异种铝合金自动双丝焊工艺优化

徐越兰[1], 王 平[2], 刘 永[1], 洪 庆[3]
(1. 南京理工大学, 南京 210094; 2. 中国石化南化公司 化机厂, 南京 210048;
3. 中集扬州通华专用股份有限公司, 扬州 225009)


徐越兰

摘 要: 针对厚度为 5 mm 的 6061与 5083异种铝合金的焊接, 采用自动双丝焊技术, 借助 Minitab软件分析研究焊接工艺参数对焊接接头强度及成形的影响。依据优化后的焊接工艺参数窗口进行的验证试验, 结果显示, 采用自动双丝焊技术焊接 6061与 5083异种铝合金, 单面焊双面成形; 接头强度达到并超过母材相应标准强度指标要求。与手工 TIG双面焊比较, 提高焊接效率 2倍。

关键词: 铝合金; 双丝焊; 焊接工艺参数; 优化设计
中图分类号: TG4 文献标识码: A 文章编号: 0253-360X(2005)10-31-04

0 序 言

由于铝合金具有坚实的氧化膜、高的热导率和大的线膨胀系数, 使铝合金熔化焊极易产生诸如夹渣、气孔、飞溅及大的热应力、变形、裂纹等质量问题; 随着铝合金应用日益扩大, 如何对铝合金进行高效率、高质量的焊接, 就成为突出的课题。目前, 生产中常用 MIG焊、TIG焊方法来焊接铝合金材料。虽然使用这两种方法能够得到良好的焊接接头, 但继续开发和应用生产效率高, 焊接质量好, 能更好地改善工人劳动卫生条件的铝合金的高效自动焊接技术仍然是焊接工作者努力的目标[1]。

课题针对手工 TIG双面焊存在的焊接接头强度偏低; 焊接效率低的问题, 采用自动双丝焊接技术焊接 5083、6061铝合金, 运用 Minitab软件分析研究焊接工艺参数与强度指标之相关性, 获得集中焊接工艺参数, 并验证分析结果。

1 工艺试验

1.1 试验用材及设备

牌号为 5083的防锈铝合金与牌号为 6061的锻铝化学成分见表 1。依据国家标准 GB/T 3880-1997和 GB/T 6892-2000强度指标见表 2。试验用板厚 5 mm。

表 1 母材和焊丝的化学成分(质量分数, %)
Table 1 Chemical component of base and welding material

牌号	Si	Mg	Mn	Fe	Zn	Cu	Ti	杂质
5083	0.40	4.0~4.9	0.4~1.0	0.40	0.25	0.10	0.15	0.15
6061	0.4~0.8	0.8~1.2	0.15	0.70	0.25	0.15~0.4	0.15	0.15
5183	0.40	4.3~5.2	0.5~1.0	0.40	0.25	0.10	0.15	0.15

表 2 5083和 6061铝合金强度指标
Table 2 Intensity of 5083 and 6061 Al-Ialby

材料	处理状态	板厚 δ/mm	屈服强度 σ_s/MPa	抗拉强度 σ_b/MPa
5083	退火; H112	>4.5~40	125	275
6061	T4焊	>16	无	165
6061	T4	>16	110	180

注: T4为固溶处理+自然失效状态。

试验所用的焊机为法国 SAF公司 STARMATIC R450 TOPMAG自动双丝焊机。

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焊前的认真清理是保证铝合金焊接质量的一个重要工艺措施。

1.2 试验方案及试验规范

双丝焊主要工艺参数包括主辅机焊接电流、电弧电压、焊接速度、坡口形式等参数，各个参数间又存在着交互作用，是典型的多因素、多水平问题。需要考核的指标主要是焊接接头的强度及单面焊双面成形状况。在进行一组基本规范试验的基础上，计算出相应焊接热输入，发现热输入与热影响区宽度之间存在如图 1所示趋势。由图 1可以看出，热输入在 5～7.4 kJ/cm之间时，焊接热影响区宽度随着焊接热输入的上升而增大，宽度范围在 5.5～9.2mm。再综合焊缝成形状况，剔除掉无法单面焊双面成形的相应焊接工艺参数，将焊接热输入控制在 5.7～8.2 kJ/cm之间，在此热输入范围内，选定主、辅机焊接电流、焊接速度、坡口形式三因素，每个因素确定三水平，采用正交设计进行试验。各个因素与水平设置见表 3。试验数据分两项，热影响区(软件编号 X)、焊缝成形(软件编号 Y)，焊接结果见表 4。

