STUD WELDING FOR ALUMINUM ROLLED PRODUCT BY ARC AND FRICTION WELDERS

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ABSTRACT The weight reduction of transport means such as automobile, rolling stock and ship have been permiating gradually to meet the requirements of reducing the fuel consumption, improving the capability and adding new functions.
Now its facing new millennium, big discussions have arison about the global environmental disruption of the earth. It is getting more important for all nations to endeavoure in maintaining the good environmental condition along with the globalization of the industries, and the tendency of the weight reduction of the vehicles is intensified very much since it is one of the effective countermeasures.
For instance, aluminum diecasting and cast alloy have been used for automotive parts except body, but rolled products are also expected to be used for the body.
Nippon Stud Welding Co., Ltd. has been developing the aluminum stud welding technology for rolled products through the experience of stud welding for LNG storage tanks made of aluminum alloy. Aluminum studs of ϕ 6 to the thin sheet from 1 to 3 m/m in thickness were experimentally welded by using the arc welder and a friction welder. The outline of the results are described in this paper.

Keywords: *aluminium, joining, stud welding, arc welding and friction welding*

1. INTRODUCTION

Stud welding by arc welders, the method of joining bolts or bars called studs, to the plate directly heated by the arc between them. There are a few kinds of welding methods. The typical way is shown in Fig. 1.
The process is as follows,

① Contact a stud with a ferrule down to a plate
② Trigger a switch of weld current to lift the stud slightly off above the

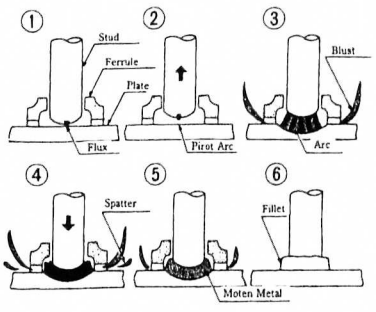


Fig.1. Typical Stud Welding Method

plate to make small arc between them.

③ Lift further the stud and increase the current to make the arc strong enough to melt both of them partially.

④ Plunge the stud into the molten metal and turn the current off.

⑤ Keep the stud still until molten metal is solidified and leave it.

⑥ Break the ferrule for removal after cooling of melted zone.

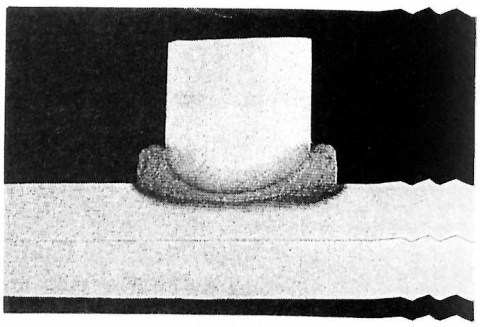


Fig.2. Macrostructure of Welded Stud

Thus, stud welding is carried out very quickly in a fraction of a second.

Fig. 2 shows a macrostructure of a welded stud in cross section. High quality of welding is brought by large current in a short time welding and plunge action of the stud, which enable the heat affected zone as narrow and the melted metal layer as thin as possible. One of the features of the stud welding is to enable a stud to connect to plate from one side stably and precisely. That is because the stud welding is utilized very commonly and widely for the products in many fields of industry.

Table 1 shows the applications of the stud welding to the various fields of industry. Power unit and arc current control are designed depending on the material and sizes of a stud and plate.

Regarding the kind of material, there is no problem with the combination of same materials, even though they are mild steel and stainless steel However, due to the melting method of joining, a limit in minimum plate thickness exists in spite of the short time welding.

Power Control Unit		Applied Size		Condition		Ferrule /Gas /Flux	Material	
Source	Arc Control	Stud	Plate	Current	Time		Steel	Al
Con-denser	Capacitor Discharge	φ mm 2～8	mm 0.3～	Amp 6,000	msec 2～3	-	Yes	Yes
	Stored Arc			2,500	30 ～50	-	Yes	NA
						Gas	-	Yes
Trans-former	Short Cycle	3～9	0.6 ～3.2	500 ～1,400	30 ～50	-	Yes	NA
						Gas	-	Yes
	Drawn Arc	5～25	3～	500 ～2,000	100～ 1,200	Ferrule	Yes	NA
						Gas	Yes	Yes
						F.&Gas	-	Yes
	Submerged Arc	27～34	12～	1,000	14～ 20sec	Flux	Yes	NA

Table 1. Applications of Stud Welding Methods

2. DEVELOPMENT

2.1 Application for automobile steel sheet

Table 2 shows the number of studs applied to automobile car body manufactured in different countries. European car uses extremely larger number of studs than the other countries. Japanese car makers require the machines supplied by us in their production lines to be of quite higher performance. In addition to this, they always challenge the innovation of weight reduction and durability improvement by introducing new materials, such as extra-deep drawing quality, high strength sheet and plated sheet.

