激光焊接条件下 20% SiC_w /6061铝基复合材料焊缝特性分析

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摘 要: 在激光焊接条件下, 分析了 20% SiC_w /6061铝基复合材料焊缝表面及内部特性, 指出在激光焊接条件下, 铝基复合材料的焊缝较窄、深宽比大; 焊缝可分为焊缝中心焊接区、熔化区及未变化区三部分; 在中心焊接区内有大量 Al_4C_3 生成, 造成焊缝较脆, 容易断裂。

关键词: 激光焊接; 铝基复合材料; 焊缝

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0 序 言

铝基复合材料作为一种新兴材料, 由于具有高比强度、高比模量、耐高温、抗辐射、尺寸稳定性好等优异的综合性能而受到人们的广泛关注并将逐步取代部分传统的金属材料而广泛应用于航空、航天、汽车制造业等领域, 成为当今金属基复合材料发展与研究的主流。铝基复合材料的焊接是形成结构件必不可少的加工手段。由于该种材料基体与增强相间物理性质(如熔点、电阻率、热膨胀系数等)相差很大, 在高温下基体与增强相之间极容易发生界面反应, 生成脆性化合物, 很难形成优质的焊接接头[1,2]。所以, 研究和控制铝基复合材料的焊缝特性对于该种材料的实际应用具有重要的意义。

1 试验材料及方法

1.1 试验材料

试验材料为购自美国 ACM(Advanceel composite materials)公司的 20% SiC_w /6061铝基复合材料(AMCs, Aluminum matrix composites)。强化相 SiC 为晶须形式, 长度为 7~20 μm, 直径为 0.5 μm, 含量(体积分数)为 20%, 在退火状态下抗拉强度为 220 MPa. 此复合材料晶粒在 500~600 ℃之间, 仍能维持 1~2 μm, 最佳高速超塑性拉伸量达 500%以上, 具有高速超塑性, 其厚度为 0.86 mm的薄板。

1.2 试验方法

将复合材料薄板裁成每片为 115 mm×20 mm 大小的长条状试片进行对接平焊。焊接前用 320号砂纸对试片表面进行研磨, 去除表面的氧化层, 以减低对激光的反射。激光焊接设备为 PRC (PRC laser corporation)公司制造的 3 kW 快速轴流式 CO_2 激光加工机, 使用 127 mm 的聚焦镜片进行试验。在焊接功率为 750W 的条件下以不同的焊接速度对复合材料进行焊接。分别用光镜和 SEM 分析在激光焊接条件下铝基复合材料焊缝表面及内部特性。

2 试验结果及讨论

表 1为焊缝界面形状特征数据。图 1为焊缝断面状况, 可见焊缝狭窄, 焊缝内布满脆性针状铝碳化合物, 由于焊缝内温度较高, 晶须细长, 可能完全反应生成化合物, 故未见到晶须 SiC 存在其中。焊缝并没有大量隆起或气孔的存在, 但是在两侧未变化区内, 可见到一些长条状的孔洞, 这些孔洞是因为快速的温度升降变化, 造成区域部位在短时间内, 承受很大的热胀冷缩应力所造成的。由于复合材料内含有 Al/SiC 两种不同的材料, 各有不同的热膨胀系数, 6061铝合金的热膨胀系数为 SiC 的 9倍, 快速的升温导致两者界面产生应力, 容易由 Al/SiC 界面分离断裂, 或是由基体内的小孔洞成为断裂源而形成此种不规则孔洞。将此激光焊缝放大如图 2所示, 可以清楚地见到中心焊接区内存在着大量的针状铝碳化合物(Al_4C_3)。图 3为反应物 Al_4C_3 的 SEM 照片。

试验中, 取一些调整参数测试的试样, 用力弯折后, 发现焊缝位置因变脆而容易折断, 将焊缝表面经

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表 1　20% SiC_w 铝基复合材料激光焊缝界面形状特征