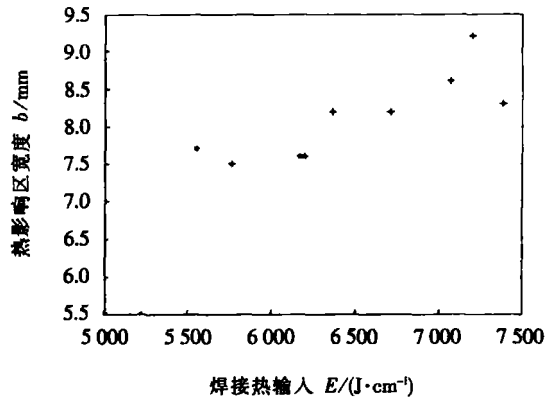

图 1 焊接热输入与热影响区宽度的关系

Fig. 1 Relation of heat input and HAZ width

表 3 因素与水平表

Table 3 Factors and levels table

水平 \ 因素	主机焊接电流 I/A	辅机焊接电流 I/A	焊接速度 v/(cm·min⁻¹)	坡口形式
1	220	244	90	90°Y形(2mm钝边，2mm间隙)
2	178	186	70	60°V形
3	170	172	50	无坡口 2mm间隙

表 4 焊接工艺参数及试验数据

Table 4 Welding parameters and test data

规范编号	主机焊接电流 I/A	辅机焊接电流 I/A	焊接速度 v/(cm·min⁻¹)	坡口形式	热影响区宽度 b/mm	焊缝成形描述	分级评定
1	220	244	90	90°Y形	6.0	焊透，成形良好，表面不饱满	2
2	220	244	70	60°V形	6.8	焊透，表面下凹，背面不饱满	4
3	220	244	50	无坡口 2mm间隙	7.2	正反面成形良好	1
4	178	186	90	60°V形	5.5	反面部分未焊透，飞溅大	5
5	178	186	70	无坡口 2mm间隙	7.8	反面焊透，正面略凹	3
6	178	186	50	90°Y形	9.5	反面焊透，正面凹陷	2
7	170	172	90	无坡口 2mm间隙	5.1	未焊透	6
8	170	172	70	90°Y形	7.6	未焊透	6
9	170	172	50	60°V形	8.6	正面略下凹，背面部分熔透	5

2 试验数据优化

Minitab软件是为了配合三次设计而产生的计算分析软件，它能应用到方差分析、回归分析、正交试验设计、稳健设计等方面，能从少量的试验中得出规律，确定最优的方案，省去大量的试验次数[2]。

为便于分析将表 4焊缝成形状况描述采用预定目标，分级评定。设定成形优良焊缝为一级，依此类推，共将焊缝成形状况分成六级。

软件采用极差分析法分析，部分分析结果如下。

Taguchi design

Taguchi orthogonal array design

L9(3 * * 3)

Factors: 3

Runs: 9

各因素对热影响区尺寸的影响显著性

Taguchi Analysis: X versus A, B, C

Response table for means

Level	A	B	C
1	6.667	5.533	7.000
2	7.567	6.667	6.967
3	6.400	8.433	6.667
Delta	1.167	2.900	0.333
Rank	2	1	3

