双丝间接电弧焊的电弧形态

曹梅青， 邹增大， 杜宝帅， 曲仕尧
（山东大学 材料科学与工程学院，济南 250061）

曹梅青

摘 要：用高速摄像系统及示波器对双丝间接电弧气体保护焊的电弧形态进行了研究。结果表明，双丝间接电弧气体保护焊在两丝端部形成电弧，其电弧本质仍然是气体放电的一种表现形式。焊接电流、电弧电压及两焊丝交点与工件间距离对电弧形态产生较大的影响，随焊接电流的变化，电弧形态会发生不同程度的集中与分散的变化；电压越大电弧越明亮电弧的形体也越大；两丝交点与工件间距离越小，电弧越集中并且变得短而亮。燃烧过程中电弧电压随时间而周期性变化，相应的电弧形态也随着时间发生周期性变化，电弧电压与电弧形态间有很好的对应关系。

关键词：双丝间接电弧焊；电弧形态；焊接电流；电弧电压
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0 序 言

电弧是一种强烈的气体放电现象。电弧焊接时，通过电弧过程把电能转换为热能，用以熔化焊丝（焊条）或母材，以实现金属的连接[1]。双丝间接电弧气体保护焊工件不接电源，电弧在两焊丝端部形成间接电弧，工件上不存在活性斑点区、熔敷系数高、节约电能、熔合比可大幅度降低。研究双丝间接电弧焊电弧形态及其影响因素对了解双丝间接电弧物理性能、焊接工艺及工程应用具有重要意义。目前对双丝间接电弧气体保护焊电弧形态的研究还未见报道。文中用高速摄像系统对双丝间接电弧焊的电弧形态进行了观察，并用示波器同步记录了电流、电压波形，研究分析了不同条件下的电弧形态及其影响因素。

1 试 验

1.1 试验材料

试验用焊丝为直径 Φ1.2 mm 的 H08Mn2SiA，用氩气作为保护气体，为了便于观察，采用空中燃烧和平板堆焊方法研究双丝间接电弧气体保弧焊的电弧形态。平板堆焊试验用母材为 Q235 钢，尺寸为 200 mm×100 mm×3 mm。焊接前用砂轮将试板表面打磨干净，防止铁锈、油污影响焊接质量。

1.2 试验设备和方法

试验用焊机为 NBC－350 型逆变式 CO_2 气体保护焊焊接电源，具有微升的外特性。所用电弧电压 U＝29～33 V。送丝机为两台额定电压 DC24 V、额定电流 5 A 的 AS 系列送丝机，负极采用原单丝焊时的等速送丝反馈电路来控制其送丝，正极采用专门设计的送丝机构来控制送丝[2]。用 Aglilent54624 示波器测试双丝间接电弧气体保护焊时的电弧电压和焊接电流波形及均方根数值。电弧形态测试采用 FASTCAMSuper－10KC 型高速摄像设备，该设备由主机、CCD 摄像头、摄像镜头、电源、氙灯背光源、监视器和计算机等部分组成，拍摄时摄像镜头前安装合适的滤光片，摄像镜头正对电弧且与两焊丝所在平面垂直，如图1所示。该高速摄像系统还可用于拍