Table 1　Laser welding line shape characters of 20% SiC_w /6061 AMCs

功率	焊接速度	焊接热输入量	焊缝深度	焊缝宽度		截面积		深宽比比值	
P /W	v /(mm·s^{-1})	E /(J·mm^{-1})	d /mm	b_I /mm	b_{II} /mm	A_I /mm^2	A_{II} /mm^2	d/b_I	d/b_{II}
	16.7	38.9	0.86	0.31	4.8	0.210 7	4.128 0	2.77	0.18
	20	32.5	0.86	0.30	4.5	0.197 8	3.870 0	2.67	0.19
	25	26	0.86	0.29	3.6	0.193 5	3.096 0	2.97	0.24
750	30	21.7	0.86	0.27	3.1	0.206 4	2.666 0	3.19	0.28
	35	18.6	0.86	0.24	2.9	0.172 0	2.494 0	3.58	0.30
	41.1	15.6	0.86	0.23	2.5	0.189 2	2.150 0	3.74	0.34
	50	13	0.86	0.23	2.4	0.189 2	2.064 0	3.74	0.36

注: 表中各参数参照图 4中所示意的范围。

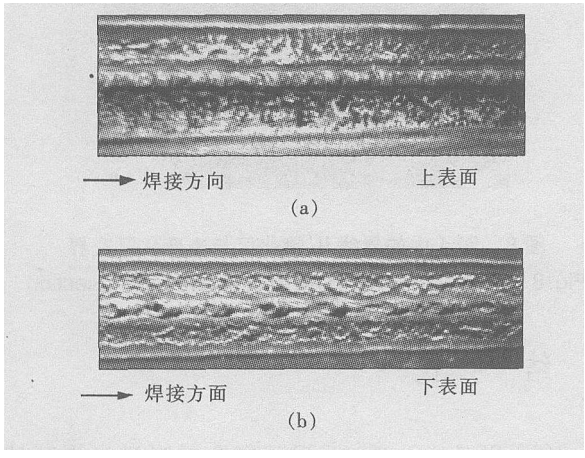

图 1　20% SiC_w /6061铝基复合材料激光焊缝照片 (P=750 W, v=41.1 mm/s)

