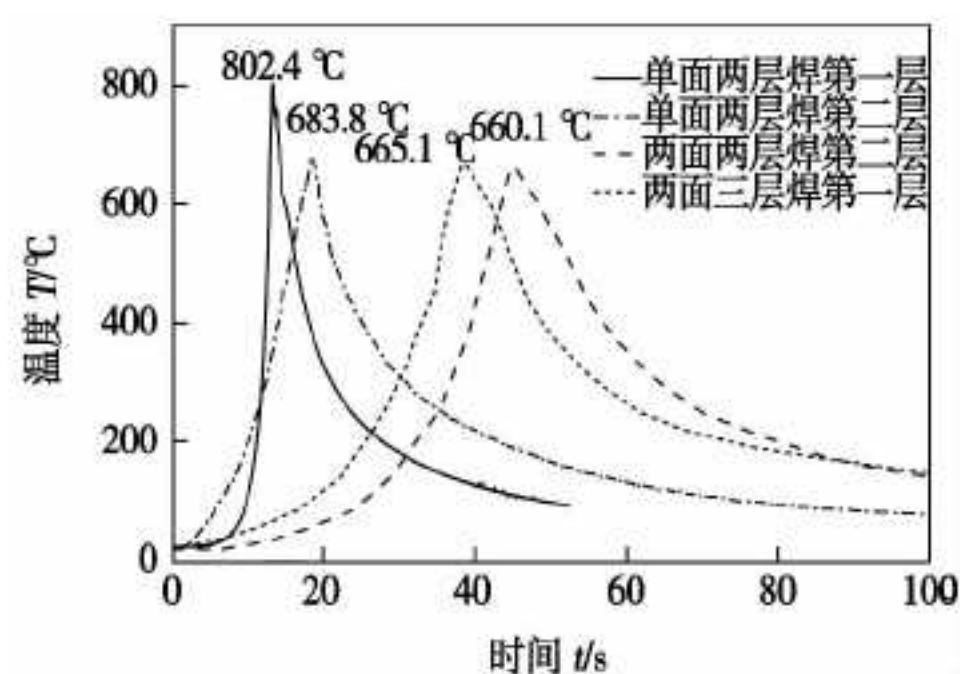


图 2 焊缝中心热循环曲线

Fig. 2 Thermal circle curve in weld center

表 4 部分热循环特征参数

Table 4 Characteristic parameters of thermal circles

	高温停留时间 (638 °C) t_H/s	凝固区(510 ~ 638 °C) 冷却时间 t_c/s
单面两层第一层	1.5	1.8
单面两层第二层	1.5	1.9
两面两层第二层	2.2	5.7
两面三层第一层	2.6	4.7

2.2 接头气孔分析

首都航天机械公司焊接实践中规定存在直径大于 0.2 mm 的宏观缺陷(为超标气孔或氧化物夹渣)的焊缝为不合格接头,需返修或报废。X 射线检测结果表明,单面单层焊、单面两层焊、两面两层焊及两面三层焊 4 种工艺焊接时均可能产生直径大于 0.2 mm 的宏观缺陷,其中两面三层焊因均采用手工 TIG 焊,稳定性不好,出现超标气孔或氧化物夹渣的情况相对其它 3 种工艺较多。

2.2.1 微气孔定量分析

微气孔分析采用 X 射线检测合格的接头,垂直焊缝方向切取接头横截面进行研磨和抛光,单面单层焊、单面两层焊第二层、两面两层焊第一层接头可观察到大量气孔,而单面两层焊第一层、两面两层焊第二层及两面三层焊接头气孔较少,如图 3 所示,图 3 中数字 1,2,3 分别表示第一层、第二层、第三层焊道。

对截面微气孔进行定量分析,考虑到沉淀相等的影响,计算时舍去半径 $13 \mu m$ (热影响区黑点的最大半径)以下的黑点。表 5 为 4 种工艺的气孔率计算结果,表 6 为 4 种工艺不同尺寸范围内气孔占焊缝截面总面积比。结果表明单面单层焊气孔问题最显著,气孔率 3.28%,并且存在尺寸较大的微气孔;单面两层焊和两面两层焊气孔问题比较显著,气孔率分别为 2.53%、2.28%,气孔直径集中在 $160 \mu m$

