DEVELOP AND USE OF STUD PENETRATE WELDING TECHNOLOGY IN COMPOSITE FLOOR OF STEEL STRUCTURE

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1. Abstract

Stud penetrate welding is an important item of composite floor in modern steel structure, especially in high-rise buildings. But it is difficult to get satisfied welding quality due to all kinds of factors. In this paper, the author put forward a new welding procedure named method of energy control through analysis and comparison of the wave curves of stud welding based on large amount of experiments and tests in laboratory and construction areas. The use of this welding procedure in some large engineering in recent years proved that this method is effective and practicable and worthy of being popularized among the enterprises of our occupation.

2. Goal and importance

With the past twenty years of reforming and great development of economic in China, steel structure fabrication and erection technology have achieved large progress and have been used in more and more areas. As the supplementary construction technique of composite floor in modern steel structure, stud is used as sheer connector in composite floor to prevent the concrete from its relative displacement from the surface of steel beams. Therefore, the stud plays an important role in steel structure, especially in high-rise buildings. The members of steel structure, such as column, beam and girder etc. should be painted prime paint and face paint in order to resist corrosion after fabricated and erected. During the course of construction, there also will be second pollution, such as concrete, slag, dust, moisture and so on besides there always be space between beam and metal profiled sheet because the surface of the beam is not so smooth and the metal profiled sheet always twists in some extent. The paint, concrete, slag, dust, moisture, oil and the space are important factors, which influence the welding quality. So in order to assure to get good welding quality, according to relative standards of construction, the traditional method is to drill hole on the metal profiled sheet and then clear away the pollutions before weld. It is called common stud welding technology. Obviously because metal profiled sheets are used in so many areas, doing as this will greatly increase the working strength and cost and limit the speed of construction. It has been proved this method is not practicable. Therefore, it has become one of the most important problems that how to insure the welding quality in the course of construction of composite floor.

The intention of this paper is to find the factors that influence the quality of stud penetrate welding in composite floor through large amount of experiments and give the suitable welding procedure to improve the quality of stud welding and promote the construction efficiency. The solve of this question will exert a positive influence on the application and expansion of stud welding in High-rise steel structure in our country and will make great economic and social benefits certainly.

3. Study method and devices

3.1 Experiment devices

The experiment devices are shown as fig1.

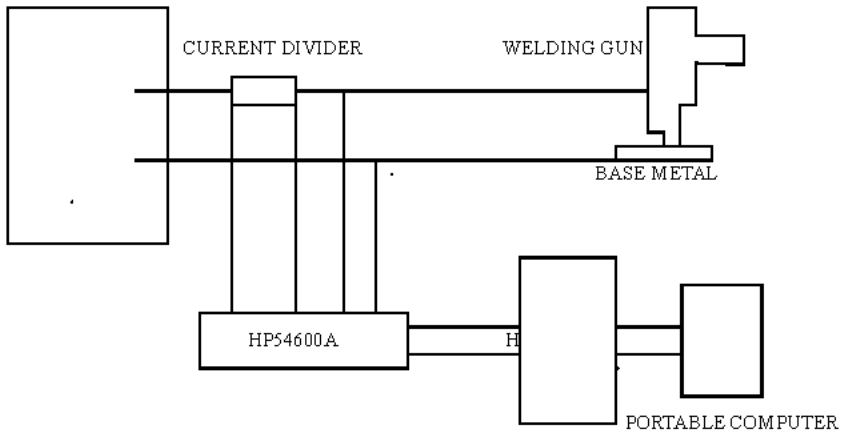

Fig1. The experiment devices and system of signals sampled

①Source of signals: Signals of arc voltage and current will be sampled from the electrodes on the panel of power source and transferred into HP oscilloscope.

②System of data sampled: HP oscilloscope 54600A＋HP54651A (module of sample)＋NEC portable computer

③Work principle: The signals of welding current and arc voltage are sampled by HP oscilloscope (54600A) and then are stored in the module of sample (HP54651A) after A/D transformation.

The module of sample can store 50 wave curves of welding current and arc voltage at the most. After wave curves have been stored in HP54651A, potable computer will collect the data from it. Then we can analyze the wave curves and print the result by computer.

3.2 Program of experiment

(1) Experiments in laboratory

①Factor of metal profiled sheet: Study the effect of various thickness and coat (galvanizing or color painting coat) on welding quality.

②Factor of beam: Study the effect of various degree of rust-eaten and the thickness of painting on welding quality.

③Factor of metal profiled sheet and beam: study the synthetic effect of space and pollutions (such as slag, moisture, water and so on) between metal profiled sheet and beam on welding quality.

In order to find the influence of each factor on welding quality, we welded thirty studs for each factor and recorded the wave curves of every welding current, arc voltage and the welding quality and then compared the wave curves with the outward appearance and quality of each joint.

(2) Tests in construction areas

In order to find the regularity that influences the welding quality. We have done a large amount of tests on welding parameters compare with the welding quality in construction areas use the result that obtained in laboratory.

