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Assembly technique for control panel enclosures with the combined use of adhesive and rivets and the reduction of energy consumption

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Abstract

We have developed a new assembly method of metal enclosures in which the combined use of acrylic adhesives and rivets (fasteners) are adopted as an alternative to arc welding. We have achieved the following effects: (1) elimination of skill working such as welding operation and strain correction, (2) improvement of working environment by the elimination of welding operation and putty work, (3) simplification of manufacturing process and cost reduction by introducing heatless bonding method (adhesive bonding), (4) compatibility of rigidity with weight reduction of products, (5) total energy consumption decrease to 78% by adopting this new assembly method, to 64% by thinner galvanized steel and to 51% by pre-coated steel.

Keywords: Acrylic adhesives; Rivets; Energy; Applications; Control panel enclosures

1. Introduction

Fig. 1 shows one example of control panel enclosures. This metal enclosure is a representative of multi-itemed short lot production, and these have mainly been constructed until now by arc welding by manual operation. In the assembly by arc welding, there are many problems such as generation of the strain by heating, necessity of skilled engineering of welding, degrading of working environment and quantity of energy consumption. From such background, a new assembly method with the combined use of adhesive and rivets (fasteners) has been developed in order to achieve the following purposes : (1) elimination of skill working, (2) improvement of working environment, (3) simplification of manufacturing process, (4) compatibility of rigidity with weight reduction, (5) reduction of energy consumption.

One example of control panel enclosures assembled by this new method is shown in Fig. 2 [1]. It has fundamentally the panel structure of sheet metal bending.

In the following outline and features, performance and effects, and reduction of energy consumption of the new assembly method are described.

2. Outline and features

2.1. Joining procedure

Joining method by the combined use of adhesive and rivets is carried out by procedures shown in Fig. 3. First, adhesive is applied to a part and parts are affixed. Next, before in adhesive hardens, a rivet is inserted into a hole and the stem is torn on tightening by pulling it by the riveter.

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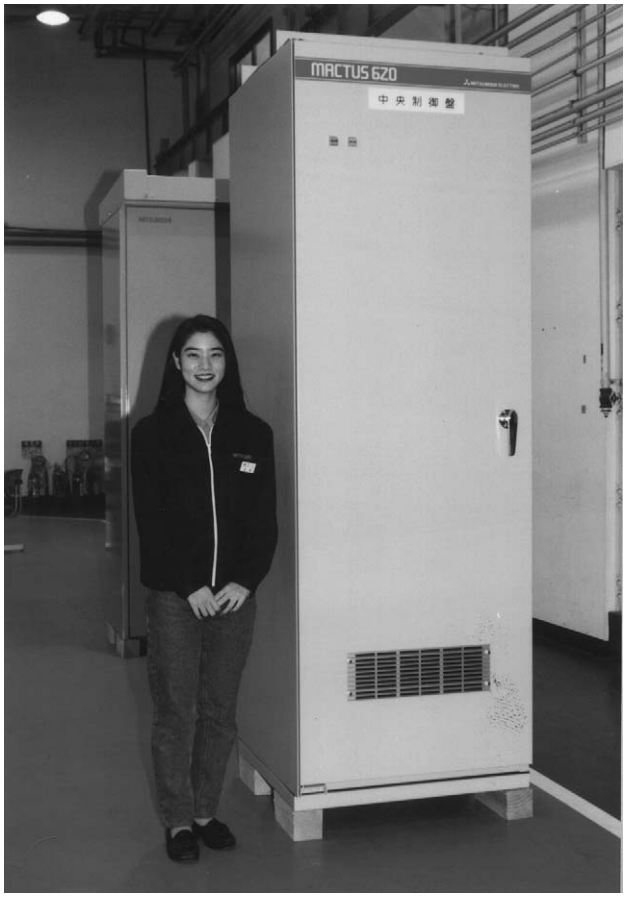

Fig. 1. One example of control panel enclosures.