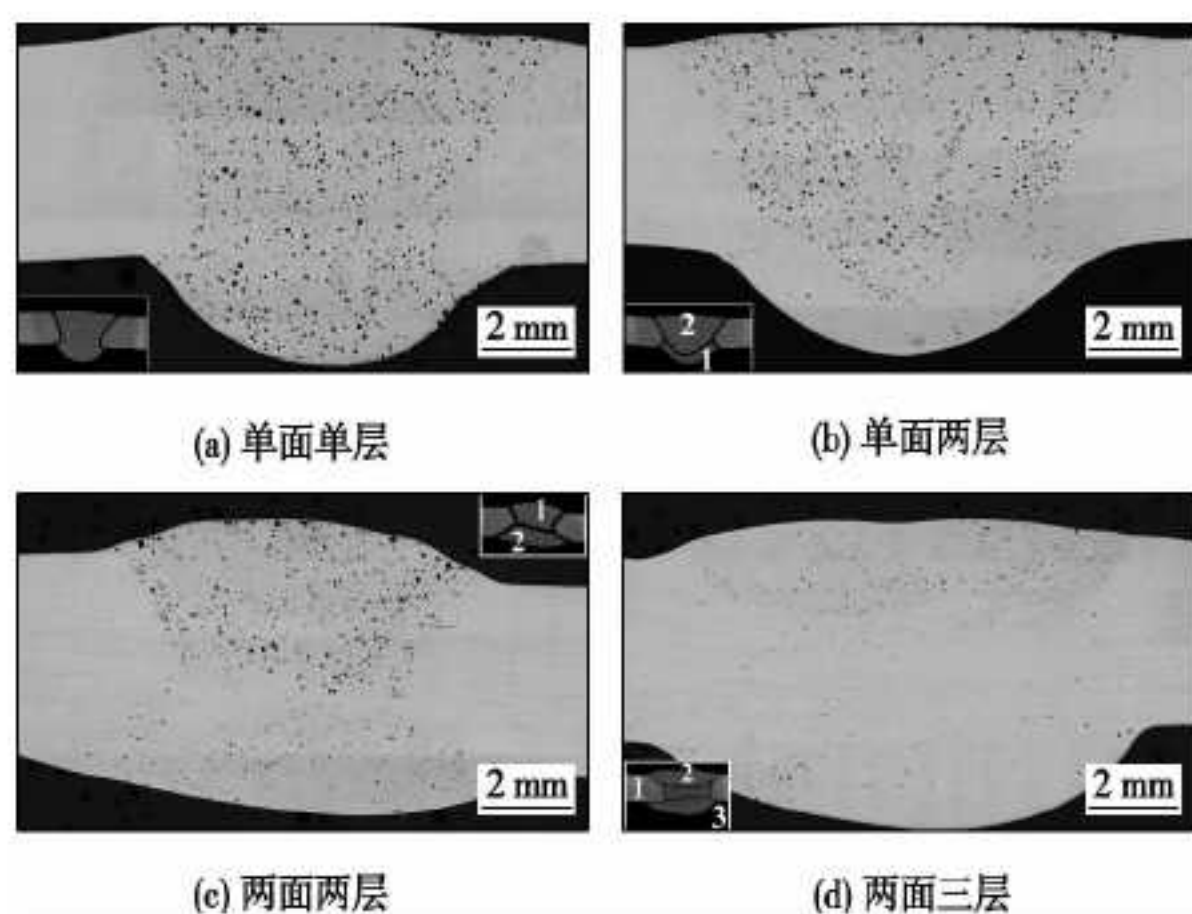


图3 接头横截面宏观形貌

Fig. 3 Cross-section morphology of joints

以下,并且两面两层焊的气孔集中在第一层焊缝中,单面两层焊的气孔集中在第二层焊缝中;两面三层焊气孔问题最小,气孔率仅为0.90%,气孔直径集中在 $100\ \mu\text{m}$ 以下,但不同截面的气孔率相差较大,从0.36%~1.44%,可见手工TIG焊的不稳定性。

表5 不同工艺的气孔率(%)

Table 5 Porosity under different processes

焊缝横截面	单面单层	单面两层	两面两层	两面三层
1	3.41	2.49	2.32	0.36
2	3.08	2.60	2.21	0.90
3	3.36	2.48	2.31	1.44
平均	3.28	2.53	2.28	0.90

表6 不同尺寸范围内气孔占横截面面积比(10^{-4})

