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Study on the Autocontrol of Stud Plunge Depth in Stepping Arc Stud Welding

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Abstract: Stud plunge depth is one of the important welding conditions in arc stud welding. With the analysis of the stud plunge process, the control of stud plunge depth in the stepping arc stud welding was studied. The extrusion pressure between the stud and the workpiece during welding process is acted as the controlled variable. And a control system based on a displacement sensor was developed. It is indicated from the welding test results that the autocontrol of stud plunge depth using displacement sensor can be realized in stepping arc stud welding. The stud plunge depth does not need to be set before welding, which will redound to the automaticity of welding process.

Key words: Arc stud welding , displacement sensor, plunge depth, extrusion force

INTRODUCTION

Welding gun behavior parameters are factors affecting welding quality in arc stud welding, consisting of stud lift speed, lift height, plunge speed and plunge depth. There into, stud plunge depth affects the formation and contour of welding joint. The setting of the stud plunge depth is mainly compensating for the stud burn-off, which will guarantee an adequate stud length to enter into the welding pool[1]. An inadequate stud plunge will result in a low quality joint[2]. The stud plunge depth parameter is set via adjusting the machine structure of welding gun before welding in traditional arc stud welding with electromagnetism gun[3].

The stepping arc stud welding is a kind of welding process based on the stepping arc stud welding gun[4]. The gun is mainly made by a stepping motor as actuating unit and a screw-driven device as moving unit to realize the stud action procedure requested by arc stud welding. A MCS-51 single-chip-microcomputer is adopted as the main control component of control system to realize the control of the stud gun and welding procedure. In the prophase study on stepping arc stud welding, the stud plunge depth is set according to the practical welding condition to accomplish the welding process[5]. The stud plunge depth needs to be reset through tests once the other parameters including welding current, welding time and stud lift height are changed, which increase the loads of welding tests. Furthermore, either the stud burn-off or the welding pool depth is not very steady, but unpredictable. The ideal stud plunge depth should guarantee an approximately consistent contact state between the stud and the workpiece.

The present study was focused on the control of stud plunge depth in stepping arc stud welding. Through the study of the stud plunge process in stepping arc stud welding, a control method was introduced. And a control system based on a displacement sensor was designed to realize the autocontrol of stud plunge depth.

MATERIALS AND METHODS

Stepping arc stud welding process: The structure of stepping arc stud welding gun is shown in Fig. 1. The weld sequence of arc stud welding process is shown in Fig. 2.

1. Loading a stud into the stepping arc stud welding gun, positioning the gun properly against the work piece and making the stud to contact closely with the work piece.
2. Starting the weld current and lifting the stud by driving the stepping motor positive rotation, then resulting in an arc between the stud and workpiece.
3. Keeping the arc in the gap lifted for melting both the stud and the work piece.

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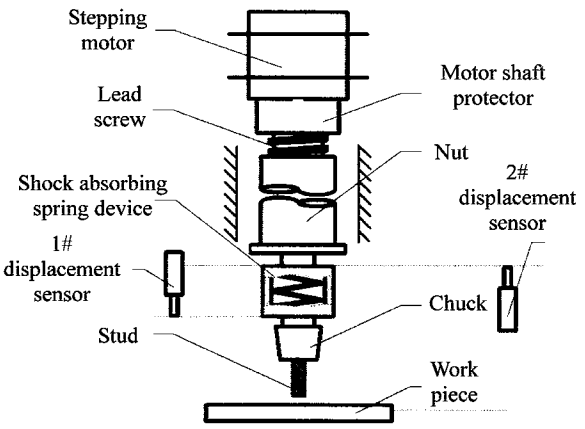

Fig. 1: Structure of stepping arc stud welding gun

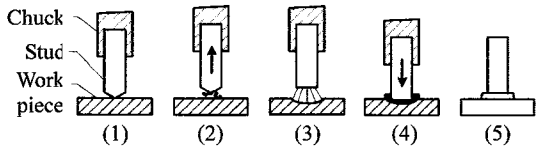

Fig. 2: Sequence of stepping arc stud welding

4. The stud is plunged into the welding pool by means of the reverse of motor and the welding current is automatically shut off when the arc period is over. The arc period is preset in the control system.
5. The weldment is completed and the gun is lifted off the stud.

The arc stud welding has the characteristics of the common fusion welding and the pressure welding. In the course of generating the arc and arc burning, the welding pool appears like the common fusion welding in the workpiece. In the course of joint formation, namely the time when the stud plunges into the pool, the stud meets with the workpiece, besides, a certain extrusion pressure come into being between them. This course is similar to the joint formation of pressure welding. It is a course in which the movement and the force coexist.