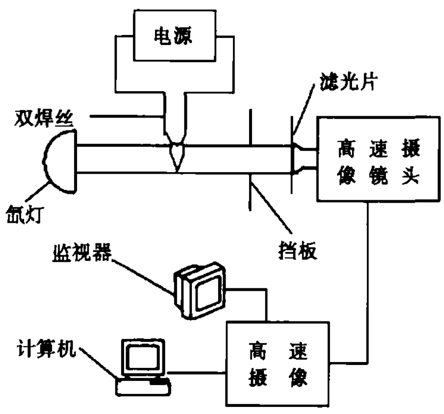

图 1 氙灯背光高速摄像系统示意图
Fig. 1 Xenon lamp optics and high-speed camera system

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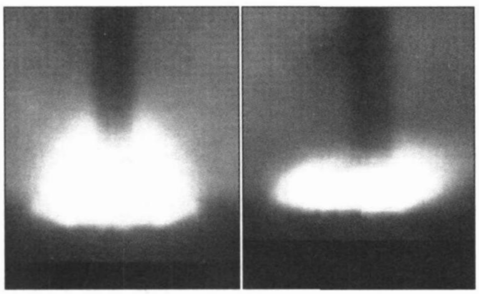
摄熔滴过渡，拍摄熔滴过渡时可将氙灯的亮度调亮一些，以去除弧光的干扰[3]。文中使用 1 000 帧/s 的拍摄速度拍摄电弧图像。每次拍摄时间约 2.1 s。拍摄的电弧图像传送到计算机并存储在硬盘中，通过看图软件对电弧图像进行观察和分析。

2 试验结果和讨论

2.1 双丝间接电弧焊的电弧形态

传统焊接电弧在电极和工件之间燃烧，图 2 为工件接电源单丝焊时的电弧。由于工件的尺寸相对于焊丝直径而言较大，电弧一般呈“钟罩形”如图 2a 所示。当弧长很短时，电弧被压扁，呈“柱状”如图 2b所示。



(a) 距工件较近　　(b) 距工件较远

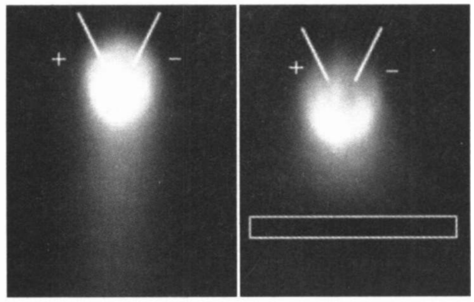
图 2　单丝焊电弧形态

Fig. 2　Arc shape of single wire welding

双丝间接电弧气体保护焊工件不接电源，电弧可在两焊丝端部任意空间位置引燃并燃烧。双丝间接电弧的本质仍是气体放电的一种表现形式，也是阴极电子发射、气体中中性粒子电离及正、负粒子定向运动与复合的综合物理现象。双丝间接电弧焊的电弧有不同的形态，当离工件较远时其电弧形态如图 3a 所示，此时电弧可自由伸展，其外观形态看起来类似气焊时的火焰，烁亮的区域为弧芯，温度很高，电弧尾部呈暗黄色，温度较低；随焊接电流、电弧电压及电弧与被焊工件间距离的变化，电弧与弧芯的外形及明亮度发生变化。当电弧离工件较近时，电弧受到压缩如图 3b 所示，此时电弧受到工件阻碍而变粗，以上所拍摄的为两焊丝横向排列时的电弧。

2.2 焊接电流对电弧形态的影响

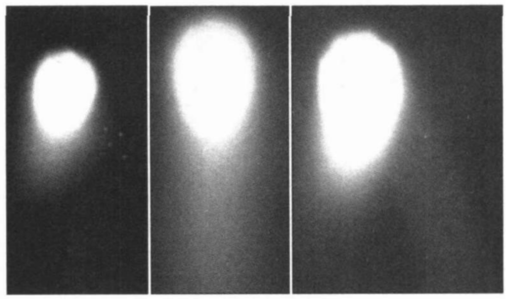
焊接电流是影响电弧形态的最重要因素，焊接电流不同，电弧的形态也会发生较大改变。图 4 为电弧电压 33 V，不同焊接电流时的电弧形态。



(a) 距工件较近　　(b) 距工件较远

图 3　双丝焊电弧形态

Fig. 3　Arc shape of twin-wire welding



(a) $I = 160$ A　　(b) $I = 210$ A　　(c) $I = 240$ A

图 4　不同焊接电流时的电弧形态

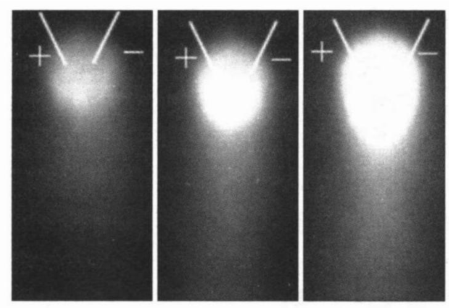
Fig. 4　Arc shape of different welding current