Table 6 Porosity of different size range

气孔半径 $R/\mu\text{m}$	单面单层	单面两层	两面两层	两面三层
13~20	93.4	71.7	67.0	51.1
20~40	166.0	134.1	120.9	37.1
40~60	51.0	45.0	34.6	1.1
60~80	11.7	1.7	3.1	0.6
80~100	3.6	0	0	0

2.2.2 焊接工艺的影响

铝合金焊接接头的气孔主要是氢气孔,其产生的根本原因是氢在铝合金中的溶解度在凝固过程中变化急剧,该过程中析出的气体若来不及逸出则形成气孔。氢气孔的产生需要满足3个条件^[4]。

(1) 气泡形核条件,主要是异质形核,以胞状晶或树枝晶凝固界面以及一些夹杂物为形核点。

(2) 气孔长大条件,即

$$p_n > p_a + 2\sigma/r \quad (1)$$

式中: p_n 为气泡内部压力; p_a 为大气压力; σ 为铝合金与气体间的表面张力; r 为气泡曲率半径。

(3) 气泡上浮速度小于凝固速度。

由以上3个条件可知,合金中的含氢量及凝固速度对气孔的产生具有重要影响,前者影响气泡形成,后者影响气泡的逸出。因此限制氢气来源,减少合金的吸氢以及增大氢的逸出时间,是降低气孔倾向的有效途径。研究表明,保护气体对气孔敏感性也有影响,氦气能够抑制气孔的产生^[4]。

由图3可以看出单面两层焊的第一层焊缝气孔很少,原因是该层焊缝不填丝,避免了焊丝含氢量的影响;而且由于采用直流氦弧焊,焊接速度很快,高温停留时间短,熔池吸氢较少;氦气还具有抑制气孔作用。

对于其它焊道导致气孔倾向相差较大的主要原因在于氢气逸出时间的不同。单面单层焊、单面两层焊第二层焊、两面两层焊第一层焊,采用强焊接工艺(大电流、快速焊)焊接,凝固区间停留时间短,热循环测试结果表明,单面两层焊第二层焊缝中心固液共存区($510\sim 638\ ^\circ\text{C}$)存在时间仅为1.9 s,凝固速度快,大量气泡来不及逸出而残留在焊缝中形成气孔。两面两层焊第二层焊和两面三层焊,采用弱焊接工艺(小电流、慢速焊)焊接,凝固区间停留时间长,两面三层焊焊缝中心固液共存区存在时间为4.7 s,两面两层焊第二层为5.7 s。可见弱焊接工艺,凝固速度慢,气泡逸出充分,气孔倾向小。

气孔减少了金属的有效工作面积,导致合金的塑性及强度降低,而且还有可能造成应力集中,引起裂纹,严重影响到动载强度和疲劳强度^[4]。接头拉伸试验时,单面单层焊接头和单面两层焊接头均断在焊缝中。图4为接头拉伸断口形貌,可以发现较

