斜特性式脉冲 CO_2 焊电源自适应控制方法

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摘　要：在脉冲 CO_2 焊设备采用恒流控制电流波形时，其外特性也就变为恒流特性，这样就需要在恒流闭环控制 CO_2 焊脉冲电流波形的基础上采用相应措施，来保证 CO_2 焊电源具有足够的电弧电压自动调节性能．从电弧能量控制的角度，研究了通过控制 CO_2 焊燃弧过程峰值电流时间的途径来闭环自动调节脉冲 CO_2 焊电弧电压的斜特性式控制方法；提出了以脉冲式 CO_2 焊逆变电源外特性斜率为判据的控制算法，使脉冲 CO_2 焊电源输出外特性斜率可调．结果表明，斜特性脉冲 CO_2 焊电源能在焊接过程中自适应调节电弧电压，并可通过改变电源外特性斜率来定量调节电源对弧长的自动调节强度．

关键词：脉冲 CO_2 焊；电弧电压；自适应调节；逆变电源
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0　序　　言

逆变式 CO_2 焊电源的工作频率高达 20 kHz，控制周期仅为 50 μs，具有非常优良的动态响应特性，以 0.1 ms 的响应速度控制 CO_2 焊燃弧过程及短路过程的电流波形，从而大幅度提高了设备的焊接性能[1－3]．美国林肯公司 STT 型 CO_2 焊逆变电源的 CO_2 焊燃弧阶段电流峰值与基值被精确控制在设定值，实现了理想的电流波形控制，使每个熔滴的能量得到定量控制，焊接过程稳定，性能优良，因而在打底焊等场合得到好评[4]．

研究表明，要进行 CO_2 焊逆变电流波形控制就必须采用恒流式控制方式，所提出的双恒流式 CO_2 焊逆变电源模式就是通过对电流峰值与基值均进行恒流闭环控制而实现 CO_2 焊电流波形控制的[5]．众所周知，在等速送丝式 CO_2 焊设备中，传统是采用平特性 CO_2 焊整流电源来解决电弧电压自动调节问题．否则电弧就不能稳定，则焊接过程也无法稳定．然而在脉冲 CO_2 焊设备采用恒流控制时，其外特性也就变为恒流特性，这样就需要在恒流闭环控制 CO_2 焊脉冲电流波形的基础上采用相应措施来保证 CO_2 焊电源具有足够的电弧电压自动调节性能．文中从电弧能量控制的角度研究了通过控制 CO_2 焊燃弧过程峰值电流时间的途径来闭环控制 CO_2 焊电弧电压，并进一步提出了以脉冲式 CO_2 焊逆变电源外特性斜率为判据，以峰值电流时间为控制量的斜特性式脉冲 CO_2 焊电源电弧电压自动控制算法．

1　斜特性式脉冲 CO_2 焊电弧电压自动控制算法

以脉冲 CO_2 焊峰值电流时间 t_p 为控制量对电弧电压平均值 U_h 进行负反馈控制时有图 1 所示的 $t_p(U_h)$ 特性曲线．即在电弧电压的工作范围内，当电弧电压变化量为 $\triangle U_h$ 时控制系统反向产生峰值电流时间调整量为 $\triangle t_p$，即 $\triangle t_p=-K_t\triangle U_h$，其中 K_t 为曲线斜率．

脉冲 CO_2 焊燃弧过程峰值电流时间调节量 $\triangle t_p$ 产生的 CO_2 焊平均电流的变化量为

$$\triangle I_h = I_p\frac{\triangle t_p}{t_0} = \frac{I_p}{t_0}(K_t\triangle U_h) \qquad (1)$$

式中：t_0 为 CO_2 焊熔滴过渡平均时间（一般 $t_0\approx$ 10 ms）．峰值电流时间调节率 K_t 与脉冲 CO_2 焊电源外特性斜率 K 的关系为

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$$K=\frac{\triangle I_{\mathrm{h}}}{\triangle U_{\mathrm{h}}}=\frac{I_{\mathrm{p}}\dfrac{\triangle t_{\mathrm{p}}}{t_0}}{\triangle U_{\mathrm{h}}}=\frac{\dfrac{\triangle I_{\mathrm{p}}}{t_0}(K_{\mathrm{t}}\triangle U_{\mathrm{h}})}{\triangle U_{\mathrm{h}}} \qquad (2)$$

得 $K=\frac{I_{\mathrm{p}}}{t_0}\cdot K_1$ 为脉冲 CO_2 焊电源外特性斜率，或 $\triangle I_{\mathrm{h}}=K\cdot\triangle U_{\mathrm{h}}=\frac{I_{\mathrm{p}}}{t_0}\cdot K_1\cdot\triangle U_{\mathrm{h}}$ 为斜特性式电弧电压自动控制算法.

