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爬行式气电立焊机器人的弧长控制

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摘 要: 气电立焊是一种重要的垂直位置焊接方法, 其焊接质量受焊接电弧长度的影响较大, 必须对其弧长进行控制。以爬行式气电立焊机器人为基础, 研究其焊接过程中弧长变化, 建立了焊接小车和滑块为基础的二级联动弧长控制系统; 利用滑块的动态响应能力强、精度高的特点实现弧长的快速、高精度控制; 利用对小车的控制实现滑块的自动归中, 增大系统的调节能力。结果表明, 系统具有较强的抗干扰能力、动态响应能力和自调节能力。

关键词: 气电立焊; 弧长控制; 机器人
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0 序 言

爬行式焊接机器人具有结构小巧、负重能力强、运动控制灵活和响应速度快的特点, 对于大型结构件如舰船、油罐的自动化焊接具有广泛的应用前景[1]。作者以爬行式气电立焊机器人为基础, 对其弧长控制进行研究, 建立气电立焊机器人的控制系统, 并对系统性能进行了分析。

1 爬行式气电立焊机器人介绍

图 1 为实验室所研究的爬行式气电立焊机器人, 它由焊接小车、焊接控制系统及其焊接设备构成, 能够吸附在大型构件的表面并沿着焊缝实现自动化焊接作业。

图 1 立焊机器人
Fig. 1 Crawl type electrogas arc welding robot

2 气电立焊弧长检测与控制

焊接过程中, 焊缝坡口大小、间隙宽窄、熔池溢流等都会造成弧长的变化, 从而使焊接电流、电弧电压的大小发生改变, 影响焊接质量。在焊条电弧焊中, 可以通过人工观察的方式来调节弧长。在气电立焊中, 要保证焊接质量, 就有必要对弧长进行控制。

对于外特性为缓降特性的电源来说, 焊接弧长 h 和焊接电流 I 之间的关系在很大范围内可作为线性系统来处理, 其关系[2] 为

$$h = (a_1 + b_1 v_f) I + a_2 + b_2 v_f \tag{1}$$

式中: a_1, a_2, b_1, b_2 为常数; v_f 为送丝速度。

对于缓降特性的电源, 采用等速送丝, 有

$$\Delta h = K \Delta I \tag{2}$$

其中 K 为比例系数。因此可通过霍尔元件对电流变化进行检测[3,4] 得到弧长变化, 通过控制系统实现其焊接过程中的稳定, 从而保证焊接质量。

3 气电立焊机器人弧长控制原理

焊接机器人的弧长控制系统由沿着小车运动方向的纵向滑块和焊接小车构成。当机器人沿着焊缝移动并焊接时, 纵向滑块可在小车运动的方向上滑动; 当焊接弧长变化时, 会引起焊接电流变化; 通过控制纵向滑块的位移和小车的车速对弧长进行控制, 实现对焊接质量的保证。图 2 所示的机器人在

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*参加此项工作的还有潘际銮

钢板上爬行,纵向滑块在小车上相对于某个点上下移动, 该点为滑块移动的中心(图 2 中小车上的 A 点),以滑块中心(图 2 中的 B 点)相对这个点的距离为滑块的位移,小车和滑块始终在一个方向上运动,焊枪固定在滑块上,焊枪嘴与熔池液面的距离就是要控制的弧长 h,即

$$h = y_2 + s - y_1 + C = \int_0^t v_2 \mathrm{d}t + s - \int_0^t v_1 \mathrm{d}t + C \quad (3)$$

式中: v_1 为熔池上升的速度; y_1 为熔池的位移; v_2 为小车的速度; y_2 为小车的位移; s 为滑块相对于小车的位移; C 为一常数,它为焊枪嘴到滑块中心的位移焊接前,通过机器人的初始化使滑块中心与小车中心重合,这样就使滑块的位移为 0。焊枪通电后开始起弧焊接, 这时电弧不稳定。经过一段时间后, 电弧稳定,熔池上升,此时将传感器测得的焊接电流作为基准电流,以后检测到的电流将与之比较,将电流的偏差作为控制信号。自动焊接由此时开始, 为 0 时刻,如图 3 所示;之前, 由手动完成;之后, 焊接由手动转为自动。

