# Mechanical Strength of Single Riveted Lap Joint Al Plates with Flowdrill Operation

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ABSTRACT The shearing strength Aluminum rivets are also very important in many rivet joints that are used at the connections in machinery, structures and so on. However, large scale experiments have been desired. Therefore the authors have evaluated the effect of rivet initial loads, material strength, rivet hole finishes that affect the shearing strength coefficients in contact surface increment. In this report the necessity loads of rivet deformation, rivet holes' shape and maximum joint force are decided. The main obtained conclusions as follow; (A) Best rivet hole size is 1.3 D (D is rivet axis diameter). (B) Maximum shearing strength found that the joint condition for flowdrill hole and solid shaft rivet joint.

Keywords: Rivet joint, Shearing strength, Tightening, Bush, Blind rivet.

## 1. INTRODUCTION

It is pointed out riveted joints will fail certain repeated torque load. Fatigue failure usually occurs in the plate rather than the rivets because the holes the endurance limit of the plate by about one-third. A flowdrilled hole will have a lowest working cost than a drilled hole or punch one. A drilled and reamed hole is best endurance limit and high working cost. Flowdrill operation is a simple operation of rivet hole forming to curved metal sheet and to pipe in low grade joint plane. High speed revolting circular cone shaped tool that made of hard metal feed to material surface. Frictional heat yield between tool tip and material, then softening of cold working material occurs around this contact zone. A bush formed at top and bottom of hole edges with the hole making. In order to antirevolving, special rivet with serrated surface under head or interlocking joint design can also be used. Use bushes for joint if torque loads are expected. Moreover, a decrease in the residual contact stress of a rivet joint induced by degradation of a fastener encourages multiple site damage. To evaluate the relation between the hole tightness of the joint and its residual contact stress, finite element analysis is performed with maximum squeezing displacement, thickness of mating plates and a coefficient of increasing maximum squeezing displacement, and contact area and residual contact stress decrease with increasing plate thickness. The diameter of rivet should be larger than the height of bush. At the same time, it should not be larger in diameter the four times the thickness of the thinnest sheet either head of the rivet. If it is too large or small the pressure required to drive the rivet head may pop damage. Present reports provide table of recommended lengths and various head styles, clearances between the rivet and hole size, and condition of flowdrilling operation.

Appearance of Flowdrill is as quadrangular pyramid which edges rounded, then cross sectional shape cuts with plane perpendicular its axis strained circle, and made it of hard metal. It can work almost metal. As recent reports some plastic sheet formed this method. Working process shown in Fig.1 from left to right side. At first, the tool set up to high speed and automatic feed drilling machine.

Then,

(A) Tool tip contacts with upper surface of material ( Aluminum sheet t=1.5 mm ).

(B) The tool feed by machine and indented into sheet material. Contact area between material and the tool become wide, and material near the tool softened by frictional heat between them.

(C) Set up a cold headed Aluminum-rivet (solid axis) in the flowdrilled hole.

(D) Tightening operation finished by an automatic riveting machine.

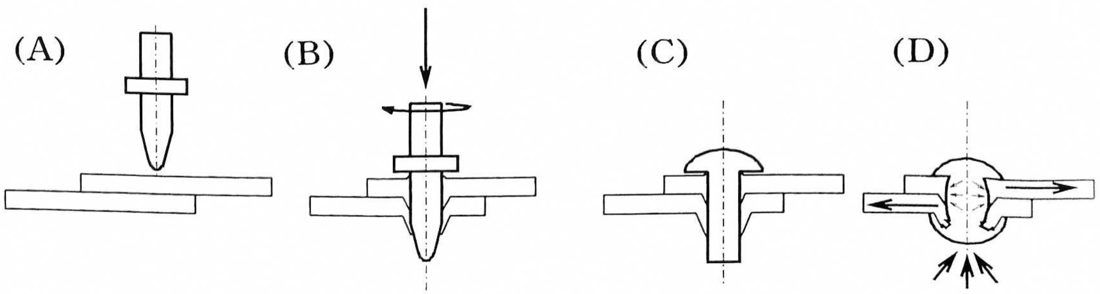



Fig.1 Waking process of flowdrill operation; (A) starts, (B) bush forming, (C) rivet forming (D) finish of rivet joint.