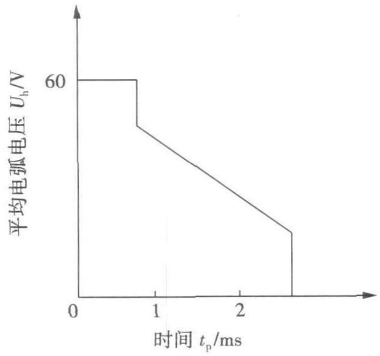

图 1　脉冲峰值电流时间调节关系曲线

Fig. 1　Curve of adjusting peak current time

设 $I_{\mathrm{p}}=400$ A, $t_0=10$ ms, $K_{\mathrm{t}}=0.1$ ms/V, 有 $K=4.0$ A/V, 即脉冲电源的外特性斜率为4 A/V, 其相应的脉冲 CO_2 焊外特性曲线如图 2 所示.

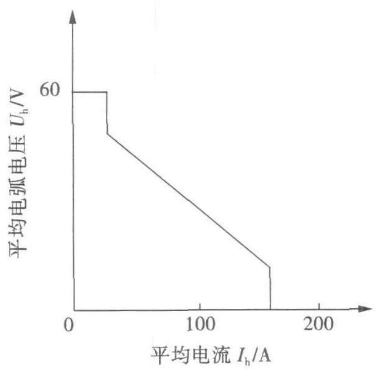

图 2　斜特性式电弧电压自动调节产生的脉冲 CO_2 焊外特性曲线

Fig. 2　Sloping output curve of arc voltage feedback control in pulsed CO_2 welder

2　斜特性式脉冲 CO_2 焊电源电弧电压自动调节原理

鉴于采用电弧电压反馈控制峰值电流时间 t_{p} 的控制模型解决了电源输出外特性斜率可调的问题，则斜降特性在焊接过程中当弧长波动使电弧电压变化时就能产生相当于平特性 CO_2 焊接电源的电弧电压自动调节过程, 如图 3 所示.

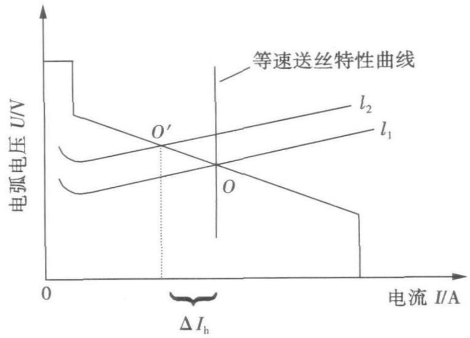

图 3　斜特性式脉冲 CO_2 焊电源电弧电压自动调节示意图

Fig. 3　Automatic arc voltage control of CO_2 welder with sloping output curve

图 3 中, 当弧长从 l_1 增加到 l_2 时, 相应的电弧伏安特性曲线与斜降式电源外特性曲线 1 的交点就从 O 点交至 O'点, 则 CO_2 焊电弧电流减少 $\triangle I_{\mathrm{h}}$ 值, 使焊丝熔化速度小于等速送丝速度, 致使焊丝末端向熔池接近, 直至弧长恢复至 l_1. 显然, 增加峰值电流时间调节率 K_{t} 就能相应增加脉冲 CO_2 焊电源外特性斜率, 从而增强电源的电弧电压自动调节作用.

3　斜特性式脉冲 CO_2 焊电源控制系统

微机控制系统如图 4 所示. 系统由单片机系统实时处理传感电路输入的焊接电流与电压信号, 根据输入电路设定值确定向恒流控制电路的输出信号值. 在燃弧阶段, 单片机根据斜特性控制算法确定 t_{p}, 在 t_{p} 时段向恒流控制电路发出峰值电流控制信号,使逆变电源产生脉冲峰值电流, 在 t_{p} 时段结束时, 单片机向恒流控制电路发出基值电流控制信号, 使逆变电路产生基值电流; 当 CO_2 焊发生熔滴短路过渡时, 单片机向恒流控制电路发出短路电流波形控制信号, 使 CO_2 焊电源输入预设的短路电流波形. 上述控制过程见图 5. 由于单片机可根据设定值调节脉冲电源外特性斜率及短路电流波形, 系统可实现柔性可调的智能控制.

4　试验结果

图 6 为实测的斜特性式脉冲 CO_2 焊电弧电压与焊接电流波形.