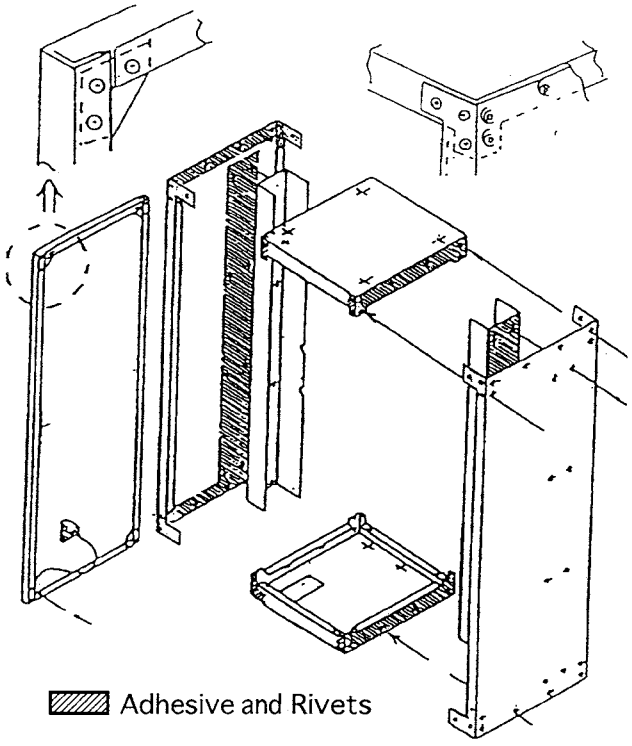

Fig. 2. One example of control panel enclosures assembled by the combined use of adhesive and rivets (800 mm $W \times 800$ mm $D \times 2300$ mm H).

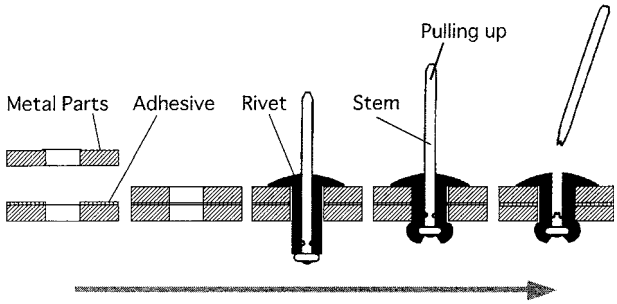

Fig. 3. Schematic illustration of the joining process used for adhesive and rivets.

2.2. Adhesive

Two-part type acrylic adhesive "HARDLOC M372" (made by Denki Kagaku Kogyo Kabusiki.Kaisha) is used for this method. Degreasing is unnecessary because this adhesive has excellent oil level property, and it hardens at room temperature within 15–20 min. Since it hardens in radical polymerization, accurate measuring and complete mixing of two parts are not necessary. It has excellent properties in impact strength, peel strength, shear strength and environmental durability. This adhesive has already had many application experiences for more than 20 years in outdoor environment.

2.3. Function of adhesive and rivets (fasteners)

In the combined use of adhesive and rivets, products are fundamentally dependent on the adhesive in respect of bond strength and durability. And rivets supplement defects of adhesive. By using adhesive with rivets, excellent workability compatible with high reliability is achieved. Adhesive and rivets are defined as follows.

Functions of adhesive: (1) Contribution of joint strength and durability, (2) rigidity improvement of metal enclosures by face-to-face conjunction, (3) maintenance of sealing, (4) improvement in vibration resistance by stress dispersion, (5) prevention of electrolytic corrosion on joints.