Fig. 1　Laser weld photograph of 20% SiC_w /6061 AMCs

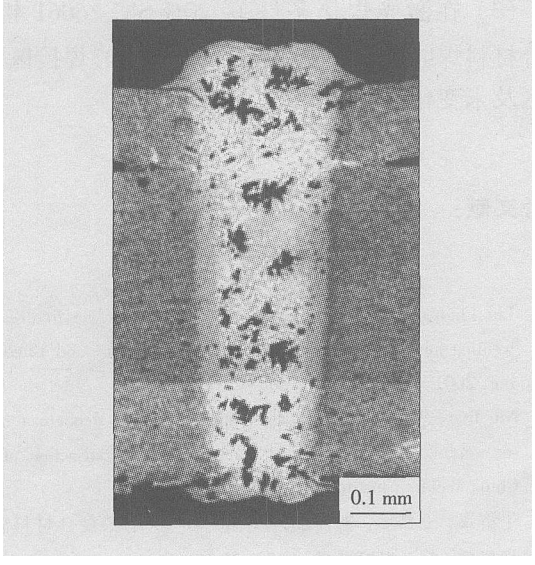

图 2　20% SiC_w /6061铝基复合材料激光焊缝截面放大图

Fig. 2　Laser weld section of 20% SiC_w /6061 AMCs

研磨、抛光、腐蚀后用扫描式电子显微镜观察, 图 4为折断后的激光焊缝上表面及未变化区域的正视

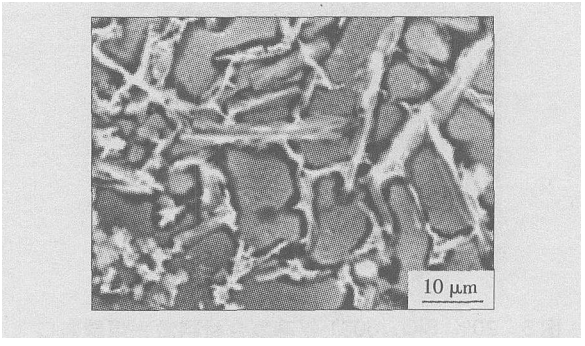

图 3　焊缝中反应的 Al_4C_3 化合物的 SEM照片

Fig. 3　SEM photograph of Al_4C_3 compound

图, 发现 20% SiC_w /6061铝基复合材料的焊缝与一般合金焊缝有所不同, 将其分为几个区域, 最右侧为焊缝中心区域 (C)焊缝中心焊接区, 是由于高温造成 SiC分解反应所造成, 稍微往左边可见到第一排孔洞, 为界线 (I)中心焊接区与熔化区交界, 再往左边移动可见到第二排孔洞区域, 其位置为边界线 (II)熔化区与未变化区交界, 也为熔合线的位置。

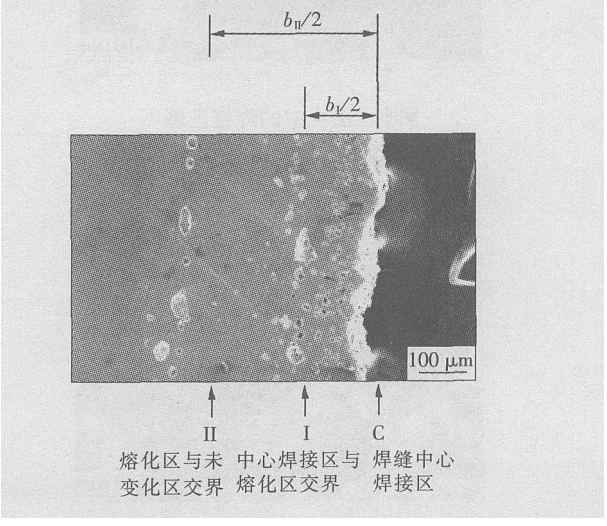

图 4　20% SiC_w /6061铝基复合材料激光焊缝正面 SEM图

Fig. 4　Laser weld obversing SEM of 20% SiC_w /6061 AMCs

图 5为区域 C右侧面, 未经过研磨的折断焊缝断面 SEM照片, 图中可见一裂缝, 断面则布满了针状化合物(Al_4C_3), 未见到 SiC晶须出现。图 6为区域 C焊缝中心焊接区上表面经过研磨、腐蚀后的照片, 可见到参差不齐的针状化合物, 无方向性地互相交叠在一起, 并造成许多的空隙。推测为焊缝容易断裂的原因, 即是因针状化合物为脆性, 且存在许多空隙而造成强度下降。图 7为界线 I中心焊接区与熔化区交界的一个大孔洞内部景象。此孔洞内右侧为中心焊接区的针状化合物, 左侧为熔化区的部分, 可清楚见到 SiC晶须仍然存在, 图中可分辨出两侧不同的微组织外观, 可知此界线为焊缝中心焊接区与熔化区的交界处, 由界限 I至界限 II间的区域即为熔化区, 此区域温度虽然达到铝基材熔点, 但是未达到发生大量反应的高温, 因此虽然铝基材熔化, 却未产生铝碳化合物。图 8为界线 II熔化区与未变化区交界内的一个孔洞景象, 可见到许多 SiC晶须分布其中, 没有化合物出现。因此, 20% SiC_w /6061铝基复合材料的焊缝包含两种区域, 即中心焊接区及熔化区。

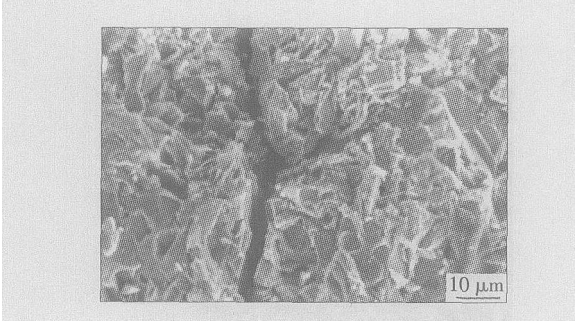

图 5 20% SiC_w /6061铝基复合材料激光焊缝断口 SEM图(图 4的焊缝区域 C断面)

Fig. 5 Fracture SEM of laser weld of 20% SiC_w /6061 AMC_s (SEM)