具体试验条件为: 电流峰值设定值 400 A, 电流基值设定值 50 A, 外特性斜率为 4 A/V. 由图 6 可见, 焊接过程稳定, 实际电流峰值和基值均与设定值一致.

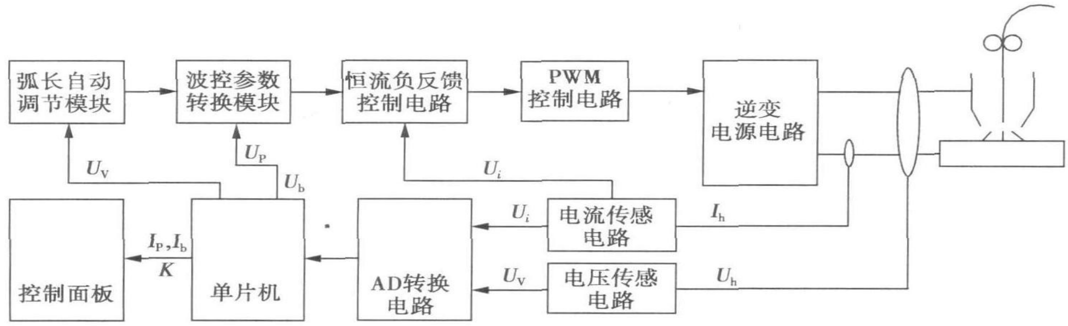

图 4　斜特性式脉冲 CO_2 焊逆变电源控制系统原理图

Fig. 4　Control system of pulsed CO_2 welder with sloping output curve

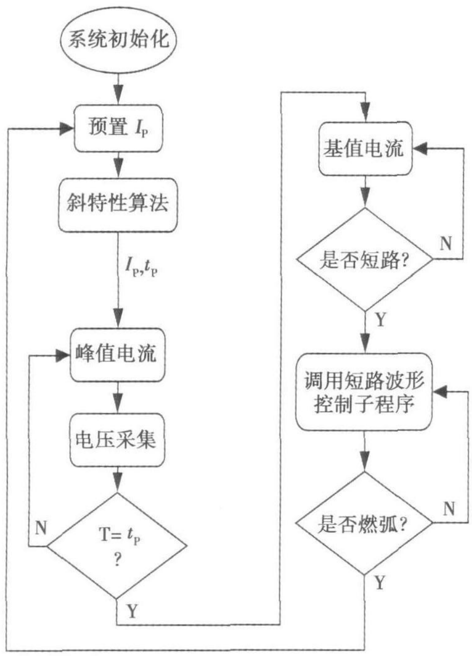

图 5　斜特性式脉冲 CO_2 焊微机控制流程图

Fig. 5　Microcomputer control flowchart of pulsed CO_2 welder with sloping output curve

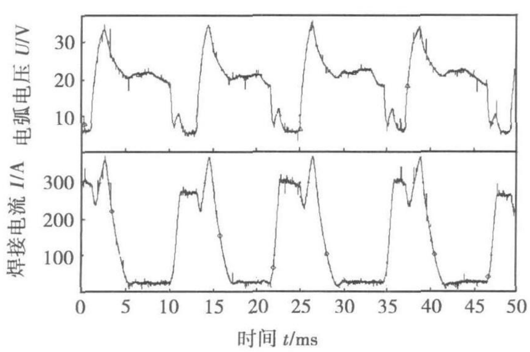

图 6　斜特性式脉冲 CO_2 焊电弧电压与电流波形

Fig. 6　Arc voltage and current waveforms of pulsed CO_2 welder with sloping output curve

5　结　　论

（1）斜特性式脉冲 CO_2 焊电弧电压自动调节方法可以既保持脉冲 CO_2 焊电流峰值与基值的恒流特性，又使脉冲 CO_2 焊电源输出外特性斜率可调，又实现等效的斜输出特性。

（2）斜特性脉冲 CO_2 焊电源能自适应调节电弧电压，其自动调节原理是：斜降特性电源在焊接过程中当弧长波动使电弧电压变化时就能产生相当于平特性 CO_2 焊接电源的电弧电压自动调节过程。

（3）提出了以外特性斜率为判据的控制算法，使脉冲 CO_2 焊电源输出外特性斜率可调。在精确控制电流波形的同时，保证电源具有足够的电弧电压自动调节强度。

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MAIN TOPICS, ABSTRACTS & KEY WORDS

Self-adaptive control method of the pulsed CO_2 welding inverter

JIANG Lipei[1], ZOU Yong[1,2], YU Jianrong[1] (1. Opto-Mechatronic Equipment Technology Beijing Area Major Laboratory, Beijing Institute of Petro-chemical Technology, Beijing 102617, China; 2. School of Automation Science and Electrical Engineering, Beijing University of Aeronautics and Astronautics, Beijing 100083, China). p1—3