当焊接电流较小时，如图 4a 所示，由于阴、阳极斑点的游动特性，并且电弧能量较低，电弧并不垂直向下，而是侧向正极一边，在负极一边有少量的液态液滴散落下来，电弧粗短且不稳定；随着电流增加，电弧较集中，挺度较好，图 4b 所示。这主要是由于随着焊接电流的增大，电弧周围磁场强度增加，且等离子流增强而使电弧受到压缩，挺度提高；而当电流过大时电弧的分散程度加大，如图 4c 所示，此时电弧外观看起来变成一明一暗，似乎是两个电弧。这主要是由于随着焊接电流的增大两焊丝间的电磁力增大，离子流受到更大的推力，阴极焰及阳极焰变长，呈现交错的现象，形成分散的离子流动路径。双丝间接电弧气体保护焊电弧形态在不同的条件下集中与分散程度不同，但电弧仍然是在两焊丝之间产生的单一电弧。

2.3 电弧电压对电弧形态的影响

电弧电压主要影响电弧的亮度和大小，图 5 为焊接电流为 210 A，不同电弧电压时的电弧形态。

双丝间接电弧气体保护焊电弧可以在双丝端部任意空间引燃和燃烧。电弧电压由阴极电压、阳极电压及弧柱压降组成，电弧电压的不同主要表现为弧柱的大小不同；并且当电弧电压升高时，电弧的总能量提高，可以电离的粒子数量增多，并且粒子的活



（a）$U=29$ A　（b）$U=31$ A　（c）$U=33$ A

图 5　不同电弧电压时的电弧形态

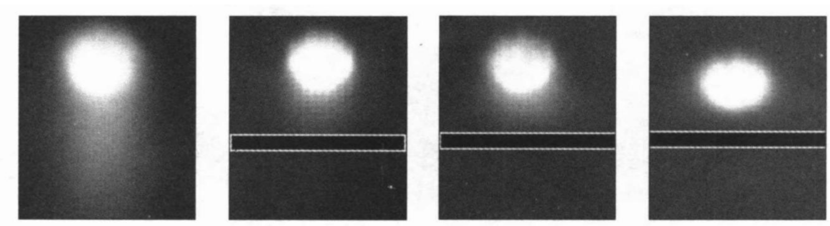
Fig. 5　Arc shape of different arc voltage

动加剧, 故当电弧电压由 29 V 变到 33 V 时, 其电弧越来越明亮, 电弧也逐渐增大。

2. 4　两焊丝交点与工件间距离对电弧形态的影响

两焊丝交点与工件间距离不同电弧形态也有一定的变化, 图 6 为初始设定电弧电压 31 V, 焊接电流 210 A, 不同距离时的电弧形态。

由图 6 可以看出, 当双丝间接电弧气体保护焊在空中或者离工件较远距离燃烧时, 电弧能自由扩展(图 6a), 由于散热空间较大散热较多, 温度较低, 电弧末端呈暗黄色; 当两焊丝交点与工件间距离较近时, 由于工件的存在, 电弧不能向下方自由伸展, 而



（a）$h=100$ mm　（b）$h=30$ mm　（c）$h=20$ mm　（d）$h=15$ mm

图 6　两焊丝交点与工件间距离不同时的电弧形态

Fig. 6　Arc shape of different distance between two wires and the workpiece

是向四周扩展, 电弧长度变短。电弧尾部变小(图 6b 和图 6c); 当电弧离工件很近时, 由于工件的存在对电弧有机械压缩作用, 电弧变得更短, 并且电弧向周围空间的散热相对减少, 电弧的温度更趋于均匀, 电弧整体颜色更加一致, 也更加明亮(图 6d)。并且当电流电压的初始设定值不变时, 随着电弧与工件间距离的增大, 焊接电流增大, 说明电弧电阻比工件电阻要小, 由于电流的增大电弧的形态也会发生一些变化。

