氧化铈对低合金钢焊条焊缝硫磷的影响

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摘　要：试验中在 E5515—G型低合金钢焊条药皮中过渡了不同含量的稀土氧化铈，目的是提高焊条性能．采用的试验有焊接接头冲击韧度试验，焊缝金属金相组织试验，X射线荧光光谱试验．结果表明，加入适量的氧化铈能够对焊缝进行脱硫、脱磷，提高熔敷金属的冲击吸收功．氧化铈的加入量不同，脱硫效果不同，且差异较大，而脱磷效果并不十分明显．药皮中加入氧化铈可以细化焊缝组织，但氧化铈的加入量应适当．当氧化铈加入量为 3%时，焊缝的组织最细小．当氧化铈加入量最佳时，焊缝金属硫的减少量可达 58.13%，而磷的减少量为 14.29%．

关键词：氧化铈；低合金钢焊条；焊缝；硫；磷
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0　序　　言

硫会使钢产生热脆现象．作为有害杂质，钢材中的硫含量通常限制在≤0.04%．磷会使钢产生冷脆现象．针对磷使钢脆化，冲击韧度降低，生产中一般把磷控制在 0.12%以下，传统上把磷含量控制在≤0.04%．焊缝金属中的硫、磷主要来自于钢材和焊条药皮，焊缝金属中的杂质硫、磷对焊接接头的性能有较大的影响，在重要的工程结构如奥运鸟巢工程要对其加以限制[1]．由文献[2]可知，焊接熔渣去除焊缝中氧、氮、硫、磷等杂质的能力取决于熔渣碱度的大小，药皮碱度越大，熔渣碱度也越大，焊缝越纯净，裂纹源越少，然而在 1999年熊征等人[3]研究依靠焊条药皮碱度的提高来增加脱硫、脱磷的效果是有限度的．因此人们将目光转向工业上的添加剂——稀土，许多学者研究添加稀土来增加脱硫、脱磷的效果，王爱华等人[4]研究在碱性铁粉焊条药皮中添加适量的稀土氧化铈粉体可有效降低熔敷金属中扩散氢及硫、磷的含量，并能显著提高焊缝金属的低温冲击韧度．Samanta，Nishimoto，Thewlis等人[5－7]研究了稀土铈等在焊接热影响区或钢中能够脱硫、脱磷，净化组织．文中将在低合金钢焊条药皮中加入不同含量的氧化铈，研究的是铈对低合金钢焊条焊缝金属硫及磷的影响．

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1　试验方法

试验用的钢板为 45号钢，板厚 20 mm．焊条型号为 E5515—G型典型低合金钢焊条及另外 4种新型的以 E5515—G焊条药皮为基的 4种稀土焊条（配方 40个，选出其中有代表性的 5种）．4种稀土焊条皆选择通过焊条药皮过渡稀土氧化铈．氧化铈是铈氧化物的总称，其中二氧化铈是最重要的、具有代表性的铈的氧化物．其分子式是 CeO_2，分子量 172.12，密度 7.3 g/cm^3．淡黄色粉末固体（纯品为白色），具有萤石结构，熔点 2 600 ℃．不溶于水，难溶于无机酸．CeO_2 可由三价的草酸盐、碳酸盐、硝酸盐的氢氧化物在空气中灼烧得到．主要用于玻璃脱色，澄清剂，高级抛光粉材料，还用于陶瓷、电子、化工、催化等．目前市场上将氧化铈分为普通级 99%，99.9%；高纯级 99.99%，99.999%；纳米级晶核粒度＜50 nm．该试验选择的是普通级，产品牌号为 CeO_2－5，也是普通级氧化铈中价格最便宜的一种，氧化铈具有良好的增塑性．通过计算、分析、试验并合理调整，E5515—G及 4种稀土焊条药皮的优选配方如表 1所示．

将表 1组分的药粉材料混合均匀后用钠水玻璃做粘结剂，在活塞式油压机上将其压涂在直径为 4 mm的 H08A焊芯上做成低合金钢焊条．按着国家标准 GB2649—89要求截取焊接接头冲击样坯，按着国家标准 GB2650—89金属夏比（V形缺口）冲击试验方法，进行冲击试验，试验设备为摆式冲击试验