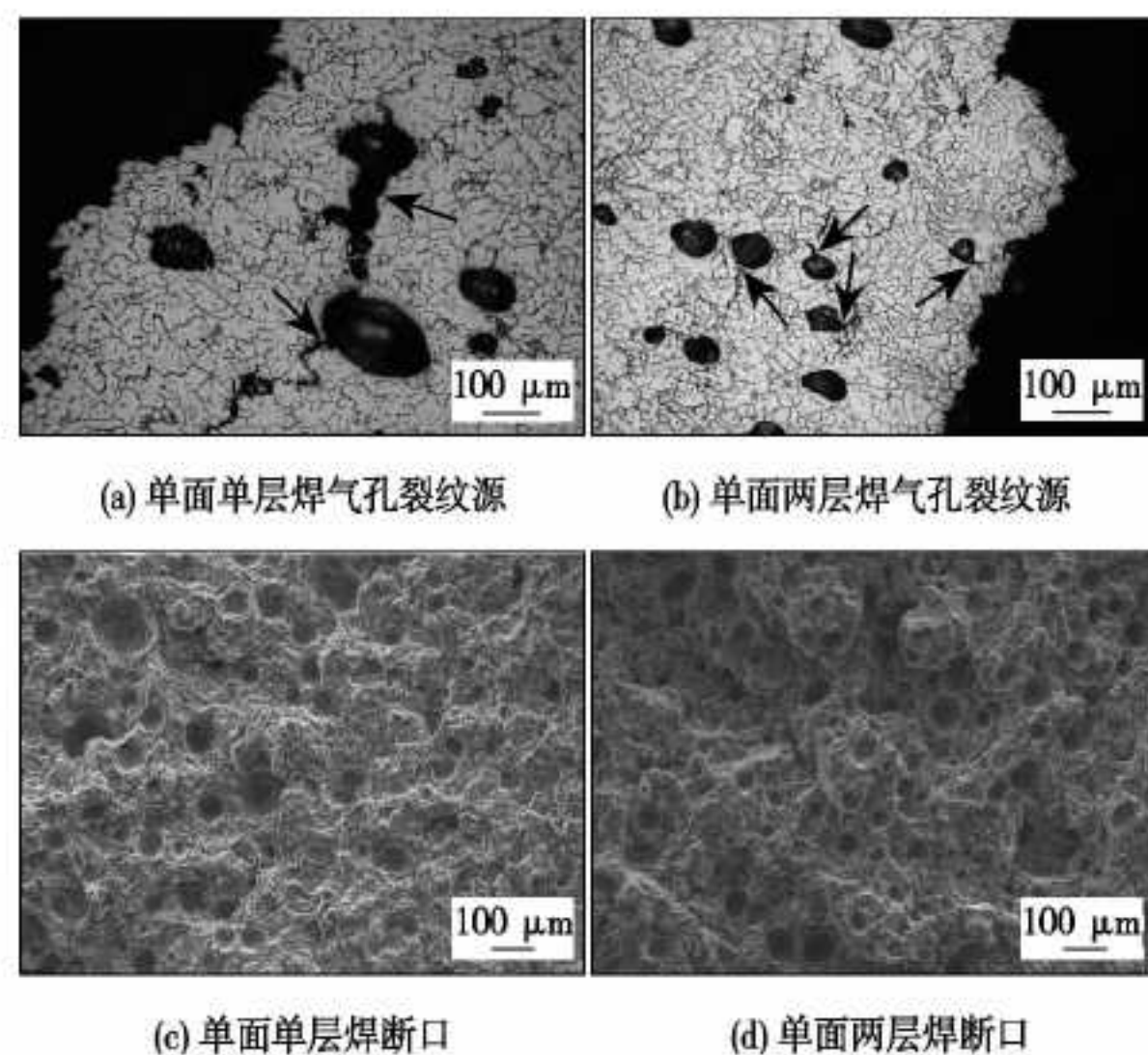


图4 拉伸断口气孔形貌

Fig. 4 Hydrogen pores in fractures

多以气孔为裂纹源而扩展的裂纹(图 4a, b), 拉伸断口表面也可以观察到存在许多气孔(图 4c, d)。因此气孔的存在对接头的强度和塑性有影响, 但其影响程度有待进一步研究。

3 结 论

(1) LD10 铝合金采用 TIG 焊时, 容易产生气孔。对直径小于 $200\ \mu\text{m}$ 的微气孔而言, 填充焊丝、保护气体以及焊接工艺参数均影响气孔的含量。无填充焊丝、氦气保护时焊缝中的气孔较少; 手工 TIG 焊时(两面三层焊和两面两层焊的第二层)由于采用弱焊接工艺(小电流、慢速焊), 气泡逸出较充分, 其焊缝中微气孔较少; 而氦气保护、填充焊丝的自动焊时(两面两层焊的第一层、单面两层焊的第二层及单面单层焊)气孔较多, 这是因为采用强焊接工艺(大电流、快速焊)时, 焊缝凝固快, 气泡来不及逸出。

(2) 接头进行横向拉伸时, 气孔减少了金属的有效工作面积, 而且裂纹容易从气孔启裂, 从而降低接头的强度和塑性。

参考文献:

- [1] 黄旺福, 黄金刚. 铝及铝合金焊接指南 [M]. 湖南: 湖南科学技术出版社, 2004.
- [2] 刘志华, 赵 兵, 赵 青. 21 世纪航天工业铝合金焊接工艺技术展望 [J]. 导弹与航天运载技术, 2002 (5): 63-68.
Liu Zhihua, Zhao Bing, Zhao Qing. Prospects for welding technology of aluminum alloy in aerospace industry in 21st century [J]. Missiles and Space Vehicles, 2002 (5): 63-68.
- [3] 王亚荣, 黄文荣, 莫仲海, 等. 2A14 高强铝合金电子束焊接头缺陷分析 [J]. 焊接学报, 2013, 34 (3): 109-112.
Wang Yarong, Huang Wenrong, Mo Zhonghai, et al. Defects in 2A14 aluminum alloy electron beam welded joints [J]. Transactions of the China Welding Institution, 2013, 34 (3): 109-112.
- [4] 于勇征, 栾国红, 孙成彬. LF6/LD10 铝合金搅拌摩擦焊工艺参数对接头性能的影响 [J]. 焊接学报, 2005, 26 (11): 67-70.
Yu Yongzheng, Luan Guohong, Sun Chengbin. Influences of FSW parameters on mechanical properties of LF6/LD10 aluminum alloy [J]. Transactions of the China Welding Institution, 2005, 26 (11): 67-70.
- [5] 周振丰. 金属熔焊原理及工艺 [M]. 北京: 机械工业出版社, 1985.
- [6] 孙忠绍, 刘宪力, 刘 欣. 航天低温贮箱箱底焊接工艺 [J]. 航天工艺, 1999 (6): 1-3.
Sun Zhongshao, Liu Xianli, Liu Xin. Welding process for space cryogenic tank's bottom [J]. Aerospace Process, 1999 (6): 1-3.
- [7] 李言祥, 吴爱萍. 材料加工原理 [M]. 北京: 清华大学出版社, 2005.
- [8] 许良红, 田志凌, 张晓牧, 等. 保护气体对高强铝合金的焊缝组织及气孔敏感性的影响 [J]. 焊接学报, 2006, 27 (12): 69-73.
Xu Lianghong, Tian Zhiling, Zhang Xiaomu, et al. Effects of shielding gas on microstructure and number of gas pore in high strength aluminum alloys weld [J]. Transactions of the China Welding Institution, 2006, 27 (12): 69-73.

作者简介: 李艳军, 男, 1990 年出生, 博士研究生, 主要从事先进材料及其焊接研究. Email: liyanjun12@mails.tsinghua.edu.cn

通讯作者: 吴爱萍, 女, 教授. Email: wuaip@tsinghua.edu.cn

η phases emerged in nugget zone and thermal-mechanical affected zone with increasing the natural aging time, which effectively pinned the dislocations and consequently enhanced the strength and plasticity of the joint.

Key words: friction stir welding; 7050 aluminum alloy; natural aging; mechanical property; precipitation

Process and properties of plasma arc welded Invar alloy 4J36

WANG Xijing¹, CHAI Tingxi¹, ZHAO Qingshan¹, WANG Jiang², WANG Qi² (1. State Key Laboratory of Advanced Processing and Recycling of Nonferrous Metals, Lanzhou University of Technology, Lanzhou 730050, China; 2. Jinchuan Group Co., Ltd., Jinchang 737100, China). pp 19–23

Abstract: Plasma arc welding of 4J36 low-expansion alloy was conducted. The microstructure and mechanical properties of welded joint were analyzed by using optical microscope (OM), scanning electron microscope (SEM), energy spectrum analysis (EDS), X-ray diffraction (XRD), and Rockwell hardness tester. The results indicate that the weld appearance was excellent and the tensile strength of the joint reached 93.6% of the base metal under appropriate parameters. The microstructure of the weld consisted of austenite with some strengthening phase $\gamma'(\text{Ni}_3(\text{Al,Ti}))$. The microstructure of the base metal was fine equiaxed grain, while that around the fusion line had dendrites structure. In the HAZ, the grains near the weld pool grew up due to overheating, but those near the base metal were fine equiaxed grains. The tensile fracture revealed obvious ductile features, and the HAZ had the minimum hardness.

Key words: Invar alloy 4J36; plasma arc welding; mechanical property; microstructure

Process and microstructure properties of laser beam welding of thin 2524 aluminum alloy sheet with filler wire

CAI Hua, LIN Kaili, XIAO Rongshi (Institute of Laser Engineering, Beijing University of Technology, Beijing 100124, China). pp 24–28

Abstract: Type 2524 aluminum alloy is an Al-Cu-Mg alloy with high damage tolerance for aerospace applications. High power fiber laser welding of 1.6 mm thick 2524 aluminum alloy sheets was conducted with 5087 aluminum alloy filler wire. The effects of laser power, welding speed and wire feeding speed on the weld appearance, solidification cracking susceptibility and microstructure were investigated. The microhardness and mechanical properties of the crack-free joints were tested. The results indicate that welding with 5087 aluminum alloy filler wire could shorten the columnar dendritic grains, refine the equiaxed dendritic grains, increase the quantity of grain boundary and reduce the hot cracking susceptibility. A defect-free joint with good surface appearance was obtained with optimized welding parameters: 2.5 kW laser power, 2 m/min welding speed and 2 m/min wire feeding speed. The tensile strength of the joints was 313–324 MPa, and ductile fracture with plenty of dimples occurred around the weld fusion line.

