# Joining of Cold-Reduced Carbon Steel Sheet and Aluminum Sheet by Impulsive Riveting Method and Punch Riveting Method

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**Abstract- The impulsive riveting method is described as the punching and joining of sheet metal carried out using the impulsive energy of a weight accelerated by an air compressor. Parts are held together between the rivet and rivet-holder. A hole is made in the sheets by the high speed collision of rivet and a weight (approximately 100 m/s or more). Another method, punch riveting, joins the sheets by pressing the rivet through with a press machine. The rivet and rivetholder are also used in this method. The deformation and strength of joined sheets were compared for each method, as influenced by the speed of the rivet. In this study, impulsive riveting and punch riveting were applied to the joining of cold-reduced carbon steel sheet and aluminum sheet, and their effects on the deformation and strength of joints was examined. The results clarify the characteristics of each riveting method for joining dissimilar sheet metals..**

**Keywords –Joining, Impulsive riveting method, Punch riveting method, Dissimilar sheet metals, Joint strength**

## I. INTRODUCTION

Cost reduction and labor saving in automotive production has been driving the use of theself-piercing rivet for joining automobile parts [1, 2]. This is an excellent method as sheets are joined without drilling, working time is very short, the automation easy,and it is capable of joining dissimilar sheet metals. Unfortunately, the method results in deformation of parts and joint strength is not high [3].

We previously proposed new riveting methods that do not require drilling[4–8]. The joints made by these riveting methods can be separated because a rivet and rivet holderare used instead of more permanent methods. The impulsive riveting method joins two sheets by punching and joining using kinetic energy [4, 5]. A hole is made in the sheets by the collision of the rivet and a weight at a speed of 100m/s or greater. In the punch riveting method, the punching and joining of sheets are carried out by pressing the rivet into them [6, 7]. The punch speed is equal to the operation speed of the press machine. We comparedthe experimental results of thesetwo methods to determine the effect of punch speed on the deformation and strength of joined sheets.

Improved joint properties can result when using the merits of each material. This is often done for weigh reduction and to improve joint strength. When sheet metals with dissimilar strengths are fastened by caulking, the lower strength material becomes deformed and joint strength greatly decreases. To avoid this, a riveting method for joining dissimilar sheet metals with different strengths is necessary.

We clarified the characteristics of joints where impulsive riveting and punch riveting were used to join dissimilar sheet metalswith different strengths. We joined cold-reduced carbon steel sheet with aluminum sheet, and then the deformation and strength of the joints were examined experimentally. We then clarified the characteristics of each riveting method when joining dissimilar sheet metals.

## II.MATERIALS AND PRODUCTION METHOD

### *A. Impulsive riveting method –*

Figure 1 shows the shape and dimensions of the lap joint made of dissimilar sheet metals. An aluminum alloy sheet (A1050P-H24) with a thickness of 1.0mm and a cold-reduced carbon steel sheet (SPCC-SD) with a thickness of 0.8mm were joined by the impulsive riveting method and punch riveting method.

Figure 2 shows the shape and dimensions of a rivet, a rivet holder and a die for the impulsive riveting method.

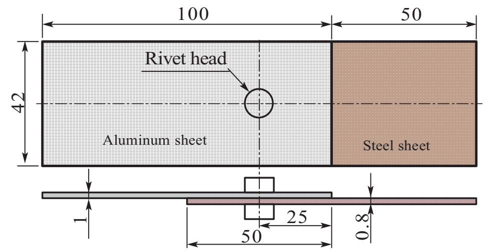



Figure 1.Dimensions of joint

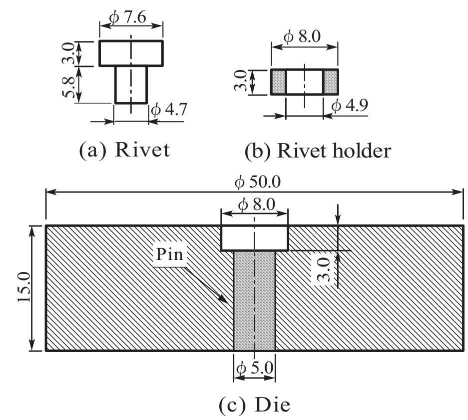



Figure 2. Shape and dimensions of rivet, rivet holder and die

Figure 3 shows the experimental equipment. Figure 4 shows the schematic illustrations of the impulsive riveting method. The impulsive riveting method was performed as follows:

(1) Air compressed to a pressure of 1 MPa by the compressor (Toshiba SP14-22T7: L2-2kW) is accumulated in the air reservoir, as shown in Fig. 3. The weight shown in Fig. 4(a) is set in the upper part of the circular pipe. It is supported by a pin linked to the launch switch.