Functions of rivets: (1) Substitution of clamping tools until adhesive hardens, (2) easy and precise alignment, (3) contribution of electric conduction for electrodeposition coating, earth connecting and electromagnetic shield, (4) prevention of deformation or destruction of adhesive joints at high temperature in paints baking process, (5) prevention of the destruction of adhesive

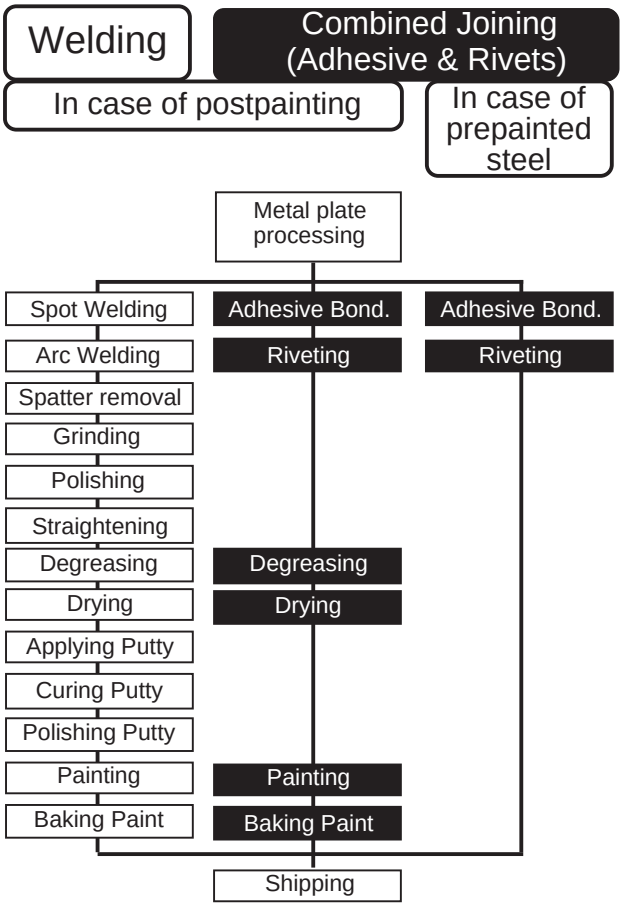

Fig. 4. Comparison of manufacturing process between welding and the combined use of adhesive and rivets.

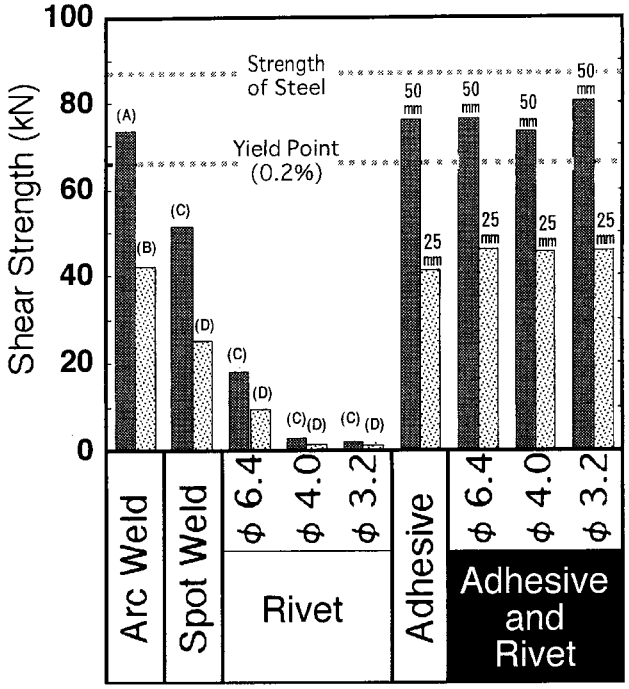

Fig. 5. Comparison of the shear strength between arc welding, spot welding, rivet, adhesive and the combined use of adhesion and rivet (substrates: 2.3-mm-thick cold-rolled steel).

joint by peel force, (6) prevention of creep deformation, (7) shape maintenance in adhesive burning up by fire hazard.

2.4. Manufacturing process

The comparison of manufacturing process between welding and the new combined method is shown in Fig. 4. In the new method, since strain correction and putty work become unnecessary, drastic rationalization of the manufacturing process is possible. The painting process can be also omitted when pre-coated steel is used. For the pre-coated steel, polyester coating with superior adhesive property for both galvanized steel and adhesive is used.