表 1　焊条药皮配方（质量分数，%）

Table 1　Electrode coating ingredients

配方	大理石	萤石	钛铁	低硅	中锰	云母	纯碱	氧化铈
E5515—G	46.3	24.9	10.7	7.0	5.9	4.3	1.0	0
1	46.3	24.9	10.7	7.0	5.9	4.3	1.0	1.5
2	46.3	24.9	10.7	7.0	5.9	4.3	1.0	1.8
3	46.3	24.9	10.7	7.0	5.9	4.3	1.0	3.0
4	46.3	24.9	10.7	7.0	5.9	4.3	1.0	3.8

机．利用 SJB—1型金相显微镜来研究焊缝金属组织．在拉伸试棒上取样，用 Venus200波长色散 X射线荧光光谱仪对焊缝进行硫磷含量分析．为了简化焊接工艺，降低生产成本，采用焊前不进行预热，焊后不进行缓冷的工艺措施．

2　试验结果及分析

2.1　对焊缝及热影响区组织的影响

图 1～图 5为 5种配方焊缝金属金相组织形貌．

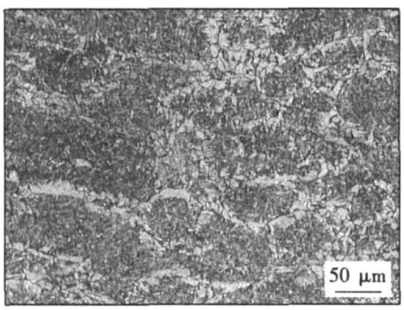

图 1　E5515—G 焊缝金属组织形貌

Fig. 1　Metallographic microstructure and morphology of E5515-G weld metal

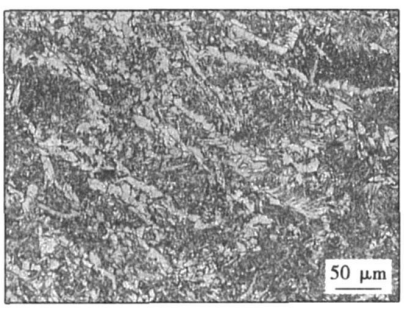

图 2　1 号焊缝金属组织形貌

Fig. 2　Metallographic microstructure and morphology of No. 1 weld metal

如图 1所示，冷却到室温时，E5515—G熔敷金属形成粗大的过热的铁素体与珠光体组织．在生产中一般可通过细化晶粒的正火、退火等方法加以消除，程度严重的可采用二次正火方法加以消除，增加了生产成本；当加入 1.5% CeO_2 时，与图 1比较组织细化（图 2）；当加入 1.8% CeO_2 时，与加入 1.5% CeO_2 组织相比较细化不明显（图 3）．如图 4所示，药皮中含 3% CeO_2 的焊条的焊缝金属组织相对细小．但是当继续加大 CeO_2 的加入量时（图 5），先共析铁素体沿柱状晶分布，晶内为针状铁素体与珠光体，组织较粗大．图 1～图 5说明，并不是加入 CeO_2 量越多越好，CeO_2 加入量适当时，能够细化焊缝的

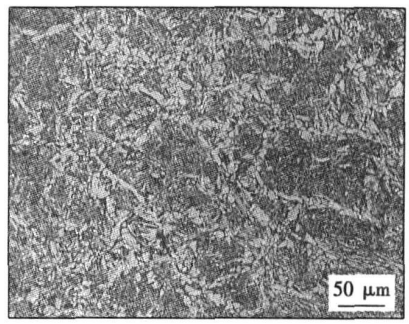

图 3　2 号焊缝金属组织形貌

Fig. 3　Metallographic microstructure and morphology of No. 2 weld metal

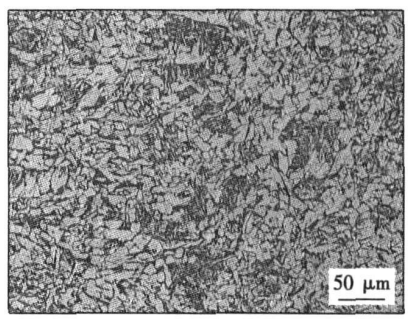

图 4　3 号焊缝金属组织形貌

Fig. 4　Metallographic microstructure and morphology of No. 3 weld metal

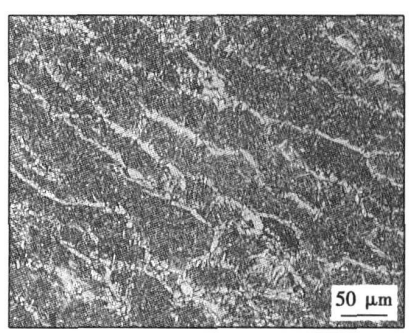

图 5　4 号焊缝金属组织形貌

Fig. 5　Metallographic microstructure and morphology of No. 4 weld metal

组织.