2. 5　电弧形态的变化

在焊接电流、电弧电压及焊丝交点与工件间距离等参数一定的条件下, 焊接过程中电弧形态并非一成不变。图 7 是电弧电压为 33. 35 V, 焊接电流为 200. 56 A, 空中燃烧时, 电弧形态随时间的变化。图中相邻两帧图片的时间间隔为 1 ms。

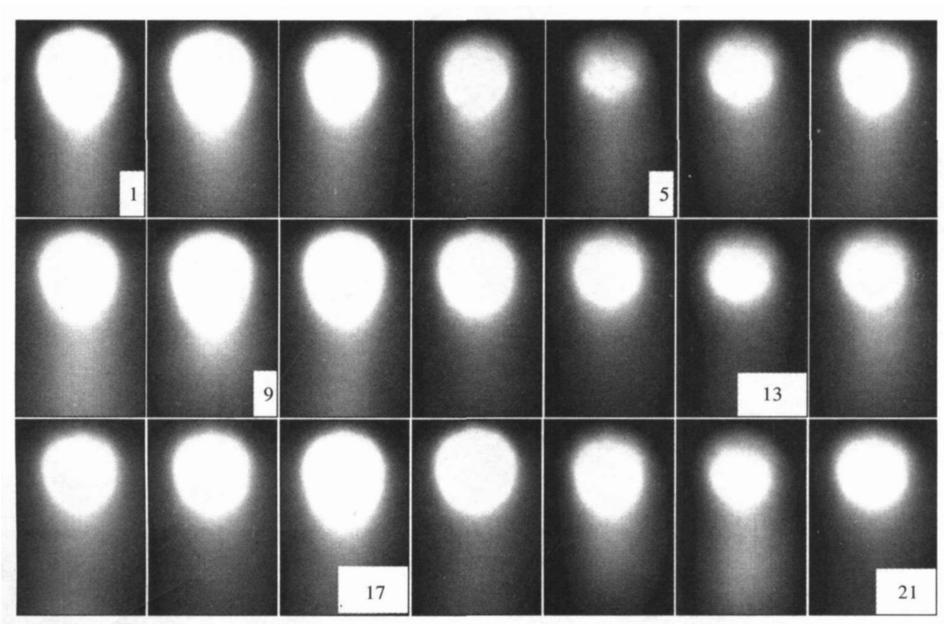


图 7　双丝间接电弧焊电弧形态的变化

Fig. 7　Arc shape change of twin-wire indirect arc welding

由图7可见,第1~5帧电弧由大变小并且由亮变暗;第6~9帧电弧由小变大且由暗变亮,到第9帧电弧又变为开始的明亮状态;从第10帧开始电弧又逐渐变暗变小,到第13帧以后又开始回复到明亮的状态,从第17帧又开始新的循环过程。当焊接电流较小时电弧的变化周期变得较长。可见,焊接参数不同,电弧形态变化的周期长短有所不同,但其变化趋势是一致的,都是由大到小,由明到暗,然后再由小到大,由暗到明这样周期性变化的。电弧形体大时对应的亮度也较亮,电弧小时亮度较暗。

双丝间接电弧气体保护焊电弧形态的周期性变化也可以从其电压波形图上反映出来,电弧形态的变化与电弧电压的变化有很好的对应关系,如图8所示。图8中电压的变化情况与电弧形态的变化周期是一致的。电压波形中较低的部分对应又暗又小的电弧,稍高的部分对应又亮又大的电弧。并且可以看出影响电弧亮度及大小的主要因素是电弧电压,焊接电流的波动尽管比电弧电压大,但其对电弧大小及亮度的影响不如电弧电压明显。

电弧出现由明亮到暗小这种周期性变化的影响因素很复杂。在双丝间接电弧气体保护焊中由于熔滴的形成、长大和向下运动过程的周期性变化,使极性斑点间距及弧柱电阻发生周期性变化,从而使电弧电压发生周期性变化,电压的周期性变化对应的电弧形态也发生周期性变化。