3. Performance and effects

Shear strengths of various joints are shown in Fig. 5. Types, shapes and dimensions of the joints are shown in Fig. 6. From this result, it is indicated that joint by the combined use of adhesion and rivets could have almost the same strength as by arc welding. The strength of adhesive and the combined use of adhesive and rivets are about the same, and the enhancement by rivet fastening is not recognized. This seems to be because the strength of rivet itself is much smaller than that of adhesive, or the force has not been almost transmitted to the rivet, since it is located in the center of the adhesive part.

The fatigue properties of various joints are shown in Fig. 7. It is indicated that superior fatigue property is obtained by the combined use of adhesive and rivet even in thin plate because of stress dispersion attempted by face to face joint.

Fig. 8 shows the results of outdoor exposure tests of the adhesion upon various adherents. It is indicated that the adhesive strength does not decrease, even if it is exposed in the long term in outdoors.

Table 1 shows the resonant frequency in vibration testing of metal enclosures (2.3 mm thickness) shown in Fig. 2. In order to get higher strength than type B in Fig. 5, lap length was designed more than 30 mm. The resonant frequency by the combined use of adhesive and rivets is higher than that by welding. It means that metal enclosures constructed by the new combined method has higher rigidity than that by welding. In a quakeproof strength test with acceleration 0.87–0.89 G at resonant frequency and in transportation endurance test with 0.75 G, the failure in bonded parts did not occur.

Other effects are shown in Table 2.

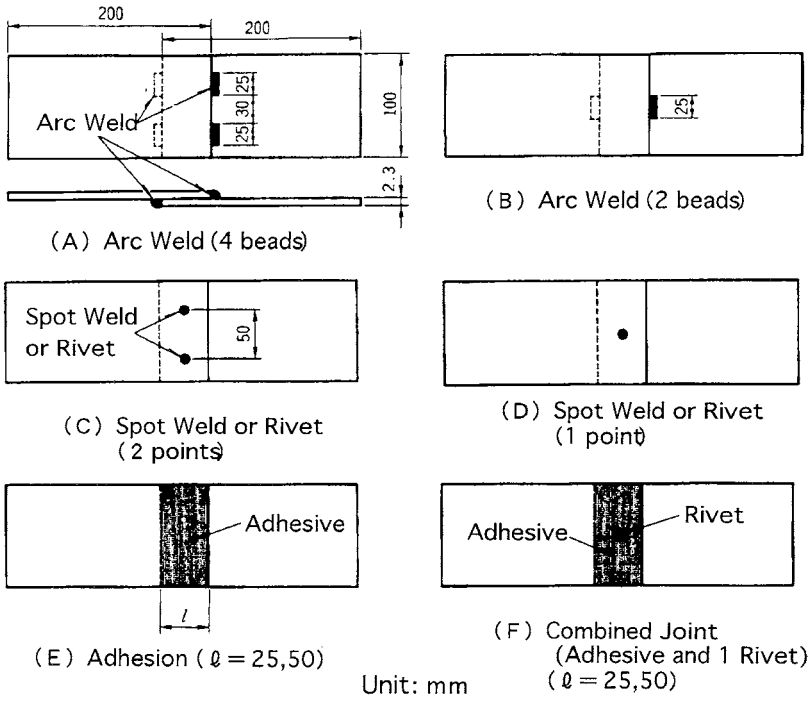

Fig. 6. Types, shapes and dimensions of test pieces.