由上面极差分析和图 2都可以看出 B因素(焊接速度)的极差最大,说明焊接速度对热影响区尺寸的影响显著性排在首位,其次是焊接电流,坡口的影响十分微弱。

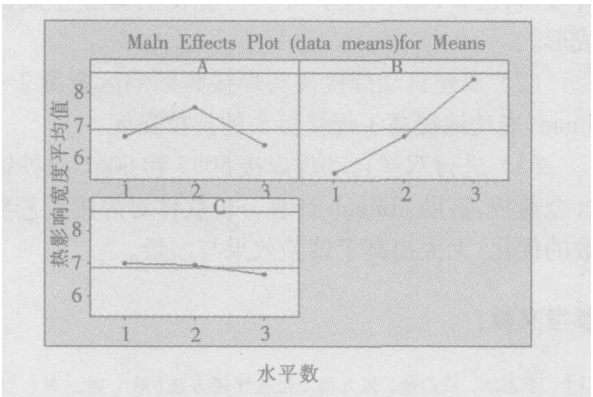

图 2　各因素对热影响区尺寸的影响显著性示意

Fig. 2　Remarkable effection of factors on HAZ width

各因素对焊缝成形影响显著性

Response table for means taguchi analysis: Y

Level	A	B	C
1	2.333	4.333	3.333
2	3.333	4.333	4.667
3	5.667	2.667	3.333
Delta	3.333	1.667	1.333
Rank	1	2	3

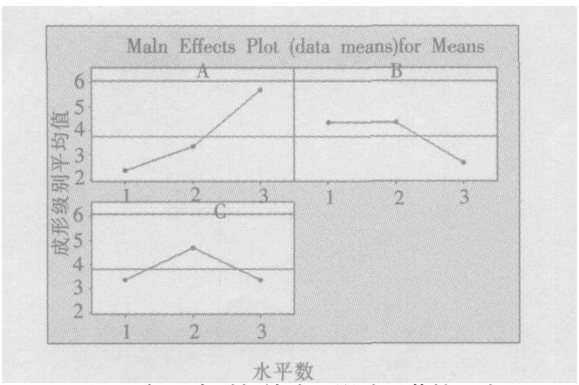

图 3　各因素对焊缝成形影响显著性示意

Fig. 3　Remarkable effection of factors on welding appearance

由上面极差分析和图 3都可以看出 A因素(焊接电流)的极差最大,说明焊接电流是影响焊缝成形的主要因素,第二是焊接速度、坡口对焊缝成形的影响。

3　试验数据验证与分析

综合上述分析结果,认为焊接 5.5 mm的 5083和 6061铝合金合适的焊接工艺参数为:主机 178~220 A,辅机 186A-244 A;焊接速度:70~90 cm/min;60°V形坡口或不开坡口,留 2 mm间隙。在此范围内进行了三组试验,坡口代号 I为开 60°V形坡口;II为不开坡口,留 2 mm间隙。焊接工艺参数及接头抗拉强度见表 5。焊缝正反面成形见图 4。

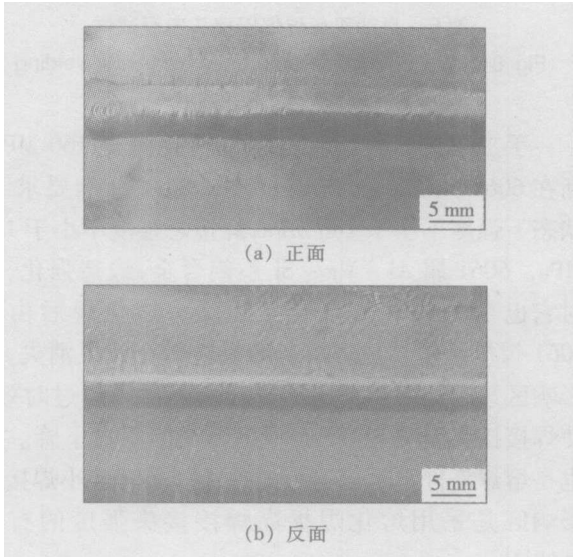

图 4　2号规范试样焊缝正反面成形

Fig. 4　Top and back appearance of 2nd sample

采用手工 TIG弧双面同时施焊[3],同时成形技术。焊接电流 240A,电压 18 V,间隙 3 mm,焊接速度 40 cm/min。焊接接头各区宏观分布见图 5,由左向右依次为 5083铝合金、焊缝、热影响区、6061铝合金。经测量 6061侧热影响区平均宽度 10.7 mm。相比较自动双丝焊 2号规范试样焊接接头见图 6,其焊接热影响区宽度底部 2 mm,上部(正面)仅 5 mm。