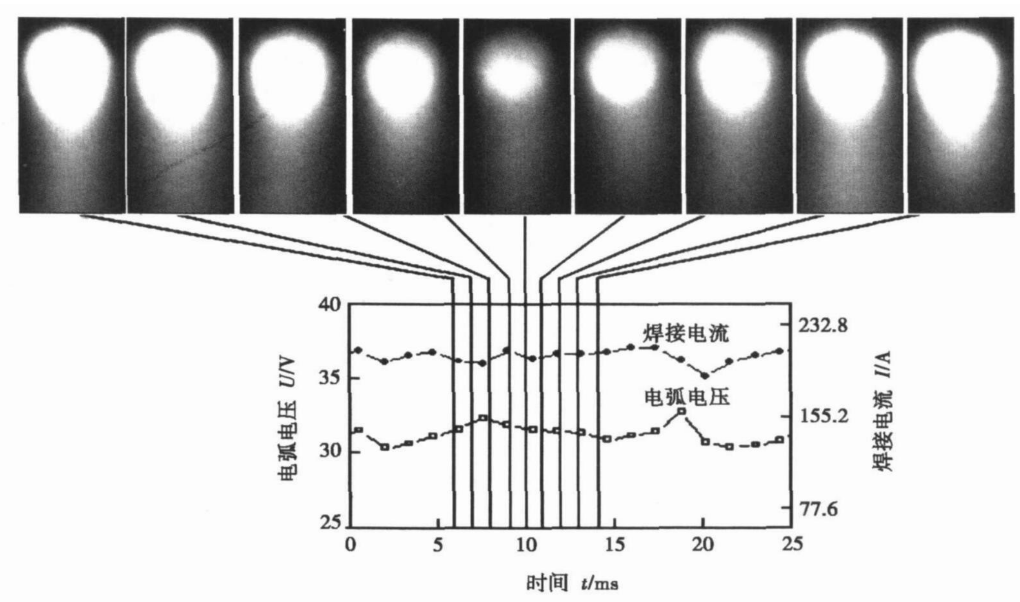


图8 电弧形态与电弧电压及焊接电流的对应关系

Fig. 8 Corresponding relation between arc shape with arc voltage and welding current

3 结 论

(1) 双丝间接电弧气体保护焊的电弧本质仍是气体放电的一种表现形式,正常条件下的电弧形态类似气焊时的火焰。

(2) 随着焊接电流的变化,电弧形态会发生不同程度的集中与分散的变化。

(3) 随着电弧电压的增加,电弧越来越明亮,电弧的形态也逐渐增大。

(4) 随着两焊丝交点与工件间距离不同,电弧也会呈现不同的形态,距离越小电弧越集中并且变得短而亮。

(5) 双丝间接电弧气体保护焊的电弧电压随时间做周期性变化,其电弧形态也相应的发生周期性变化,电弧形态与电弧电压之间有很好的对应关系。

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作者简介:曹梅青,女,1977年5月出生,博士研究生。主要从事新材料及连接技术的研究工作,发表论文10篇。

Email: cmq@mail.sdu.edu.cn

structed with stationary valves and the other used proportional relief valves. The effect of system oil temperature on axial pressure was analyzed in emphases. The results show that the static and dynamic characteristics of axial pressure with the proportional valve system are better than those with the switch valve system; the axial pressure of the proportional valve control system is independent on oil temperature. In long period welding production, the control precision of axial pressure with the proportional valve control system is higher, and the repeatability is better than that of switch valve control system.

Key words: friction welding; proportional valve; computer control

Image processing of seam tracking system with laser vision

ZHAO Xiang-bin[1], LI Liang-yu[2], XIA Chang-liang[1], FU Ling-jian[2] (1. Tianjin University, Tianjin 300072, China; 2. Tianjin Polytechinc University, Tianjin 300160, China). p42—44, 48

Abstract: The method of real time image processing in the laser vision sensing seam tracking system was studied. In the course of pretreatment, the contrast of image was intensified by the image intensify treatment; the noise in the image was removed by medium filtering treatment ; and the aim image was obtained from the back ground image by the binariantion treatment. Then in the image post-treatment, for the key technology in laser stripe extraction and character point detection, some feasible method was proposed. The single and consecutive laser stripe was obtained by the method of inside stalk transformation. The convenient and reliable characteristic points were detected by analyzing slop. The method proved that the character point can be detected exactly and rapidly, and the demand of real time seam tracking system can be meeted by this method.