Coping with the severe and advanced requirements, we have made a concept for the new stud welding system which is shown in Fig. 3.

Most of requiement from users has led to development of a larger capacity power unit equipped with transistor inverted control of the current. The new power unit has become to produce a wider range of welding current in a shorter time as shown in Fig. 4, which is refered to the performance with large flanged studs M6 X 20. The defect ratio of stud to fall off was reduced down to some ppm order from percent order for the conventional one.

Country	No. of Stud in average
Japan	50 p/car
Germany	180
Europe (ave.)	150
U. S. A.	50
Korea	40

Table 2 Number of Studs for Automobile Car body by Country

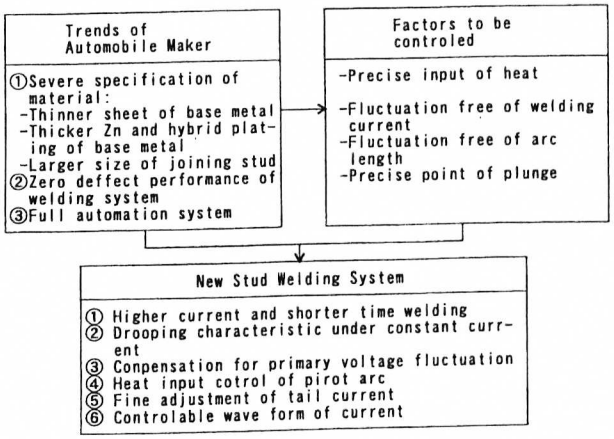


Fig.3. Design Concept of New Stud Welding System

2.2 The application for LNG Aluminium Tank

Studs attached to the sphere and skirt surface of LNG tanks are required to fix the insulation panels to the tanks. Base metal of aluminium tank is alloy A5083 and about 40mm in thickness, and alloy A5356 is used as a stud.

Fig. 5 shows an inert gas flow of shrouding by Schlieren method.

Table 3 shows an example of the stud welding condition and the technology and quality control system of Al stud welding have been established. This method is being used very commonly for LNG Tanks.

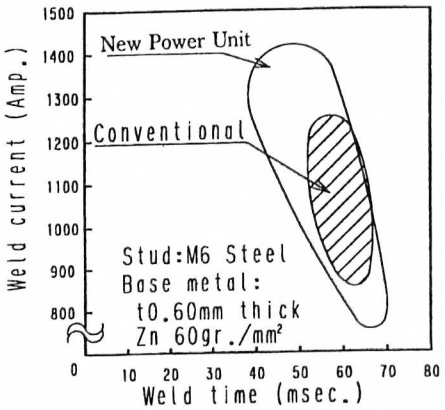


Fig.4. Relation between Welding Current and Time of New Power Unit

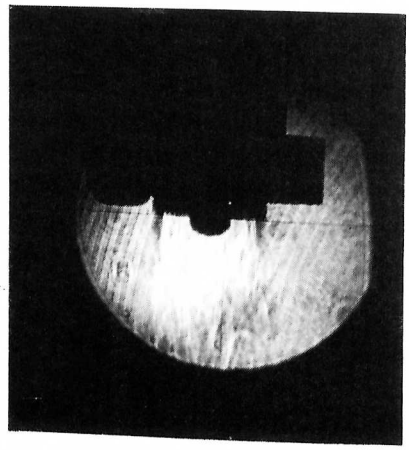


Fig.5. Inert Gas Flow of Schlieren Method

Power control Unit		Material		Condition		Ferrule /Gas	Position of Welding
Source	Arc Control	Stud	Plate	Current	Time		
Trans-former	Drawn Arc	A5356 ϕmm 6.4	A5083 mm 40	Amp 240	msec 500	Ar Gas with Ferrule	Down, Horizontal and Upward