(2) The rivet holder is inserted into the hole of the die. Two sheets without holes are then set on the die, as shown in Fig. 4(a). They are set under the exit of the circular pipe and the rivet is set so that the tip of the rivet shank can contact the sheet.

(3) By opening the air reservoir valve andremoving the pin that supports the weight, the weight is accelerated by the compressed air and collides with the rivet head set on the sheets.

(4) The rivet shank penetrates the sheets and passes into the hole in the rivet holder set under the sheets. The rivet shank finally collides with a pin inserted in the die, and the rivet shank and rivet holder are joined by plastic deformation of the rivet shank. The sheets are held tight between the rivet head and rivet holder, as shown in Fig.4(b).

A weight made of alloy tool steel SKD 11 with a diameter of 7.5 mm, a length of approximately 10 mm, and mass of 3.3 g was used for the experiments. The weight collided with the rivet head with an average velocity of 100m/s. The velocity of the weight was measured using two light sources and two photo-sensors set in the circular pipe, as shown in Fig. 3. The kinetic energy of the weight was approximately 38 J.

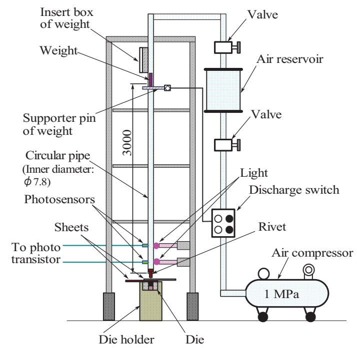



Figure 3.Experimental equipment used for impulsive riveting method

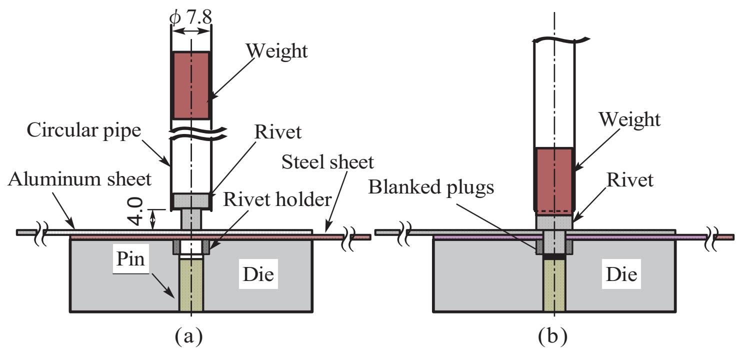



Figure4.Schematic illustrations of impulsive riveting method

*B. Punch riveting method –*

Figure 5 shows schematic illustrations of the punch riveting method. The rivet, rivet holder, and the die shown in Fig. 2 were also used in this riveting method. The punch riveting method was performed as follows:

(1) The rivet holder is inserted into the hole of the die. Two sheets without holes are set on the die. The rivet is then set on these two sheets, as shown in Fig. 5(a).

(2) The rivet shank is pushed into the sheets by pressing the rivet.

(3) The rivet shank punches out the sheets and enters into the hole in the rivet holder. The rivet shank and the rivet holder are joined by plastic deformation of the rivet shank. The sheets are held tight between the head of the rivet and the rivet holder, as shown in Fig. 5(b).

Punch speed and pressing load were 10mm/min and 20kN, respectively.The conditions used for each riveting method are shown in Table 1. The joint is called the T1-A joint when an aluminum sheet was lapped on a steel sheet and joined using the impulsive riveting method, and it is called the T1-B joint when a steel sheet was lapped on an aluminum sheet and joined. Similarly, the joint is called the T2-A joint when an aluminum sheet was lapped on a steel sheet and joined using the punch riveting method, and it is called the T2-B joint when a steel sheet was lapped on an aluminum sheet.