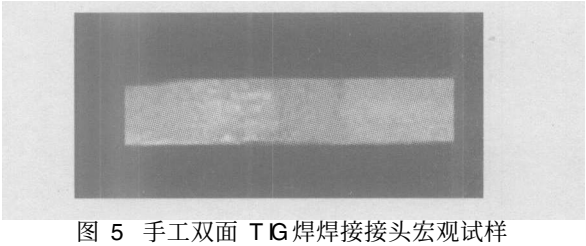

图 5　手工双面 TIG焊焊接接头宏观试样

Fig. 5　Welded joint of manual TIG double side welding

表 5 拉伸试验所用焊接工艺参数

Table 5 Welding parameters for tension test

试样编号	坡口代号	主机		辅机		焊接速度	抗拉强度	断口位置
		电流 I/A	电压 U/V	电流 I/A	电压 U/V	v/(cm·min^{-1})	σ_b/MPa	
1	Ⅱ	178	20.6	186	19.0	75	177.33	断在热影响区
2	Ⅲ	220	23.8	244	23.2	80	170.71	断在热影响区
3	Ⅱ	220	23.8	244	23.2	90	170.27	断在热影响区

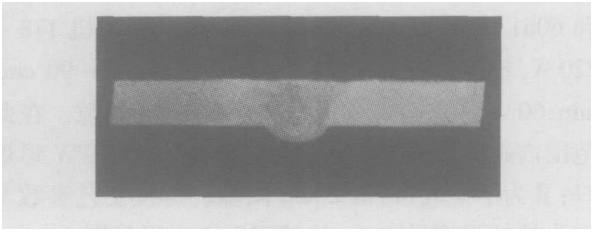

图 6 自动双丝焊焊接接头宏观试样

Fig. 6 Welded joint of automatic twin-wire welding

手工 TIG 弧双面焊接接头抗拉强度 160MPa，断在 6061 热影响区部位。6061 相关标准要求 T4 状态下强度不小于 180MPa，焊接态强度不小于 165 MPa。6061 属 Al-Mg-Si 系铝合金，锻造强化，同时它也是可热处理强化铝合金。熔化焊后由于 6061 焊接后母材热影响区的锻造强化效果消失，热影响区第二相脱溶析出聚集长大产生，而“过时效”使焊接接头强度在 6061 侧热影响区明显下降。这也是熔焊条件下不可避免的现象。因而减小焊接热影响区是采用熔化焊提高焊接接头强度的有效办法[4]。

自动双丝焊在保证良好的焊接成形基础上，明显减小了焊接热影响区，使接头强度稳定的保持在 170MPa 以上，焊接速度提高 2 倍左右，并大大的降低了劳动强度，实现了焊接自动化，此外，不开坡口的工艺还可降低生产成本，简化生产工序。

4 结 论

(1) 采用双丝自动焊接技术焊接 5083、6061 异种铝合金，工艺参数为主机 178～220 A，辅机 186～244 A；焊接速度 70～90 cm/min；60°V 型坡口或不开坡口，留 2 mm 间隙。可获得优良的焊缝正反面成形。

(2) 双丝自动焊接接头焊接热影响区宽度 2～5 mm，成功地提高了焊接接头的抗拉强度。

(3) 进行双丝自动焊焊接 5083 和 6061 异种铝合金薄板，借助 Minitab 计算分析软件对焊接工艺参数的优化，大大提高了试验效果与质量。

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作者简介：徐越兰，女，1952 年出生，教授。主要研究方向为焊接材料智能化设计、新材料的焊接，发表论文 20 余篇。

Email: xuyuelan33@sina.com

ernal irradiation from the hot workpiece within the near infrared area. With the characteristics of the near infrared spectrum and the varied tendency of spectrum respondence of the CCD camera, the clear image was obtained in the band area around 980 nm. The imaging principle of the solid surface of Cr plating layer heated by plasma was analyzed, and then useful information was gotten by image processing on the basis of analyzing the image characteristic of the heated area.