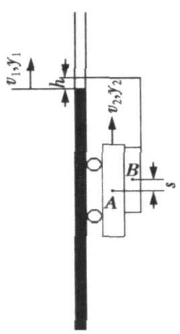
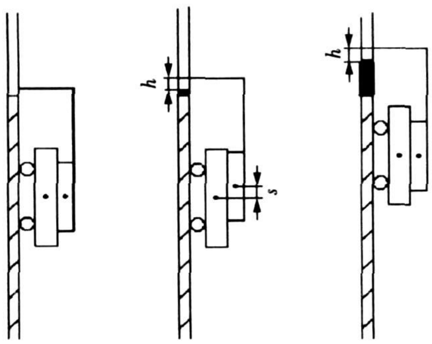


图 2　弧长控制原理

Fig. 2　Principle of arc length control



(a) 焊接前　(b) 起弧至稳定焊接过渡　(c) 稳定焊接

图 3　焊接起弧阶段(h 为弧长, s 为滑块相对小车位移)

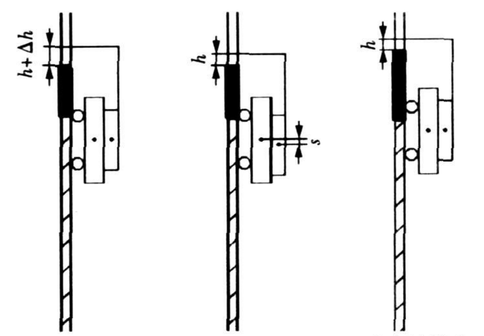
Fig. 3　Arc starting

在 0 时刻, 滑块和小车的速度都为 0。当继续焊接时,熔池上升,势必会使电弧长度减小,这时检测到焊接电流增大,利用电流增加量,控制滑块向上移动, 以保证弧长的稳定。滑块向上移动的同时,会与小车产生一个位移偏差, 如果小车不动,滑块将会到达极限位置,最终不再能调节弧长,因此小车也要跟着向上移动,结果就会使滑块向小车中心移动。经过一段时间的调整, 滑块的中心位置回到小车中心,而小车获得一个速度,这个速度与熔池上升速度基本一致,到达稳定焊接过程。

通过以上的分析可知,焊接控制的并不是具体的弧长大小, 而是控制弧长与指定值的偏差在一定范围内,也就是控制在一定范围内,即

$$\Delta h = \Delta y_2 + \Delta s - \Delta y_1 = \int_0^t \Delta v_2 \mathrm{d}t + \Delta s - \int_0^t v_1 \mathrm{d}t \quad (4)$$

当熔池上升速度突然变慢时,比如坡口截面变大时,熔化金属要填充的体积就会增加,所以熔池上升的速度会减小, 这时就会使弧长比设定的弧长大,检测到焊接电流变小, 通过控制系统使滑块迅速向下移动,保证弧长的稳定。滑块向下移动的同时,会与小车有一个位移偏移, 根据这个偏移, 使小车减速,滑块相对于小车向中心移动, 最后滑块归中, 而小车减小到与新的焊接速度一致, 适应新的焊接速度,反之依然,如图 4 所示。



(a) 弧长变化设定　(b) 滑块迅速调节保证h　(c) 小车速度变化使滑块归中

图 4　弧长变化(Δh 为弧长变化, h, s 同图 3)

Fig. 4　Variation of arc length

4　气电立焊机器人弧长控制仿真

根据如上的分析建立气电立焊弧长控制系统(图 5),其弧长控制结果见图 6。图 5 主要包括如下几个组成部分。

(1) 滑块模块(slider control)包括滑块的传递函数和 PID(proportional plus integral plus derivative)模块,