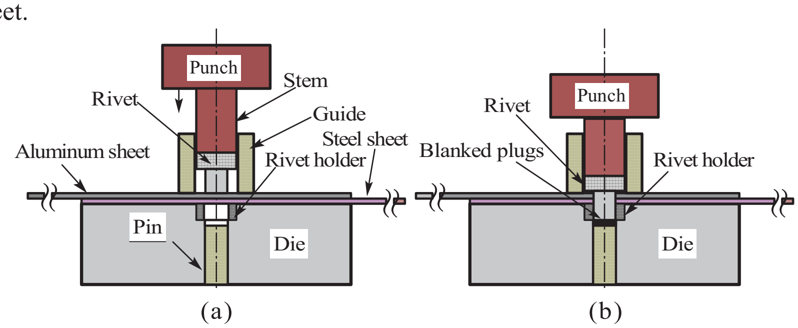



Figure 5. Schematic illustrations of punch riveting method

Table -1 Riveting conditions

| Joint | Riveting methods | Conditions |
|---|---|---|
| T1-A | Impulsive riveting<br>Velocity of weight: 100 m/s<br>Impact energy: 38J | Upper sheet:<br>aluminum sheet |
| T1-B | | Upper sheet: steel sheet |
| T2-A | Punch riveting<br>Punch speed:10 mm/min<br>Pressing load: 20 kN | Upper sheet:<br>aluminum sheet |
| T2-B | | Upper sheet: steel sheet |

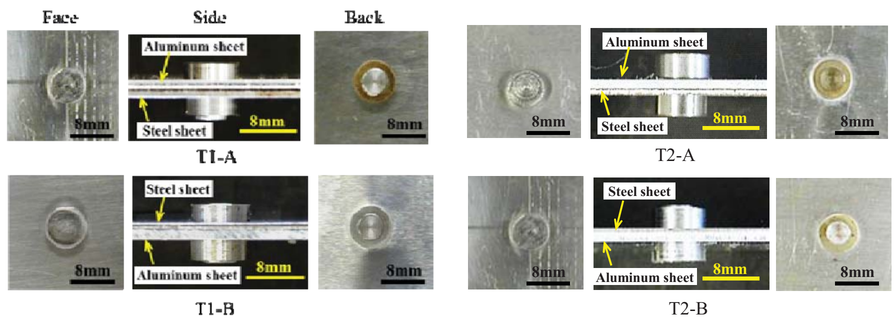
*C. Tensile Shear Test of Joints –*

To evaluate static joint strength, a tensile shear test on the joint was performed using a tension tester(Shimadzu Corp., AG-X50kN). In the tensile shear test, both edges of the joint were held using offsets between the upper chuck and the lower chuck to make the two sheets effectively parallel. The joints were pulled at a tension speed of 10mm/min.

## III. Experimental Results and Discussions

*A. Aspects of fastening parts of joints –*

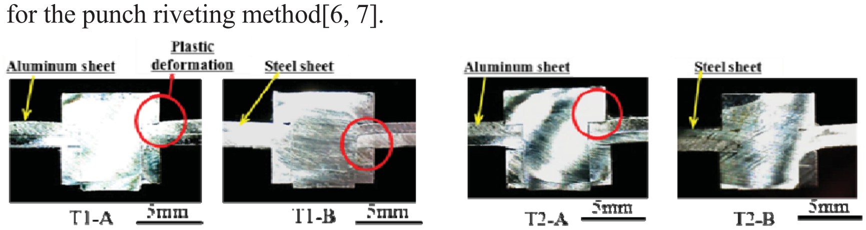
Figure 6 shows the aspects of fastening parts of the joints. These photographs show that an aluminum sheet and a steel sheet can be joined by both the impulsive riveting method and the punch riveting method without drilling.




(a) Impulsive riveting method (b) Punch riveting method

Figure 6. Aspects of fastening parts of the joints

Figure 7 shows cross sections of fastening parts of joints. The sheets were fastened uniformly with the rivet head and rivet holder in both the joints made by the impulsive riveting method and punch riveting method. The deformation around the fastening parts of the joints was very small. We found that the thickness of an aluminum sheet in the area fastened by the rivet head and rivet holder(the area surrounded by the red circle) was decreased. The reduction in the thickness of the aluminum sheet for the joints made by the impulsive riveting method tended to be slightly larger than that of the joint made by the punch riveting method. The thickness of the aluminum sheet decreased because aluminum sheet deforms plastically with lower flow stress under compression by a rivet head and a rivet holder with a higher flow stress. Because the reduction in the thickness of the aluminum sheets for the joints made by impulsive riveting was greater than that of the joints made by the punch riveting method, we concluded that the aluminum sheet was deformed to a greater degree because of the large force generated by the collision of the weight and the rivet. A good joint can be obtained if the impact velocity is suitable but when using compressed air, control of the impact velocity is very difficult. To determine the appropriate impact velocity, we have proposed the method of estimating the appropriate kinetic energy of the weight in the impulsive riveting method from the working energy necessary for the punch riveting method[6, 7].