进行冲击试验,发现 4号焊缝的冲击吸收功最低,3号的最高,这与表 2[8]的试验结果是一致的.说明稀土铈适量时能够净化焊缝,使焊缝在常温时冲击韧度明显提高.

表 2 冲击试验结果

Table 2 Results of impact toughness test

配方	稀土含量(质量分数,%)	冲击吸收功 $A_{KV(0℃)}$/J	断后伸长率 A_{13}(%)
E5515—G	0	151	19
1	1.5	120	14
2	1.8	147	16
3	3.0	191	22
4	3.8	108	19

2.2 对焊缝金属硫磷的影响

用 Venus200波长色散 X射线荧光光谱仪对焊缝进行光谱分析,激发条件为 50 kV/4 mA,铬靶.其分析结果如表 3所示.

表 3 焊缝金属中硫和磷的含量(质量分数,%)

Table 3 Content of P and S in weld metal

配方	S	与 E5515—G配方相比S的减少量	P	与 E5515—G配方相比P的减少量
E5515-G	0.020 3	—	0.035 0	—
1	0.019 9	1.97	0.031 0	11.43
2	0.017 3	14.78	0.035 0	0
3	0.008 5	58.13	0.030 0	14.29
4	0.020 2	0.49	0.032 5	7.14

加入稀土后焊缝中硫下降幅度为 0.49% ~ 58.13%,下降幅度较大;磷下降幅度为 0 ~ 14.29%,下降幅度较小.这说明铈能够脱硫、脱磷,而且在一定范围内脱硫效果优于脱磷效果.当加入 3.8%的铈时,脱硫、脱磷效果不明显,这说明,铈的加入量应适当,尤其是加入 3.0%的氧化铈时脱硫效果良好,可以使焊缝金属硫的质量分数减少到 0.008 5%,与 E5515—G配方相比硫的下降幅度达 58.13%.加入 3.0%的氧化铈时,硫磷含量都较低,因此熔敷金属的吸收功最大,这与表 2的冲击试验结果也是相吻合的.

3 结 论

(1)药皮中加入氧化铈,能降低焊缝金属中硫磷的含量,提高熔敷金属的冲击吸收功.但氧化铈的加入量并不是越多越好,氧化铈的加入量应适当.

(2)氧化铈的加入量不同,脱硫效果不同,且差异较大,而脱磷效果不十分明显.当氧化铈加入量为 3%时,焊缝金属硫的减少量可达 58.13%,磷的减少量可达 14.29%.

(3)药皮中加入氧化铈可以细化焊缝组织,但并不是越多越好,当氧化铈加入量为 3%时,焊缝的组织最细小.

(4)氧化铈加入量适当时,能使金相组织的细化、硫磷含量减少,因而使冲击吸收功提高.

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Microstructures and properties of SiC_W/2024Al MMCs joint by capacitor discharge welding XU Feng[1], ZHAI Qiuya[2], XU Jinfeng[2] (1. School of Material Science and Engineering, Shaanxi University of Technology, Hanzhong 723003, China; 2. School of Material Science and Engineering, Xi'an University of Technology, Xi'an 710048, China). p. 57—60

Abstract: The capacitor discharge spot welding on SiC_W/2024Al alloy matrix composite sheet with 0.2 mm thickness was study. The microstructures and properties of the joint were analyzed, and the temperature field and cooling rate of nugget were calculated. The results show that the joint microstructure consists of nugget zone, heat-affected zone and semi-melt zone. The cooling rate of the joint reaches to 5.25×10^6 K/s. The microstructure of the nugget is obviously refined and the SiC-Al interfacial reaction is not found in the middle of the joint because of high cooling rate. The width of semi-melt zone is 10 to 15 μm, which divides the nugget zone and base metal. The microstructure of heat-affected zone is not obviously coarse and keeps conformation with base metal. To obtain the high quality spot weld joint, the welding parameters are a welding voltage of 80 V, a capacitor of 3 300 μF and a electrode pressure of 18 N.