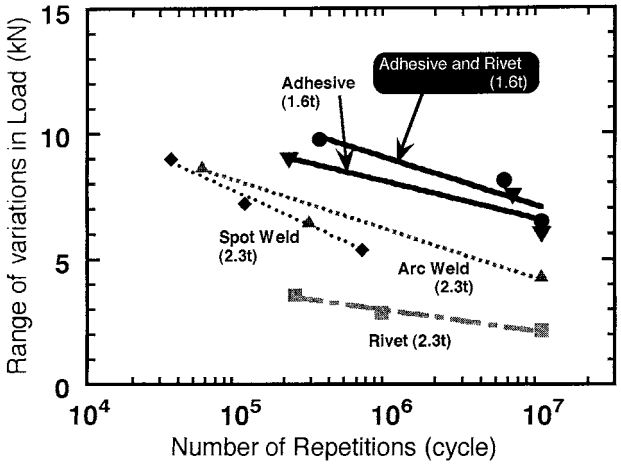

Fig. 7. Comparison of fatigue strength of the various kinds of joints.

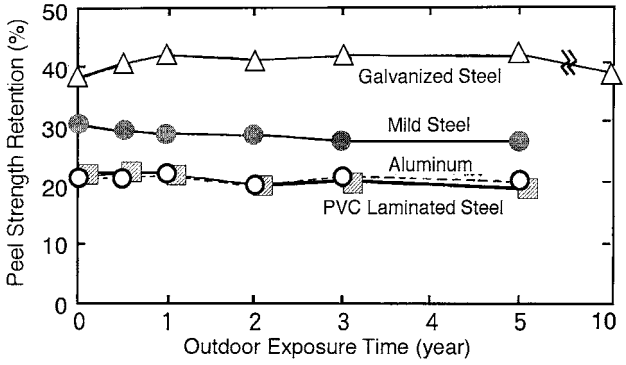

Fig. 8. Results of outdoor exposure tests of adhesion upon various adherents.

4. Reduction of energy consumption

Energy consumption in the manufacturing of metal enclosures shown in Fig. 2 has been calculated. Calculations have been carried out by five model cases shown in Fig. 9–11. Structural modification has been done in order to supplement lowering rigidity of metal enclosures anticipated by reduction in the thickness of sheet metals, so that rigidity of all enclosures are almost the same.

Fig. 9 shows the comparison of electric power use in production processes (from the material reception to the shipping). It is possible that the consumption of electric power is reduced 36% by adopting the combined use of adhesive and rivets as alternative to welding, and is

Table 1
Resonant frequency in vibration testing of metal enclosures shown in Fig. 2

Direction of vibration	Combined Joining (Adhesive and Rivets)	Welding
Right and left (Hz)	8.8	5.0
Front and back (Hz)	9.5	9.3
Top and bottom (Hz)	>55.0	>55.0

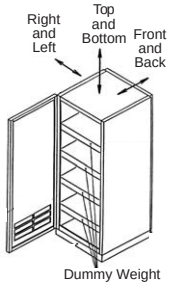

Table 2
Comparison of weight of products, work time, cost, construction period and factory noise

	Welding—combined joining (adhesive and rivets) Mild steel Full-painted		Galvanized steel Half-painted		Prepainted steel
	3.2 mm thick	2.3 mm thick		1.6 mm thick	
Weight of an enclosure	100% (246 kg)	82% (201 kg)	82% (201 kg)	57% (140 kg)	57% (140 kg)
Work time (%)	100	69	53	58	36
Cost (%)	100	80	69	70	61
Work period (%)	100	82	73	73	64
Noise of factor (phon)	98	80	80	80	80

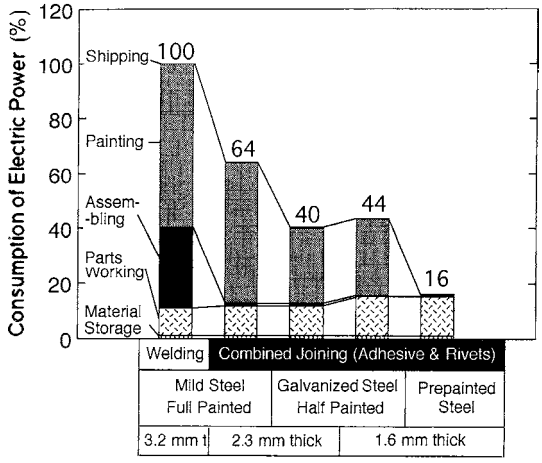

Fig. 9. Change of consumption of electricity in manufacturing process of an enclosure.