Control method of stud plunge depth: The stepping arc stud welding gun has a higher controllability because of the use of electronic control mode. The stud movement can be controlled effectively if the stud position can be detected during the stud plunge process, which is to say, the stud plunge depth can be adjusted timely according to the practical condition of welding process. Consequently the key problem of realizing the autocontrol of stud plunge depth in stepping arc stud welding is how to adopt and detect the controlled variable, which can be looked upon as the problem of control method.

As before, the setting of stud plunge depth is mainly for the sake of compensating the stud burn-off, guaranteeing the stud length plunged into the pool. However either the stud burn-off or the molten pool depth is difficult to be collected during welding. The extrusion pressure between the stud and the workpiece during the stud plunge reflects the tight extent of joint connection. Through that whether the stud has reached the requirement of plunge depth can be judged. Furthermore, the extrusion pressure is easier to detect than the stud burn-off, so it can be regarded as the control variable of stud plunge depth.

The chief action of shock absorbing spring device of welding gun as shown in Fig. 1 is changing the stud displacement into spring compression when the stud plunge depth is excessive, which protect motor and other parts against breakage. The shock absorbing spring device should preset a definite spring force before welding lest the spring entering into compressive state precociously in the course of stud plunge and impact the normal process of the stud plunge. In the stage of stud lifting and arc burning during the welding, the spring is always in a certain stability condition, which means the spring can not generate compression displacement. In the course of stud plunge, the extrusion force between the stud and the workpiece increases gradually after the stud entering into molten pool and contacting with workpiece. When the value of the extrusion force exceeds the presetting force of the shock absorbing spring device, it may generate a definite compression displacement, whose size has the direct proportion with that of extrusion force. The presetting force P of the shock absorbing spring device is determined by the following equation:

$$P = K\lambda \tag{1}$$

$$K = \frac{Gd^4}{8D^3n} \tag{2}$$

here, λ is spring deforming; K is spring constant, G is shear modulus of spring material, d is the gauge of spring wire, D is the intermediate diameter of the spring and n is the number of effective coils of the spring.

Based on the above analysis, the extrusion pressure between the stud and the workpiece during welding process is acted as the controlled variable for realizing the autocontrol of stud plunge depth. Through the acquisition of the compression displacement of the spring in the welding gun by the 1# displacement sensor as shown in Fig. 1, the contact state between the stud and the workpiece is achieved. If it accorded with the demand phase, the stud plunge will be ceased and then

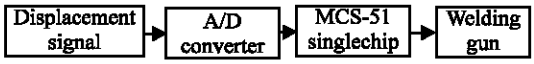

Fig. 3: Block diagram of stud plunge depth control system

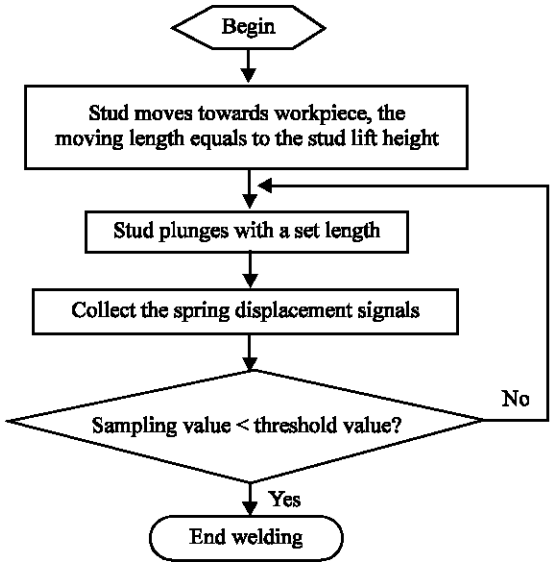

Fig. 4: Programming flow chart of stud plunge process

the welding process is ended. The displacement sensor No. 2 is used to collect the complete moving situation of the stud during the welding and has a function of monitoring.

Control system of stud plunge depth: The control system of the stud plunge depth is showed in Fig. 3. The displacement signal is collected via using frequency-modulated inductance displacement sensor (model BWG3), which has following features: the test specification is 0~20 mm, the output signal voltage is 0~5V and the precision is around 4%, namely 0.08 mm. The A/D converter is an ADC0809 with 8 bits resolution, which can convert 0~5V analog signal into 0~255 digital signal. It can be known via calculation that the unit digital signal is equivalent to 0.0784 mm displacement length. The displacement sensor matches with the A/D conversion in test precision which is contented to measure the stud plunge depth. According to the sample signal the MCS-51 singlechip judges the state of stud plunge and then controls the action of welding gun.