Key words: plasma beam; vision sensor; near infrared band; CCD imaging; image processing

Effects of rare earth element Ce on physical properties and mechanical properties of Sn-Ag-Cu lead free solder XUE Song-bai, LIU Lin, DAI Yong-feng, YAO Li-hua (College of Materials Sciences and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China). p23 - 26

Abstract: Effects of rear earth element Ce on physical properties, wetting properties, tensile strengths and microstructures of Sn-3.5Ag-0.5Cu lead-free solder were studied. Results indicate that its conductibility will be improved and its density will decrease if Ce is added into the lead-free solder. In the range of 0.03wt% to 0.05wt% of Ce, the wettability of the solder is improved, especially when the content of Ce is about 0.03wt%, the grains of the micro structure in lead-free solder are smaller and more homogeneous and the tensile strength of the soldered joints is higher than that of the solder containining other contents of Ce. When the content of Ce is more than 0.1wt%, it is harmful to the properties of the Sn-3.5Ag-0.5Cu solder, the wetting time becomes longer, the values of the tensile strengths of the soldered joints become much lower. All of the results show that the optimal content of Ce in Sn-3.5Ag-0.5Cu solder is about 0.03wt%.

Key words: Ce; lead free solder; physical properties; mechanical properties

Measurement and analysis of the eutectic aluminum alloys of 6082 and ZL101 LIU Ren-pei[1], DONG Zu-jue[2], PAN Yong-ming[2] (1. Nanjing University of Aeronautics & Astronautics, Nanjing 210016, China; 2. Harbin Research Institute of Welding, Harbin 150080, China). p27 - 30

Abstract: The melting point of the eutectic and morphological distribution between the grains had great effects on the susceptibility of weld solidification cracks during solidification. The morphological distributions of aluminum 6082 and ZL101 had been obtained by water quenching method and the melting temperature and heat absorption of the weld metal had been measured with DSC. The results show that the type of eutectic and their morphological distribution are different with different aluminum alloy. Al+Mg_2Si and Al+Mg_2Si+Si+Al+AlFeMnSi are two kinds of eutectics for 6082 alloy which are shaped of thin films between the grains and their melting temperatures are 555℃ and 595℃ respectively. For ZL101 alloy there are two kinds of eutectics, namely Al-Si and Al-Mg_2Si-FeMgSi$_6$Al$_8$Si which are distributed with continuous nets between the grains and their melting temperatures are 544℃ and 577℃ respectively. These results are in favor of studying the cracking behaviors of weld solidification cracks.

Key words: Weld solidification cracks; Aluminum alloys; eutectic

Optimization of twin wire automatic welding process for dissimilar Al-alloy XU Yue-lan, WANG Pin, LIU Yong (1. Nanjing University of Science and Technology, Nanjing 210094, China; 2. SINOPEC Nanjing Chemical Industrial CO., LTD. Nanjing 210094, China; 3. Yangzhou CIMC Tounghua Special Vehicles CO., LTD, Yangzhou 225009, China). p31 - 34

Abstract: With automatic twin wire gas shielded arc welding process dissimmilar aluminium alloy 6061 and 5083 of 5 mm thickness were welded. Influence of the welding process on joint strength and formation were investigated with MINITAB. The results which had been proved by optimizing welding process showed that joint strength can reach and even exceed the standard. The efficiency is twice as high as the manual TIG double side welding.

Key words: aluminium alloy; twin wire gas shielded arc welding; welding process; optimization design

Weld workpiece model design system based on feature LIU Yong[1,2], WANG Ke-hong[1], XU Yue-lan[1], YANG Jing-yu[2], YU Jin[1] (1. Material Science & Engineering Department, Nan Jing University of Science & Technology, Nanjing 210094, China; 2. Computer Science & Technology Department, Nanjing University of Science & Technology, Nanjing 210094, China). p35 - 38

Abstract: To realize information share among CAD, CAPP and CAM, A weld workpiece model design system was developed based on feature. Conception and classification of weld workpiece feature were introduced. The design method of weld workpiece based on feature was discussed and a model of weld workpiece was divided into workpiece part and welded joint part. This workpiece model was built by 3D CAD system, design was realised by redevelopment of the CAD based on feature of welded joint. A weld workpiece model design system framework was introduced, and the design was realised and developed based on feature of groove.

Key words: weld feature; design based on feature; off line programming

Brazing technology of aluminium alloy containing scandium WANG Shao-gang, XIANG Ding-han, ZHENG Yong (College of Materials Science and Technology, Nanjing University of Aeronautics and Astro