4. Result

Condition of experiments

Welding materials: stud (made from ML15) specification: Φ19mm×120mm

Welding apparatus: NATIONAL and OTC (made in Japan), KOCO (made in German), Hongguang and Gongda (made in China)

4.1 Effect of metal profiled sheet

Preparation before weld:

The surface of base metal should be grinded to appear the metal itself, and there is no space and other pollution between the metal profiled sheet and the base metal, the welding parameters are shown in table1.

(1) Effect of coat and its thickness

① We can obtain good welding quality when the zinc content is under 180g/m^2. The qualified ratio is over 90% on average.

② When the zinc content of metal profiled sheet reaches 275 g/m^2, the qualified ratio falls down to 70%～75% because the melt point of zinc is lower than that of steel and it produce mist during the course of weld and enhance the pressure in ceramic ferrule. All of this make the arc can't burn stably and produce large amount of spatter. Therefore, we proposal that we should not use metal profiled sheet which zinc content is 275 g/m^2 as possible because 180 g/m^2 can completely meet our requirement of prevention from corrosion in general condition.

③ When the coat is color paint, it's difficult to burn the arc because most of the paints are insulating materials. So we process the tip of studs to make a special arc point which can make it easy to burn arc. Under this condition, we also can get good welding quality.

④We recommend that we should use the metal profiled sheet which zinc content is 180g/m^2 instead of 275g/m^2 as possible.

(2) Effect of the thickness of metal profiled sheet

① When the thickness is below 1.2mm, we can obtain good quality in every condition.

② When the thickness is over 1.6mm, the welding quality is poor.

4.2 Factor of beam

(1) Test Condition

Metal profiled sheet:

Zinc content: 180g/m^2

Thickness: t=0.8mm(there is no space between the metal profiled sheet and the beam)

Beam:

①Degree of rust-eaten: The rust is light and meet the basic requirement of steel base metal in relative standard.

②Water on the surface: the water on the surface is correspondent to the condition that four hours after raining in the construction areas.

③Thickness of painting: according to the relative standards, the thickness of painting will be 100 μm, 150 μm or 200 μm

(2) The parameters are shown in Table1.

Table 1 Welding Parameters

Protrusion (mm)	Lift (mm)	Welding current (A)	Welding time (S)
8～9	2.5	1500	1.2

(3) Conclusion

① The effect of water on the surface is the most serious problem and the ratio of qualified is only 35%.

② The thicker the coat of painting is, the more serious the effect is. When the thickness is over 200 μm, there are large amount of gas pores in the joint and the ratio of qualified decreases much.

③The light rust can't cause serious effect on the welding quality; the ratio of quality is over 90%.

4.3 Effect of the space between metal profiled sheet and beam

Metal profiled sheet: Zinc content: 180g/m^2

Thickness: t=0.8mm

The welding parameters are shown in table 2

Table 2 Welding Parameters

Protrusion (mm)	Lift (mm)	Welding current (A)	Welding time (S)
≥9	2.5	1500	1.2

① When the space is over 3.0mm, the quality of joint is very poor because the protrusion already reaches its limit and the stud can't plunge into the molten pool fully.

② During the course of weld, the arc transfers onto the beam when the metal profiled sheets melt after the arc burns. Therefore the length of the arc becomes the sum of the protrusion and the space and the thickness of the metal profiled sheet. The increase of the length of arc will cause the arc burns unstably. Therefore, in order to stabilize the arc, we should select small protrusion as possible.

4.4 Synthetic effect of the metal profiled sheet and beam

(1) Condition of construction areas

In construction areas, generally, the factors of metal profiled sheet and beam are regular, but the space between metal profiled sheet and beam is variable due to the reasons of construction. We can't know how large the space is before weld; especially we can't evaluate the amount of water, moisture, slag and other things in the space. Therefore, due to the synthetic effect of all above factors, the ratio of qualified is unstable if we use the parameters obtained from ideal welding condition. Obviously, in order to improve the welding quality, the parameters must be modified timely to fit the condition of construction areas.

(2) Method of energy control

In common stud welding, the welding parameters are constant and the total energy ($W=U\times I\times t$) is certain because the effect of all the factors can be ignored when the surface of the beam has been grinded before weld.

In penetrate stud welding, we have collected almost 10,000 parameters and wave curves in construction areas. Through analysis and comparison of the wave curves with the welding quality, we find that the process of stud welding can be divided into four different courses:

① Course of striking arc

② Course of arc burns unstably

③ Course of arc burns stable

④ Course of arc dying out and top-forged

During these courses, the course of arc burns stably affect the effective input energy directly, through comparison analysis, we find that the time of arc burns stably (with good welding quality) is certain at the same specification of stud while the time of arc burns unstably is changed with the welding surroundings. Therefore, although we can't avoid the effect of all kinds of factors, but we can improve the welding quality through control the effective input energy, which is named as method of energy control in this paper. In the following part, we will verify it through experiments.