Key words: fiber laser welding; 2524 high strength aluminum alloy; 5087 filler wire; welding process; microstructure property

Size control of carbide in plasma cladding Fe-based composite materials strengthened by superfine NbC

WANG Zhihui¹, ZHAO Xuefei¹, HE Dingyong¹, JIANG Jianmin¹, HUANG Caiyan² (1. College of Materials Science and Engineering, Beijing University of Technology, Beijing 100124, China; 2. Harbin Welding Institute, China Academy of Machinery Science & Technology, Harbin 150028, China). pp 29–32

Abstract: Two methods were used to control the size of in-situ synthesized NbC in Fe-Cr-B-C-Nb hardfacing alloy. The size of carbide in four kinds of Fe-Cr-B-C-Nb hardfacing alloys with niobium content of 2.2%, 3.2%, 3.9%, and 5.0%, respectively, were studied in this paper. A new kind of wear-resistant alloy with dispersed micro/submicron NbC was in-situ synthesized by plasma cladding. The results show that the size of NbC could be controlled, and increasing niobium content increased the size of in-situ synthesized NbC, and the carbide tended to agglomerate. The cooling conditions played an important role in controlling the size of carbide. The size of NbC decreased with water cooling, but would increase when the cooling rate decreased.

Key words: carbide niobium; plasma cladding; alloy; micro/submicron

Full digital multi-function square wave welding inverter based on ARM

WANG Zhenmin, FENG Yunliang, FENG Ruijie, TANG Shaojie (School of Mechanical & Automotive Engineering, South China University of Technology, Guangzhou 510640, China). pp 33–36

Abstract: A full digital multi-function square wave welding inverter based on ARM was developed. To achieve the efficient energy transformation, double inverter structure was adopted in the main circuit, while full-bridge inverter circuit topology was used in the primary inverter circuit, and the secondary inverter was with double parallel half-bridge inverter circuit structure. The LM3S8971 ARM microprocessor with Cortex-M3 kernel was used as the cybernetic core for the full-digital control system. Through the current closed-loop feedback control and digital PID regulation, the constant current output characteristic of the primary inverter circuit was obtained, while a variety of output current waveforms could be extracted through digital low frequency modulation for the secondary inverter circuit. A digital control panel with double-core structure based on ARM and CPLD was designed to realize the digitization of human-machine interaction. Both performance test and actual welding process test indicate that the developed welding inverter was with such advantages as perfect dynamic performance, flexible control, convenient operation, and reasonable and feasible design.

Key words: welding inverter; multifunction; full digital control; square wave

Influence of TIG welding parameters on porosity in LD10 aluminum alloy joint

LI Yanjun¹, KANG Ju¹, WU Aiping¹, ZHAO Gang², GAO Yanjun², ZOU Guisheng¹ (1. Key Laboratory for Advanced Materials Processing Technology (Ministry of Education), Department of Mechanical Engineering, Tsinghua University, Beijing 100084, China; 2. Capital Aerospace Ma-

chinery Company, Beijing 100076, China). pp 37–40

Abstract: LD10 aluminum alloy is mainly used in domestic aerospace vehicle propellant tank and mostly joined by TIG welding, and pores often appeared during fusion welding of aluminum alloy. This paper conducted TIG welding of 5.5 mm thick LD10 aluminum alloy plates with different welding parameters and calculated the porosity in the joints. The experimental results show that LD10 aluminum alloy joints made by TIG welding were prone to high porosity. The joints produced by double-faced three-pass welding technique had a higher unqualified rate after X-ray detection, but contained fewer micro-pores in the qualified ones. And micro-pores were much more easier to form in robot automatic welding than in manual welding. Porosity of the welds was 3.28%, 2.53%, 2.28% and 0.9%, respectively. During tensile test, cracks often generated at the pores in joints with high porosity.