The programming flow chart of stud plunge process in welding is showed in Fig. 4. Firstly, the stud moves towards the workpiece, the moving length equals to the stud lift height. In this process, spring will not generate compression displacement, so it is not need to be detected. Then the displacement signal will be collected after the stud plunges with a set length. And the sampling value is compared with the threshold value that is the displacement signal before the stud and the workpiece contacting. If the sampling value is smaller than the threshold value, then it means that the stud has entered the welding pool, furthermore the extrusion pressure between the stud and the workpiece has exceeded the presetting value. In this case the welding current will be shut off and the welding process is ended. On the contrary, the program will go back and continue the stud plunge process.

RESULTS AND DISCUSSION

The welding tests based on stepping arc stud welding gun and stud plunge depth control system are done. The material of stud and work piece is a kind of low-carbon steel (Q235). The stud is round with diameter 5 mm. And the stud weld base is flat without flux. The thickness of work piece is 5 mm. The area to weld should be cleaned before welding to remove the deleterious substances such as heavy rust, oxide layer, paint, grease, heavy oil, moisture, etc. The presetting pressure of spring is about 40 N. When the extrusion pressure between the stud and the workpiece exceeds the setting value, the stud plunge and welding process will be ended. A digital oscilloscope (model TDS220) with two input channels is used to collect the date of the welding current and the 2# displacement sensor in welding process. Its extended communication module (model TDS2CM) connects with the serial interface of computer through RS232. The results of sampling can be displayed and processed by computer.

The typical waveforms of welding current and stud displacement in welding process with 1.7 mm stud lift height are shown in Fig. 5. The home position of the stud is act as the base point of the displacement coordinate. The welding process involves stud lift stage, holding (arc burning) stage and stud plunge stage.

The stud plunge stage begins after the arc burning time. At the time denoted by point C as shown in Fig. 5 (b), the change of stud displacement finish. That because the extrusion force between the stud and the workpiece exceeds the presetting value and thus the compression displacement of spring occur, which result in that the program execute the instruction of ending welding. Such welding process indicates that the autocontrol of stud plunge depth using displacement sensor in stepping arc stud welding is realized.

The line section ab in stud plunge stage denotes the process in which the stud returns to the preweld position. The line section bc denotes the process in which the stud

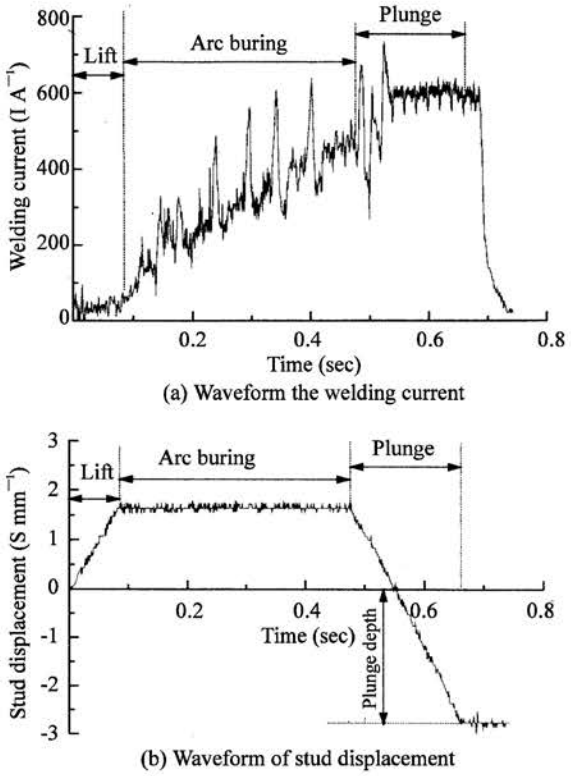

Fig. 5: Waveforms of welding current and stud displacement in welding process with 1.7 mm stud lift height

Fig. 6: Welded joint

plunge from preweld position to the welding pool in the workpiece. And the stud displacement in this process can be defined as the stud plunge depth and has the same meaning with extrusion length in common arc stud welding. It can be indicated from the slope coefficient of line section ac that the stud keeps a fixed plunge speed, which illuminate the increase of extrusion force does not result in the out-of-step of stepping motor.

The welded joint is shown in Fig. 6. It also testifies that the control of stud plunge depth using displacement sensor in stepping arc stud welding is successful.

CONCLUSIONS

1. Through the acquisition of the compression displacement of the spring in the welding gun by displacement sensor, the extrusion pressure between the stud and the workpiece is achieved. Based on which, the autocontrol of stud plunge depth is realized.
2. Because of the realization of autocontrol, the stud plunge depth need not to be set before welding to adapt the different stud configuration and it can be adjusted via program in welding process according to the practical requirement, which will redound to the automaticity of welding process.

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