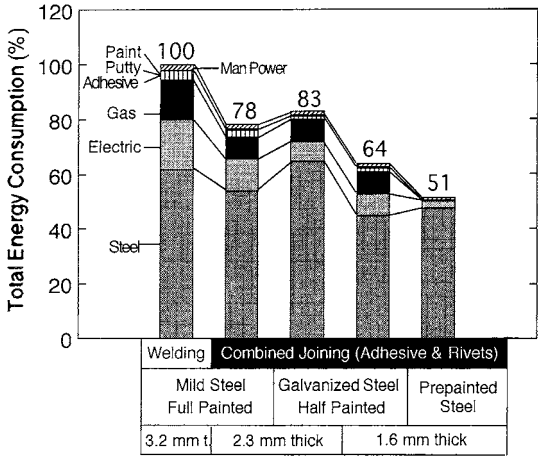

Fig. 11. Change of total amount of energy consumption from mining iron ores and crude oil to completion of enclosure assembling.

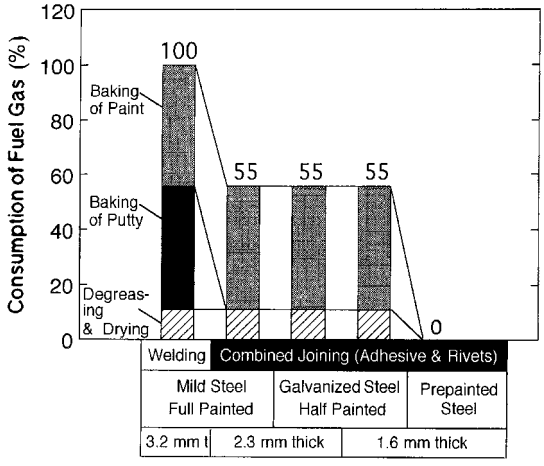

Fig. 10. Change of consumption of heating fuel gas used in the painting process of enclosure factory.

reduced 60% by omitting the painting of the inner surface by converting it into galvanized sheet metal. Moreover, 84% of electric power can be reduced when pre-coated steel panels were made into.

Fig. 10 shows the comparison of the amount of fuel gas consumed on painting and putty processes. Since the drying of the putty becomes unnecessary, the consumption of fuel gas is reduced by half. Naturally it becomes zero for use of pre-coated steel.

Even if the energy consumption in the control panel factory was able to be reduced, it must be a problem if energy consumption in the material supplier reversibly increases with the material function enhancement. Then, the energy amount consumed from the raw material mining stage (iron ores, crude oil) to the material completion was calculated on steel and galvanized steel, pre-coated steel, coating material, putty, adhesive. By totaling these with electric power and fuel gas shown in Figs. 9 and 10, the overall energy consumption was calculated. The result is shown in Fig. 11. Total energy consumption decreased to 78% by adopting the combined use of adhesive and rivets from the welded structure, to 64% by thinner galvanized steel and to 51% by pre-coated steel. Still, it is necessary to consider adopting thinner metal plate in order to achieve further energy reduction because energy consumption to produce steel is considerably high.

5. Conclusion

We have developed a new assembly method of metal enclosures in which the combined use of acrylic adhesives and rivets is adopted as an alternative to arc welding. We have achieved the following effects: (1) elimination of skill working, (2) improvement of working environment, (3) simplification of manufacturing process, (4) compatibility of rigidity with weight reduction, (5) total energy consumption decrease to 78% by adopting this new assembly method from the welded structure, to 64% by thinner galvanized steel and to 51% by pre-coated steel.

This report is an improvement on the content presented at the SAE VI (Sixth International Conference on Structural Adhesives in Engineering) on 4–6 July, 2001.

References

[1] Haraga K, Tani N, Midorikawa A. 38th Adhesion Society of Japan Annual Conference Extended Abstracts, Osaka, Japan, 2000. p. 7.