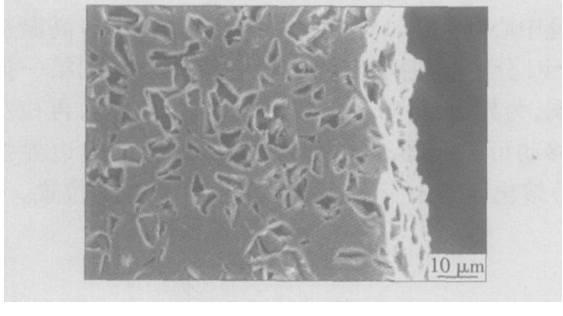

图 6 图 4中的焊缝区域 C

Fig. 6 Weld C of Fig. 4

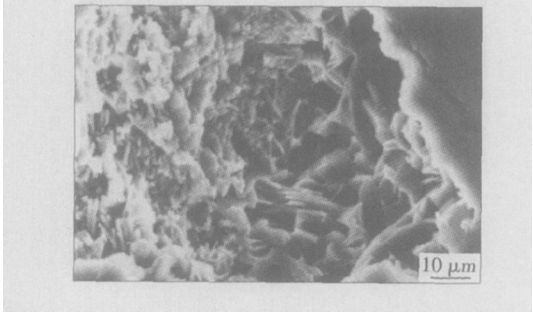

图 7 图 4中的界线 I中心焊接区与熔化区交界

Fig. 7 Boundary of center jointing section and melting section

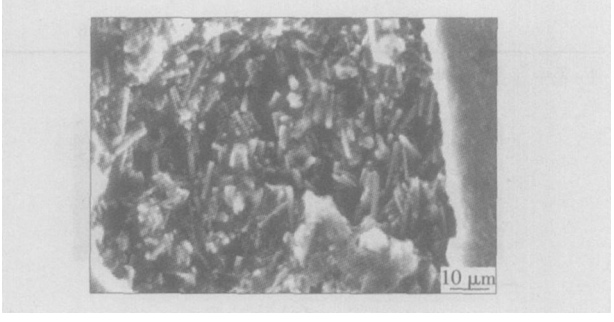

图 8 图 4中的界线 II熔化区与未变化区交界

Fig. 8 Boundary of melting and not changing section

4 结 论

(1) 20% SiC_w /6061铝基复合材料激光焊缝较窄, 深宽比大。

(2) 焊缝处较脆, 容易裂断裂, 是因为焊缝中心焊接区处有大量 Al_4C_3 化合物生成。

(3) 在激光焊接条件下, 20% SiC_w /6061铝基复合材料焊缝可分为三个区域, 焊缝中心焊接区、熔化区及未变化区。

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(Ni, Fe), γ — Ni, WC, W_2C, $Mn_{31}Si_{12}$, $Cr_{23}C_6$, Cr_7C_3, CrNiB, Ni_3B etc. Wear resistance and hard – ness of the surface in creased evidently.

Key words: plasma – arc surfacing; nickel – based composite pow – der; mierostructure; hardness; wear resistance

Corrosion failure process of NiCrBSi coatings deposited by high ve – locity oxyfuel ZHAO Wei – min[1,2], WANG Yong[2], XUE Jin[1], WU Kai – yuan[2] (1. School of Material Science and Engineering, Xi' an Jiaotong University, Xi' an 710049, China; 2. School of Mechanical and Electrical Engineering, University of Petroleum, Dongying 257061, Shandong, China). p41 – 44, 48

Abstract: The NiCrBSi alloy powder was sprayed to a steel sub – strate using high velocity oxyfuel (HVOF) and the corrosion Mlure process of the coating in 3. 5% NaCl aqueous solution was investigated u – sing electrochemical impedance spectroscopy. Preferential corrosion hap pened in the corrosion process of steel coated by HVOF coating. Firsdy, because the defects such as po rosities were ham ful to the uniform itv of electrochemical behav ior and local corrosion occurred in these sDots. And then, the steel substrate was preferentially corroded after the solution pen – etratiag into the interface between the coating and the steel. The corrosion resistance of the coating fell sharply at the early stage, and then increased because corrosion products had blocked some corrosion paths. The CO rro – sion resistance of the steel substrate coated by NiCrBSi coating fell contin – uously after the steel taking part in the electrochemical reaction.