A: Experiment condition

Metal profiled sheet: Zinc content: 180g/m^2

Thickness: t=0.8mm

Parameters: In order to stabilize the arc and decrease the spatter in welding, the protrusion should be selected as long as possible to increase the amount of plunge and the lift should selected as short as possible to decrease the length of arc. The parameters are shown in table 3.

Table 3 Welding Parameters

Protrusion (mm)	Lift (mm)	Welding current (A)	Welding time (S)
≥9	2.5	1500	Controllable

B: Typical wave curve

We do some modification on the time control circuit of the welding machine, change it from automatically control into manual adjusts. The effective welding time is controlled by worker according to the situation of arc burning .The typical wave curve is shown in fig2. We collected a series of wave curves with satisfied welding quality in construction areas to make statistical analysis of the effective energy.

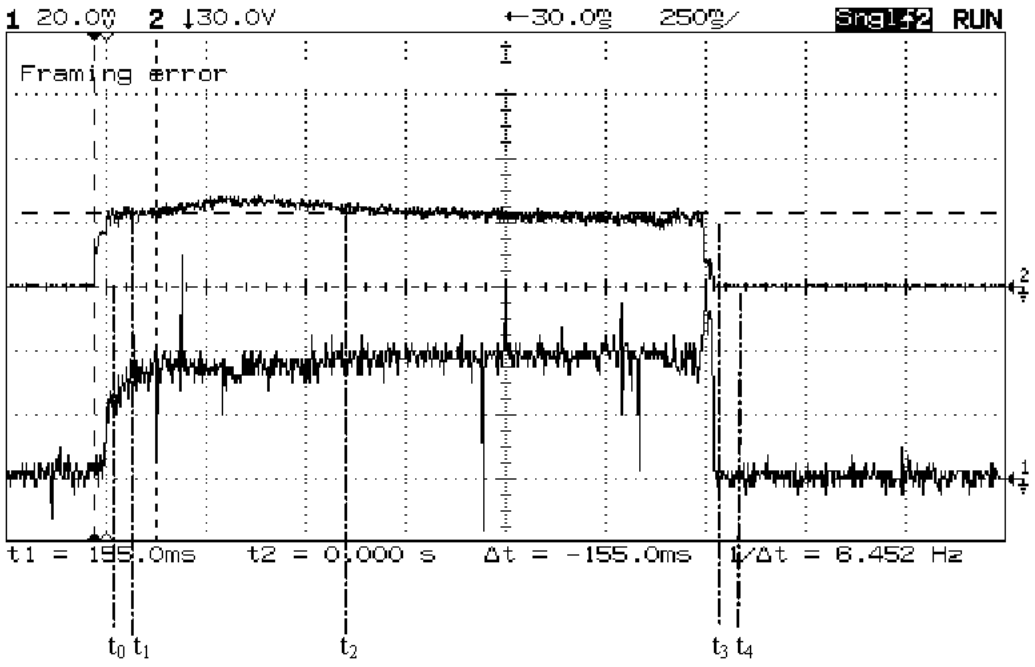

Fig 2: Typical wave curve of stud penetrate welding

C: Analysis

Although the total energy (t0-t4) of every joint is not same with each other, but their

effective energy is same approximately, the effective welding time (time of burns stably) is always in the range of 0.8-1.0s. Correspondently, the effective energy is same as that in common stud welding. We can regard the energy produced in the course of arc burns unstably as extra energy to overcome the effect of all the factors. Obviously, it's reasonable and practicable to improve the welding quality through the method by control the effective welding time.

D: Basic principle of the method of energy control

① Detection of the wave curve of welding current: Detect the wave curve of welding current and catch the point at which the arc begin to burn stably, before this point is the course of arc burns unstably, its time change with the welding surroundings.

② Detection of welding effective time: It begins to time when the sensor catches the point of arc burns stably (the time is decided by the effective time in common stud welding with the same specification of stud under ideal condition).

E: Development of automatic machine of stud welding using Fuzzy control theory.

From the analysis above, we can find that the stud penetrate welding is so complex and the welding circumstance is constantly changing, that it is difficult to get satisfied result with classical control theory. Therefore in the development of the new welding machine, we considered to use the theory of Fuzzy control.

According to the method of energy control and use Fuzzy control theory, we designed Fuzzy controller and compiled program. With the machine uses Fuzzy control, we get satisfied result in laboratory. But to use it in construction areas, we still have many works to do to prove the stability and reliability of the machine.

F: Examples of engineering use method of energy control

Because the automatic stud-welding machine with Fuzzy control using method of energy control is now being developed. We trained special welders and changed the timer from automatically control into manual control according to the fundamental principle of method of energy control and the requirement of construction. The effective welding time is decided by the welders according to their experience, the welders will shut down the current after a certain time when the arc begin to burn stably. This method has been used in construction of Shanghai information building (44 stairs and 360,000 cases 0f studs). It has achieved obviously fine result in stud welding .The one time qualified ratio of stud penetrate welding reached 90% which is ten percent higher than that of use traditional method. It reduced the waste of studs, raised productivity and gained great economic benefits. The welding quality has won great praise from supervise enterprise. This method is worthy of being popularized among the enterprises of our occupation.