Table 3. Stud Welding Condition for LNG Tank

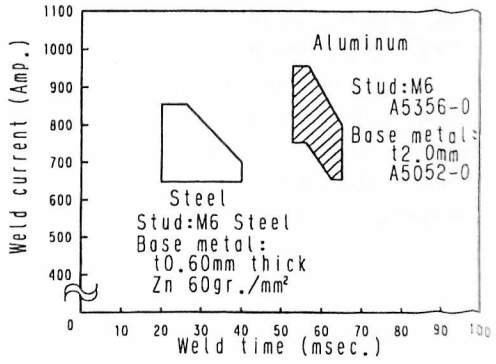


Fig.6. Welding Conditions for Al and Steel Studs of M6

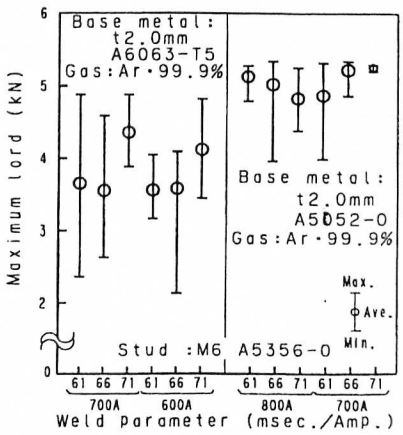


Fig.7. Results of T.S.Test for Arc Welded Al Stud

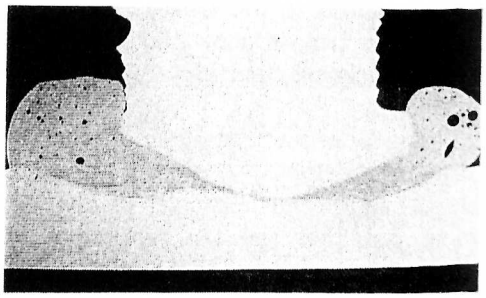


Fig.8. Macrostructure of Arc Welded Al Stud

3. EXPERIMENT

3.1 Arc Stud Welding For Al Alloy Sheet

Control of stud welding for aluminum sheet is required much more severe to have sound melted zone and heat affected zone. Some experimental tests have been carried out by using an existing welding system modified with Ar gas shrouding device.

Fig. 6 shows one of the stud welding condition for aluminum sheet comparing with steel sheet.

The result of tensile strength test is shown in Fig. 7, in which the values of tensile strength are scattered a little bit widely.

The macrostructure of welded stud in cross section, shown in Fig. 8, has some blow holes and a little defect like crack in the melted zone.

Countermeasures were discussed from designing material to machine control system, and a new design concept was made as shown in Table 4. Considering that the experimental tests were carried out under the good condition, there must be still a big gap between the test and actual practice. Much more factors must be taken into account so as to promote the new concept through having more tests under the actual conditions.

3.2 Friction stud welding for Al alloy sheet

From the result of arc stud welding described above, we are interested in this joining method, which process does not melt materials nor cause the defects during melting and solidifying. Fortunately we had some experience of handling friction welder, so we decided to set out a experimental test of friction stud welding for Al alloy sheet. Fig. 9 shows schematic diagram of our friction stud welding process.

Fig. 10 shows the stud welding condition and the result of tensile strength test case of alloy A5052 stud and sheet. The macrostructure, shown in Fig.11, looks very good without any defects in the joining boundary. As far as we observe, friction stud welding must have possibility to reduce the barrier against Al alloy sheet. It has a weak point of need of back-up plate for welding, but there is a considerable room to develop many applications for it.

Aims	Factors to be improved	Countermeasures
① Sound Melted Zone	- Matching of Alloys	a) Material Design
	- Contamination free	b) Design of Stud
② Stable Joining Strength	- Shrouding Gas Method	c) Sealing Device and Laminar Flow of Gas Shrouding
		d) Design of Shrouding Gas
③ Fully Automated System	- Precise and Quick Action of Gun	e) Total Control System of Welding Functions