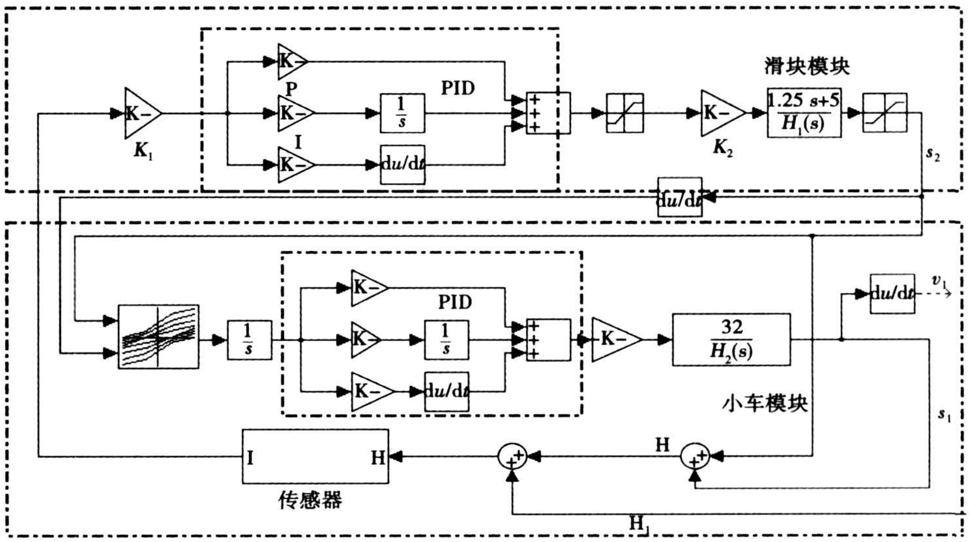


图 5　气电立焊弧长控制图

Fig. 5　Chart of electrogas arc control

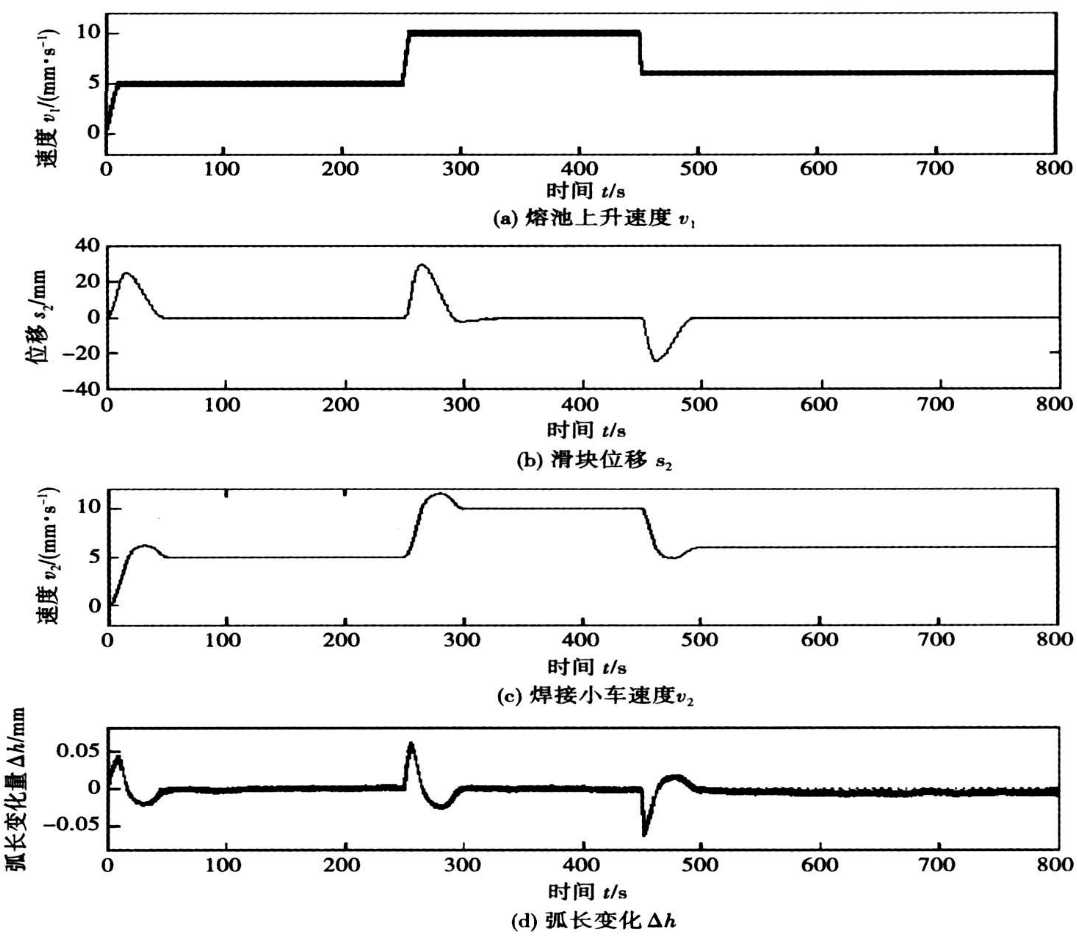


图 6　弧长控制结果

Fig. 6　Results of arc control

其输入信号是经霍尔电流传感器检测到的信号，输入信号经过 PID 调节，然后控制滑块电机，调节滑块的位移 s_2。

（2）小车模块（vehicle control）包含小的传递函

数和小车的控制模块,根据滑块的位移和速度采用模糊查表的方法[5]输出小车的速度控制信号。

(3) 弧长检测模块(sensor)把随弧长变化的电流信号通过霍尔传感器转化为电压信号,用来控制滑块。

控制系统利用滑块动态响应速度块、控制精度高的特点来实现弧长快速而精确的调整,利用对小车控制来使得滑块回中,从而保证一个较大的动态范围。

如图 6a 所示,在 0 ~ 10 s之间,熔池上升速度从 0 增加到 5 mm/s;在 250 ~255 s增加到10 mm/s,在 450 ~452 s 之间降到 6 mm/s。图 6b 为滑块位移变化,图 6c 为小车速度变化,图 6d 为焊接弧长变化。可以看出,当熔池上升速度发生变化时,滑块首先运动,以适应变化的熔池上升速度。滑块偏离中心的位移和速度驱动小车的速度产生变化,使得滑块回到中点。当小车速度达到了熔池上升速度(焊接速度)时,滑块回归零位。在整个过程中,焊接弧长始终保存恒定,其误差达到了之内。

5 结 论

(1) 系统具有较好的响应速度和控制精度。系统用滑块来保证弧长控制的响应速度和精度,因为滑块的动态响应能力强,控制精度高,能够保证很好的弧长控制效果。

(2) 系统具有较大的响应范围。当滑块偏离中心位置时,小车速度发生变化,使得滑块回中,从而保持一个较大的动态范围。

(3) 系统容易实现。由于小车的惯性大,运行条件差,可控性差,系统利用滑块控制性能的优点,降低了对小车的控制要求,使得系统容易实现。

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reliability in a CCGA device GAO Lili, XUE Songbai, ZHANG Liang, SHENG Zhong (College of Materials Science and Technology, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China). p93—96

Abstract: ANSYS software was employed to establish three-dimensional strip model of CCGA624 device and optimized simulation of soldered column dimension was also studied. Results indicate that the most dangerous soldered column locates in the furthest distance from the device center; and the strain concentration occurs in and around the interface between the eutectic solder and the Sn3.5Ag solder column where will be the foremost location for cracking. Optimization of soldered column dimensions show that the value of strain increase with the increase of column pitch; with increase of soldered column height the strain curves present parabolic-shaped and can acquire the minimum equivalent strain in the height of 2.07 mm; with the increase of soldered column diameter, the value of strain increases and the curve shows a clear monotone trend. In practical applications, proper soldered column dimension can be choosed based on the principle of smaller strain.