Key words: nickel alloy; metallic coating; electrochemical im – pedance spectroscopy; corrosion; high velocity oxyfuel

Teaching and playback control system for numerical con trolled welding positioner SHI Yu, FAN Ding, WANG Zheng, CHEN Jian – hong (State Key Lab of Advanced New Non – errous Materials, Gan – su Province, Lanzhou University of Technology, Lanzhou 730050, Chi – na). p45 – 48 Abstract: The designed and experimental process of the teaching and playbalk control system of numerical controlled (NC) welding posi – tioner is narrated. Three teaching devices: teaching – box, joy – stick and computer keyboard were fulfilled with industry control com puter and sin – gleehip, and a set of control command system of NC welding positionerwas also designed, including program com mand, track description com – mand and I/O communicating comm and. The teaching and playback process of NC welding po sitioner was executed as follows. Firstly, the co – ordinates of all welding positions obtained by teaching devices mentioned above were recorded in the computer. Secondly, relationship and se –. quenee of each teaching point is described by command system. Finally, computer explmned the command and controlled move ment of NC weldinl positioner. Using such teaching and playback system, the NC welding po – sitioner could be associated with the welding robot or other auto – weldin equipment, therefore, a flexible welding process upon various metallic components could be realized. The experimental results showed a good effect.

Key words: numerically controlled welding positioner; teach ing; playback

Computer – aided optim izing design of discharge circuit for a capaci – tor stored energy spot welding machine WANG Mia, SHENG Jing – zhi, LEI Ming (School of Materials Science and Engineering, Shang – hai Jiaotong University, Shanghai 200030, China). p49 – 52

Abstract: Based on simplifying for resistance – inductance capaci – tance discharge circuit of a capacitor stored energy spot wehting machine, discharge circuit mathematical model was set up and the discharge current curve was simulated by the aid of computer. The influence of indue tance and capacitance on the shape of the discharge current curve, peak value current and time of the discharge was studied systemically in order to guide the design of discharge circuit.

Keywords: capacitor stored energy spot welding; welding current curve; computer – aided design

Finite element simulation of lim it pressure pipeline with cracks using critical crack – tip – opening – angle LI Hong – ke, ZHANG Yan – hua (Beijing University of Aeronau tics and Astronautics, Beijing 100083, China). p53 – 57

Abstract: The lim it pressure of pipeline with cracks is one of the important aspects in structure integrity assessment. We used finite ele – ment method, crack tip opening angle (CTOA) as the parameter to in – vestigate the applicability of critical CTOA in pipeline lim it pressure mod – eling, which containing longitudinal penetrating crack. Here the critical CTOA was used as the critical failure rule of the pipe. Factors affecting numerical results were also studied. Then a predictive model was estab – lished based on these results and compared with other models. From the analy sis we could conclude that critieoula CTOA could be used t0 model ing penetrating crack in pipelines as long as the finite el ement model and element size were properly chosen. When the crack was small, the known formulas would heavily underestimate pipe carrying capacity. But for large cracks, they might give over estimated results and lead to safety problems for pipes.

Key words: gas pipeline; penetratig cracks; critical crack tip open – ing angle; lim it pressure

Characterizstics of welding bead of laser welded 20% SiC / 6061 alu – minum matrix composites HUANG Yong – pan, LI Dao – huo (Anhui Istitute of Optics and Fine Mechanics, Chineses Academy of Sciences, Hefei 230031, China). p58 – 60

Abstract: The exterior and interior characteristics of welding bead of laser welded 20% SiC /6061 aluminum matrix composites were studied. Laser welded the bead of aluminum matrix compos ites was nalTow and the ratio of pentration and width was great. The welding bead could be divided into three parts: the center melt reaction section and melt unreaction sec – tion and heat af feted section. Many Al4C3 platelets were created in the center melt reaction section and made the welding bead brickle and ea sy to be ruptured.

Key words: laser welaing; aluminum matrix composites; weld