(a) Impulsive riveting method (b) Punch riveting method

Figure 7. Cross sections of fastening parts of joints

*B. Joint strength –*

Figure 8 shows the aspects of joints fractured by the tensile shear tests. All the joints were fractured by extension of the holes in the aluminum and steel sheets.

Figure 9 shows the comparison of joint strength. The bar heights in the graph are the average of 5 samples and the error bars correspond to the standard deviation. InFig. 9, joint strength using the caulking method is also shown. The data from the caulking method was obtained from previous experiments [8]. In the caulking method, the sheets were joined by pressing the rivet shank with a load of 35kN using a flat punch. The diameter of the formed rivet head was approximately 1.6 times the initial diameter (4.7 mm) of the rivet shank as a necessary condition for riveting [9].The joint is represented as the T3-A joint when an aluminum sheet is lapped on a steel sheet, and it is represented as the T3-B joint when a steel sheet is lapped on an aluminum sheet.From the experimental results, the strength of T1-B, T2-B, and T3-B joints in which a steel sheet was lapped on an aluminum sheet was almost the same. In contrast, when an aluminum sheet was lapped on a steel sheet, the strength of the T1-A joint made by the impulsive riveting method was higher than that of the T3-A joint made by the caulking method, but lower than that of the T2-A joint made by the punch riveting method. For the T1-A joint, we attributed the decreased strength to the reduction of the aluminum sheet thickness. Similarly, the decreased T3-A joint strength is believed to be caused by the large reduction in the thickness of the aluminum sheet [8]. This result shows the usefulness of the punch riveting method for joining dissimilar sheet metals.

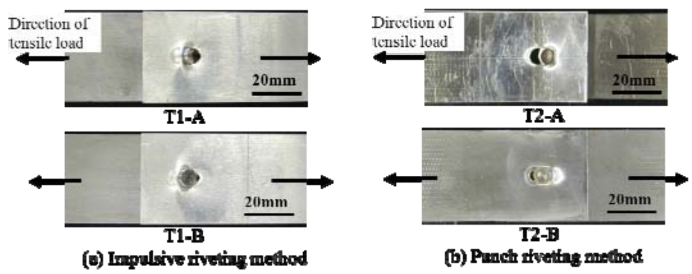



Figure8.Fracture of joints

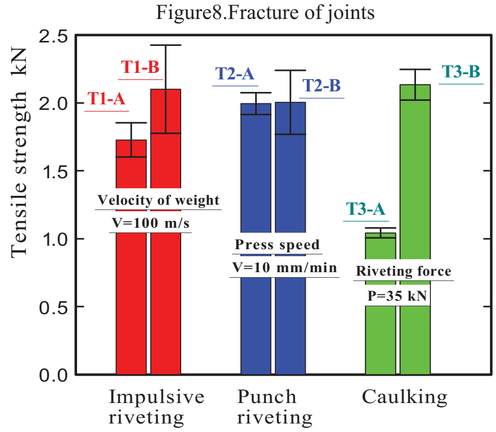



Figure 9. Strength of joints

## IV.CONCLUSIONS

This study clarifies the characteristics of joints where impulsive riveting and punch riveting methods were applied to the joining of dissimilar sheet metals. The joining of cold-reduced carbon steel sheet and aluminum sheet was performed using two riveting methods, and the characteristics of each riveting methodon the deformation and strength of the joints were then examined.

When impulsive riveting was used, it was found that joint strength when an aluminum sheet was lapped on a steel sheet was lower than that of the joint in which a steel sheet was lapped on an aluminum sheet. This appeared to be caused by the reduction in thickness of the aluminum sheet in the area fastened by the rivet head and rivet holder. When punch riveting was used, we found that joint strength did not depend on the stacking order of the sheets. Deformation of sheet materials was also small.

We found the punch riveting method very useful for joining dissimilar sheet metals. In contrast, when joining dissimilar sheet metals using impulsive riveting, it is necessary to improve the method so that the thickness of the sheet with the lower flow stress does not decrease.

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