Key words: LD10 aluminum alloy; TIG welding; porosity

Friction and wear properties of the zirconia coatings prepared by plasma spraying and laser remelting

WANG Hongying, LI Zhijun, TANG Weijie, HAO Yunfei (Industrial Training Center, Shenzhen Polytechnic, Shenzhen 518055, China). pp 41–44

Abstract: The conventional and nanostructural zirconia coatings were prepared using plasma spraying, and then the nano zirconia coating was melted by laser. Friction and wear properties of conventional, nanostructural and laser remelted zirconia coatings were investigated at room and high temperatures. The experimental results show that the wear resistance properties of the nanostructural coating were obviously better than the conventional ones, and the nanostructural coating treated by laser remelting had the lowest friction coefficient and the best wear resistance. The analysis on surface micrographs of the three coatings shows that the surface roughness, porosity and cracking status were significantly different from each other, which resulted in a large difference in friction and wear properties for three zirconia coatings. The results indicate that nano powders plasma spraying, combining with laser remelting, was an effective approach to improve the performance of the zirconia coating.

Key words: plasma spraying; zirconia coating; laser remelting; friction and wear property

Dimensions optimization of ultra-high strength steel spot weld based on response surface methodology

YU Huiping, WANG Weiwei, LIU Yuehua, LI Xiaoyang (College of Mechanical Engineering and Applied Electronics Technology, Beijing University of Technology, Beijing 100124, China). pp 45–48

Abstract: A parametric model for the tensile-shear spot welded structure of ultra-high strength steel was established with software ANSYS by APDL to analyze the static strength of the structure, and was verified with experiments. Based on the simulated results, the optimized model was built to decrease the whole materials, and some sizes of the structure were also optimized. The response surface methodology was adopted to make

the stress constraints explicit, and the sequential quadratic programming algorithm was used to achieve the most suitable solutions of the optimized model. The results show that this method could effectively enhance the solving efficiency and avoid oscillation. The calculation procedure was programmed with C language in order to improve efficiency, and the results indicate that the optimization was feasible and effective.

Key words: ultra-high strength steel; spot-welded; dimensions optimization; response surface; sequential quadratic programming

Effect of filler metal on vacuum brazing of high volume fraction SiC_p/Al composites

QI Junlei¹, WAN Yuhua¹, ZHANG Lixia¹, CAO Jian¹, FENG Jicai^{1,2}, LIANG Yingchun³ (1. State Key Laboratory of Advanced Welding and Joining, Harbin Institute of Technology, Harbin 150001, China; 2. Shandong Provincial Key Laboratory of Special Welding Technology, Harbin Institute of Technology, Weihai 264209, China; 3. School of Mechatronics Engineering, Harbin Institute of Technology, Harbin 150001, China). pp 49–52

Abstract: Three different filler metals, Cu foil, Al-Si-Mg foil and Al-Si-Mg/Cu/Al-Si-Mg (ACA) composite foil, were used for vacuum brazing of 45% SiC_p/2024 Al composites. The microstructure of the interface in brazed seams was examined with SEM, EDS and XRD. And the effect of different filler metals on the interfacial microstructure and bonding strength was also analyzed. The formation of interface during vacuum brazing of 45% SiC_p/2024 Al composites with different filler metals and the fracture mechanism of the joint were revealed. The results indicate that ACA composite filler metal, combining the advantages of both Cu foil and AlSiMg foil, had lower liquidus temperature and better flowability. Through the diffusion of Cu atoms and prior eutectic reaction at the interface between aluminum alloy substrate and its oxide film, the removal ability of oxide film of the filler metal was enhanced and joining of 45% SiC_p/Al composites was achieved with high quality.

Key words: Al-based composite; vacuum brazing; composite material

Property and microstructure of deposited metal with high strength wire

WU Bingzhi, XU Yujun, AN Hongliang, SUN Jingtao (Harbin Welding Institute, China Academy of Machinery Science & Technology, Harbin 150028, China). pp 53–57

Abstract: The microstructure and mechanical properties of deposited metal under different shielded gases were investigated by means of optical microscopy, scanning electron microscopy with EDS, tensile and impact tests. The results indicate that the best mechanical properties of deposited metal with the medium alloy solid wire were acquired when welded with Ar + 5% CO₂ mixed gas. The granular bainite dominated the microstructure of the deposited metal, and the existence of fine lath bainite improved the toughness effectively. In addition, carbon obviously enriched in M/A constituents, and massive M/A constituents could cause stress concentration by dislocation pile-up between M/A and base metal. Meanwhile, the micro crack appeared fre-