Key words: ceramic column grid array; Anand equation; reliability; optimized simulation

Structure and performance of plasma-sprayed TiC/NiCrMo coatings prepared by different types of spraying gun SUN Shibin, ZOU Zengda, LIU Xuemei, SHI Hanchao (School of Materials Science and Engineering of Shandong University, Jinan 250061, China). p97—100

Abstract: TiC/NiCrMo coatings were prepared on the substrate of Q235 steel (low carbon steel) by using two types of SG-100 plasma spraying gun labeled by Subsonic and Mach I. Morphology and phase composition of coatings were characterized by X-ray diffraction (XRD), scanning electron microscope (SEM) utilising back scattered imaging mode (BSE) and electron probe micro-analysis (EPMA). Wear tests were performed by using a ring-on-block tester under dry sliding condition. Results show that the coating prepared by Mach I gun banded well to the substrate and no delamination appears, while detachment between coating and substrate could be observed in the coating prepared by Subsonic gun. Meanwhile, large pores can be observed in the Subsonic gun-produced coatings. The Mach I gun-produced coating shows superior wear resistance to that of the Subsonic gun-produced coating. Partial oxidation of TiC and reaction between TiC and Mo occurred in both coatings.

Key words: plasma spraying; TiC/NiCrMo; subsonic; mach I

The mechanism of strengthening and toughening of crack-free Fe-based alloy with high hardness for laser cladding LI Sheng[1], ZENG Xiaoyan[2], HU Qianwu[2] (1. Department of Mechanics and Electronics, Dongguan University of Technology, Dongguan 523808, China; 2. Division of Laser, Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology, Wuhan 430074, China). p101—104

Abstract: Crack-free laser-cladding layers with high hardness were obtained by using self-made Fe-based alloy powders for laser cladding without preheating and tempering. This paper revealed the mechanism of strengthening and toughening of the developed Fe-based alloy. The mixed martensite with medium carbon content contributes high hardness and high strength, as well as somewhat toughness; the retained austenite, which is distributed along grain boundaries, contributes excellent plasticity and toughness. The retained austenite can absorb and reduce the stress of the layers, and decrease the cracking susceptibility while it will not obviously decrease the hardness and strength of the cladding layers.

Key words: laser cladding; Fe-based alloy; mechanism of strengthening and toughening

Arc length control study for crawl-type electrogas arc welding robot ZHENG Jun, LIU Zhengwen, CHEN Lianglei, CHENG Bai, PAN Jiluan (Key Laboratory for Advanced Materials Processing Technology, Ministry of Education, Tsinghua University, Beijing 100084, China). p105—108

Abstract: Electrogas arc welding (EGW) is an important method for vertical position welding; the quality of welding product is highly depended on its welding arc length stabiliy, so there is a necessity of arc length control for EGW. Based on crawl type arc-welding robot, this article studies the variation of the arc length during the welding, and brings up a two-level linkage arc length control system composed by a slider and the welling vehicle. The advantage of the slider in dynamic response gives the system a good performance of fast and high precision arc length control. By controlling the vehicle travel speed, the slider always stays in its neutral position, which makes the system maintains the ability of widest range adjustment. This system has an wide-range adjustment, high dynamic response and high precision as well.

Key words: electrogas arc welding; arc length control; robot

Finite element calculation and regression analysis on stress concentration factors of undermatching butt joints ZHAO Zhili, YANG Jianguo, LIU Xuesong, FANG Hongyuan, WU Fangbin (State Key Laboratory of Advanced Welding Production Technology, Harbin Institute of Technology, Harbin 150001). p109—112

Abstract: To enhance the static and fatigue strength of undermatching butt joint of high strength steel under transverse loading, the influences of geometric parameters such as excess of weld metal, radius of curvature at weld toe, plate thickness and total width of cover pass in butt-welded joint on stress concentration factors at weld toe and weld root were studied by finite element method. Based on these simulation results, the empirical equations of stress concentration factors at weld toe and weld root were obtained by regression analysis, which offers a significant guide for joint design of undermatching butt joint of high strength steel.

Key words: joint geometry; stress concentration factors; weld toe and weld root; undermatch; butt-welded joint design