Abstract: The pulsed CO_2 welder, which controls its pulse current wave by the constant current control method, is need to solve an important problem of automatical regulating the pulsed CO_2 welding arc voltage, since without the constant arc voltage output curve it will lose the ability of self-adjusting arc length. In this paper, a new method is proposed for self-adaptive control of the pulsed CO_2 welding arc voltage. Its operating principle is through arc voltage feedback control of the peak current time to make the pulsed CO_2 welder yield sloping output characteristics so as to realize the self-adaptive adjusting of its arc voltage. By taking the slope rate as the criterion of its algorithm, this control method can determine the slope rate of welder output curve and adjust the self-adaptive control intensity in quantity.

Key words: pulsed CO_2 welding; arc voltage; self-adaptive control; inverter

Sensing and control on the keyhole condition during controlled pulse key-holing plasma arc welding

JIA Chuanbao[1], WU Chuansong[1], ZHANG Yuming[2] (1. Institute for Materials Joining, Shandong University, Jinan 250061, China; 2. Center for Manufacturing, University of Kentucky, Lexington KY 40506, USA). p4—8

Abstract: According to the strategy of controlled pulse keyholing, a new sensing and control system is developed for monitoring and controlling the keyhole condition during plasma arc welding (PAW). Through sensing and processing the efflux plasma voltage signals acquired during the welding processes with different levels of welding current, the quantitative relationship of the welding current, efflux plasma voltage and backside weld width of the weld is established. PAW experiments show that the efflux plasma voltage can reflect the state of keyhole and backside weld width accurately. Based on this, welding experiments under closed-loop control are conducted on ordinary plate and workpiece with varied thermal conditions, which have validated the stability and reliability of the developed keyhole PAW system.

Key words: controlled pulse key-holing; efflux plasma voltage; keyhole; plasma arc welding

Full-load range zero-voltage zero-current soft-switching inverter arc welding power supply

ZHU Zhiming, ZHAO Gang, CHEN Jie, WANG Linhua (Key Laboratory for Advanced Materials Processing Technology, Ministry of Education, Tsinghua University, Beijing 100084, China). p9—12

Abstract: Depending on the research and classification of typical full-bridge soft-switching power converters, a full-load range zero-voltage zero-current soft-switching full-bridge power converter topology with auxiliary resonant network was put forward, designed and analyzed. By using dead time adaptive regulated phase-shift-control method, which makes the dead time conjugate with the resonance processes affected by the circuit energy, the full-load range zero-voltage turn-on and proximate zero-voltage soft turn-off with effective results are realized for the power devices of converter' s lead leg. At the same time, aimed at the problem of soft turn-on and soft turn-off being difficult to be compatible in the full-load range for the power devices of converter' s lag leg, a realizing method of soft-switching is proposed, which makes the zero-voltage and zero-current technology combined together. Through the cooperative function of various auxiliary measures, the full-load range zero-voltage turn-on, and soft turn-off combined zero-voltage with zero-current are realized for the power devices of converter' s lag leg.

Key words: zero-voltage zero-current soft-switching; auxiliary resonant network; dead time; full-load range; inverter arc welding power supply

Special welding machine and welding process for all position automatic pipeline welding

CHEN Shujun[1], LU Zhenyang[1], REN Fushen[1,2], LIANG Junzhi[3], YAN Zheng[3], CHEN Jiang[3] (1. School of Mechanical Engineering and Applied Electronics Technology, Beijing University of Technology, Beijing 100022, China; 2. School of Mechanical Science and Engineering, Daqing Petroleum Institute, Daqing 163318, China; 3. Pipeline Research Institute of CNPC, Langfang 065000, China). p13—16

Abstract: A special arc energy regulator is developed to realize the all postion automatic root welding of pipeline welding. This generator adopting the self-adaption technology of short circuit energy and burning energy, breakthrough conventional matching relationship of the output voltage and the wire speed for the GMAW. Ensure the arc stability under the lower voltage and higher current, to adapt the high energy input of the all position root welding of pipeline.

Key words: pipeline welding; root welding; all position welding; single sided weld with double sided formation

Analysis of arc interference and control strategy for double wire AC-DC SAW

GAO Ying, LI Huan, HUANG Zongren, YANG Xinxin (School of Materials Science and Engineering, Tianjin University, Tianjin 300072, China). p17—20

Abstract: In the AC-DC double wire SAW system, the interference of two arc is serious. It makes the welding process unstable.