Table 4. Basic Concept of Arc Stud Welding for Al Stud

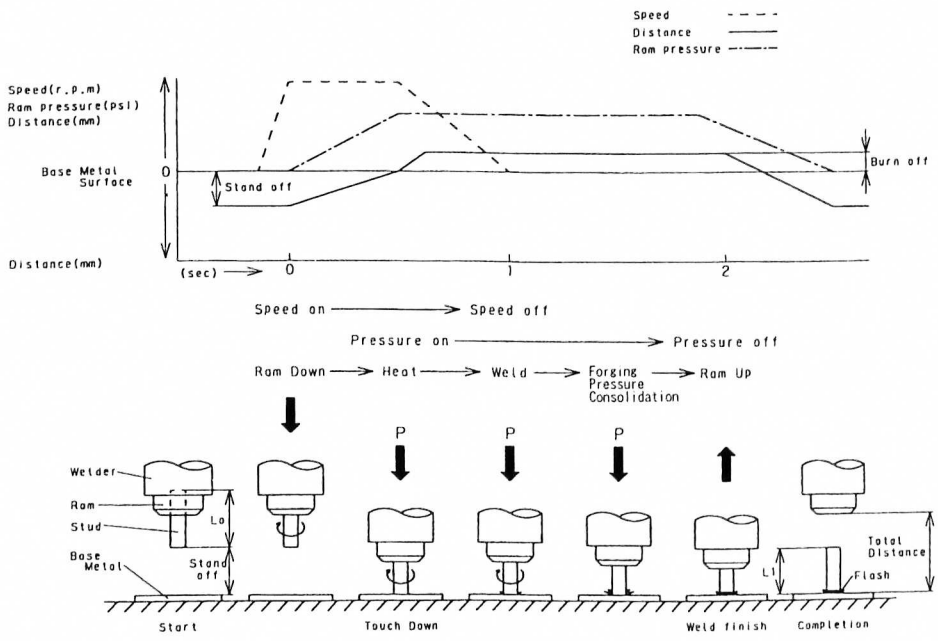
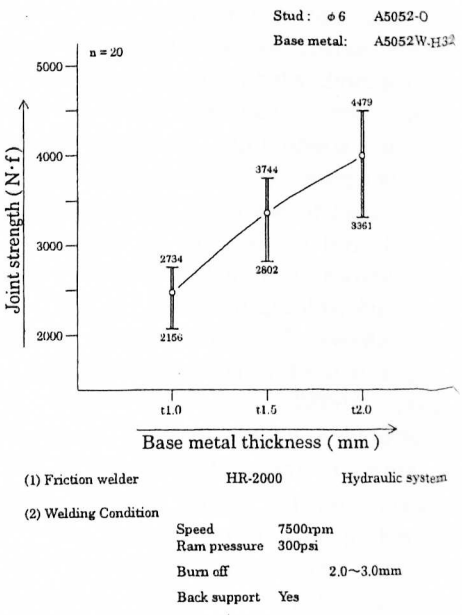


Fig.9. Schematic Diagram of Friction Stud Welding Process

4. SUMMARY

Experimental tests of stud welding for Al alloy sheet were carried out by arc and friction welders. The results brought us many possibility to challenge further tests under more actual conditions. Affiliate metal like aluminium seems to have some limitation in the joining process, and also market demand for thinner sheet encounters a limitation in case of arc stud welding because a certain amount of molten pool is physically necessary to make joint between them. On the other hand, solid joining method i,e, friction welding, seems to be helpful in joining of such kind of metal. The joining method is definitely a key technology for material in expanding its application in the new field. We think it is better to manage and develop both arc and friction technology for Al stud Welding. Combination use of them will be realized in the production line of aluminum car body in the near future, we believe.



(1) Friction welder HR-2000 Hydraulic system

(2) Welding Condition

Speed	7500rpm
Ram pressure	300psi
Burn off	2.0~3.0mm
Back support	Yes

Fig.10. Friction Stud Welding Condition and Results of Al Stud

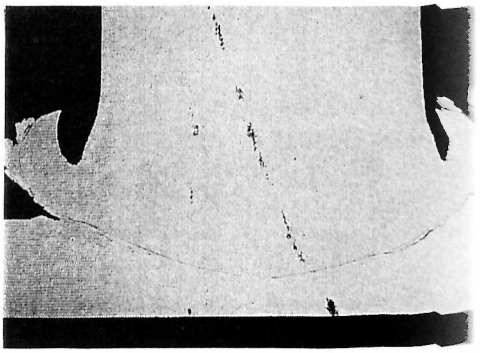


Fig.11. Mcrostructure of Friction Welded Al Stud