Key words: vision; seam tracking; image processing; character point detection

An new discretization algorithm for intelligent modeling in welding

LI Wen-hang, CHEN Shan-ben, LIN Tao, DU Quan-ying (Institute of Welding Engineering, Shanghai Jiaotong University, Shanghai 200030, China). p45—48

Abstract: Discretization method is usually important in intelligent modeling or controling for welding process. The evaluation criterion for discretiztion methods in welding field were discussed. Based on the selected evaluation criterion, common discretization methods were compared, where a welding data set was obtain in pulsed GTAW experiment as modeling data and rough set modeling method was used to obtained a model that can predict backside width of melten pool. It showed that discretization method based entropy performes better. Based on the entropy algorithm, a modified discretization algorithm was put forward, and the last result showed that this method was better and suited for the welding field.

Key words: discretization; welding process; rough set; intelligent modeling

Electric arc shape of twin-wire indirect arc welding

CAO Mei-qing, ZOU Zeng-da, DU Bao-shuai, QU Shi-yao (Shandong University, Jinan 250061, China). p49—52

Abstract: With high speed camcorder system and digital oscillogragh, the electic arc shape of twin-wire indirect arc welding was investigated. Results show that the arc was burning between the two wires in twin-wire indirect arc welding, and the arc was still a type of gas discharge in nature. Welding current, arc voltage and the distance between the two wires and the workpiece have great influence on the arc shape. With the welding current changing, the arc shape presents different degree of concentration and scatter. The arc becomes brighter and bigger with the increase of arc volgage. When the distance between the two wires and the workpiece reduced, the arc concentrated and became shorter and brighter. Arc voltage changes periodically, and its corresponding electric arc shape changes also periodically, and it has well corresponding relationship between arc voltage and electric arc shape.

Key words: twin-wire indirect arc welding; arc shape; welding current; arc voltage

Microstructure of dissimilar metal joint with magnesium alloy AZ31B and steel 304 for laser-tungsten inert gas lap welding

ZHAO Xu, SONG Gang, LIU Li-ming (State Key Laboratory of Materials Modification, Dalian University of Technology, Dalian 116024, Liaoning, China). p53—56

Abstract: The lap welding of magnesium alloy AZ31B and steel 304 dissimilar joint by laser-tungsten inert gas (TIG) welding was investigated, and the microstructure was analyzed by SEM, EPMA etc. The results showed that Mg and Fe can be joined effectively due to the new phase forming in transition zone of the joint. It also found the new phases were different because the extent to oxidation was different. One was " bamboo" MgO phase, another was consecutive $Mg_xFe_yO_z$ phase. During the latter phase forming, the phenomenon of Mg diffusion can be found.

Key words: Mg/Fe dissimilar materials; laser hybrid welding; microstructure

Quality monitoring of resistance spot welding based on image processing of welding spot surface

ZHANG Peng-xian, CHEN Jian-hong, DU Wen-jiang (Key Laboratory of Non-ferrous Metal Alloys, The Ministry of Education, Lanzhou University of Technology, Lanzhou 730050, China). p57—60, 64

Abstract: A new method was explored to monitoring joint quality based on information processing in digital image of welding spot surface in resistance spot welding. At first, through analyzing the image character, 4 characteristic zones related to welding processing were mined from the image of welding spot surface. And then, their areas were measured to be taken as characteristic parameters for evaluating spot welded joint quality. Secondly, through the correlation analysis between 4 characteristic zones areas and tensile-shear strength of spot welded joint, 3 characteristic parameters were selected as input vectors from them, and tensile-shear strength of the joint was target vectors. On the basis, Radical Basic Function neural network model was set up to estimate the weld quality. At last, the results of simulation and test show that it is feazible that spot-welded joint quality can be monitored based on image information of welding