Key words: composite material; SiC whisker reinforced Al alloy matrix composites; capacitor discharge welding; microstructures and properties of joint

Robust joint tracking with structured-light vision sensing GONG Yefei, DAI Xianzhong, LI Xinde, ZHANG Jie (Key Laboratory of Measurement and Control of Complex Systems of Engineering, Ministry of Education, Southeast University, Nanjing 210096, China). p. 61—64

Abstract: The performance of joint feature extraction is degraded greatly during welding because of severe disturbances, so a prediction-matching-estimation combined close-looped iterated method is proposed for weld feature tracking. The position and shape of the joint stripe profile in the image is predicted at first, then the joint is recognized by a model-based profile matching method, and lastly the weld trajectory is filtered and estimated based on the confidence of the extracted feature. Experiments show that the method promotes the joint recognition results to ensure a robust and real-time weld seam tracking, even in the face of gross error or failure occurrence in joint feature extraction.

Key words: joint tracking; structured-light vision; prediction; filtering

High-temperature oxidation behavior of cerium on the surface of Sn-Zn lead-free solders WANG Hui, LIU Xincai, PAN Jing, MA Yongcun (Faculty of Materials Science and Chemical Engineering, Ningbo University, Ningbo 315211, China). p. 65—69

Abstract: The distribution and existing form of Ce on the surface of Sn-9Zn-0.15Ce and Sn-9Zn-0.002Al-0.2Ga-0.25Ag-0.15Ce solder are investigated by atomic emission spectrometry and X-ray photoelectron spectroscopy. Results indicate that Ce enriches on the surface of the Sn-9Zn-0.15Ce solder in the range of 0 to 40 nm. The concentration of Ce in the enriched zone is about 3.0 at%, which is 2.50 times of that in the bulk solder, and the enriched Ce on the surface is mostly oxidized as CeO_2 and Ce_2O_3. With the multi-addition of Ga and Al in the Sn-9Zn-0.002Al-0.2Ga-0.25Ag-0.15Ce solder, Ga enriches in range of 0 to 6 nm on the surface, while Al enriches in range of 2 to 20 nm in oxidized form. The Ce-enriched layer is in the range of 2 to 60 nm on the surface covered by the Ga and Al enriched layers, and the oxidation of Ce is depressed significantly.

Key words: Sn-Zn; lead-free solder; Ce; oxidation; surface enrichment

Influence of ceria on phosphorus and sulphur of low alloy steel weld FAN Xiying, GUO Yonghuan (College of Mechanical and Electrical Engineering, Xuzhou Normal University, Xuzhou 221116, China). p. 70—72

Abstract: The coating of E5515-G, a low alloy steel electrode, was added in different amount of ceria (CeO_2) for enhancing electrode properties which was studied by means of impact toughness, metallographic examination and X-ray fluorescence spectrometry test. The results show that the proper addiction of CeO_2 is beneficial to the desulfurization and dephosphorization of the weld and improves the impact absorbed energy of deposited metal. Different addition amount of CeO_2 can lead to various desulfurization efficiency which makes a great difference, whereas the dephosphorization efficiency is unconspicuous. The microstructures of the weld can be effectively made fine by adding CeO_2 into electrode coating, but the addition amount of CeO_2 should be proper. The microstructure of the weld is the finest when the addition amount of CeO_2 is 3%. When the amount of CeO_2 is optimal, the S content in weld metal will decrease by 58.128 1%, while the P content 14.285 7%.

Key words: ceria; low alloy steel electrode; weld; sulphur; phosphorus

Numerical simulation on keyhole thermal effect of vacuum electron beam welding of magnesium alloy LUO Yi[1,2], LIU Jinhe[1], YE Hong[2] (1. School of Material Science and Engineering, Northwestern Polytechnical University, Xi'an 710072, China; 2. School of Material Science and Engineering, Chongqing Institute of Technology, Chongqing 400050, China). p. 73—76

Abstract: The keyhole thermal effect of vacuum electron beam welding for magnesium alloy was analyzed. In view of the thermal effect of high-temperature metal vapor and the deep-penetration effect of keyhole during welding, a composite heat source model applying to magnesium alloy, which was made up of Gaussian surface source and cone body source, was developed. By the different valuation to the power coefficients of Gaussian surface source and cone body source, the various focus states of electron beam were simulated to get the welding temperature fields. And then, the simulation results were favorable for the shape calculation to keyholes and welds. The experimental results show that the simulation results have good consistency with the experiment welds.

Key words: magnesium alloy; vacuum electron beam welding; composite heat source model; keyhole thermal effect; weld shape

Damage of two-spot welds under two level loading WANG Ruijie[1], SHANG Deguang[2], LIU Hongbin[1] (1. Faculty