The dimensions of bush part $B_{up}$, $B_{down}$ and $B_t$ are shown in Fig.2 with blind rivet. The merit of this operation is as follows: The making a hole, forming of bushing and sealing of edge can perform one process. Essential part of forming mechanism for this method is material softening by increasing temperature through generation of frictional heat between tool and material. Hence, it desired that high concentration of heat yield in small area of material that is in contact with tool. Material that has low thermal conductivity is proffered this point of view. Furthermore, material that has higher rigidity than ductile one also preferred, because the former subject only small deflection with working process than the latter. Because these points of view, Aluminum sheet has high thermal conductivity and high ductility, therefore, Aluminum(A2041-O/H24) is dormant difficult material with this operation. Therefore, these indicate that we could form Aluminum with this operation in various aspects, then adjustment of conditions. It is very valuable to simplistic systems because light joint of this material. Mechanism of bush forming with Flowdrill studied for sheet metal [1] and plastics [2], but strength and of threaded bush, of riveted bush not yet studied. One of authors investigated the strength [3] of threaded strength for bolt joint, experimentally. In this report,the following contents treated.

1) Bush forming process used to lap joint sheets.
2) Shear strength of the sheets measured for bush+rivet or bush+blind rivet.

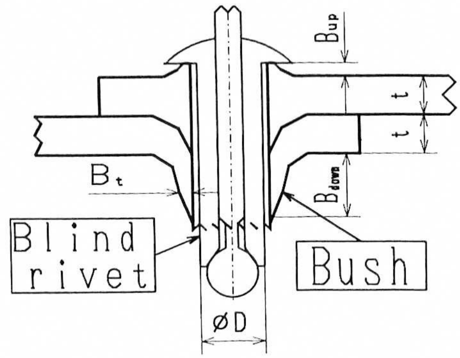



Fig. 2 Bush dimensions at each parts: $B_{up}$ upper; $B_{down}$ down hieght; $B_t$ thickness.

## 2. EXPERIMENT

The shape of a die and a flowdrill influenced upon hole-workability. (1) Experimental method: The dimensions of a die and flowdrilles used in this experiment are shown in Fig.3(a), in which the diameter of the die dd is fixed to a constant value of 10 mm, but the diameter of the flowdrilles varied for 3 kinds of 4.0, 5.0 and 6.0 [mm]. The blanks are of 3.0, 2.0 and 1.6 mm thick in nominal size. For the material of the specimens, the rolled aluminum sheets of 99.5% purity sold at the markets are used which, after shearing to rectangular plates of 20 mm X 50 mm are annealed at 340°C for one hour. This annealing temperature was decided to this value because at the temperatures 300°C and 350°C. The formation of ear was observed. In these tests, used apparatuses are high speed drilling machine with rotary speed at 1575 up to 3675 rpm and feed speed at 110 up to 750 mm/min. Riveting machine, torsion tester of 5kgf·mm and torsion tester of 5 Ton Instron type are used. The breaking tests are performed by setting the tightening specimen [ see Fig.3(b)] in the tension part of the 5 Ton universal testing machine at the velocity of 2.0 to 30.0 mm/sec and recording the shearing force Sf and displacement stroke L, automatically.

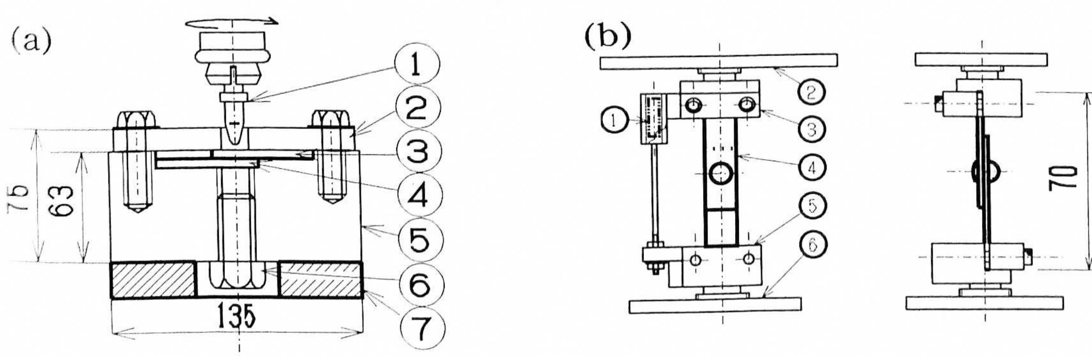



Fig. 3(a) Setting of the test piece. ① flowdrill,② upper part,③ test piece 1, ④test piece 2, ⑤down die,⑥ bolt, ⑦ vice; Fig. 3(b) Schematic of experimental apparatus for shearing force,① differential transformer,② upper beam,③ jig,④ specimen,⑤ jig,⑥down beam.

## 3. STRESS ANALYSIS BY MEANS OF TWO DIMENSION FINITE ELEMENT METHOD [4]

Figs.2 (a), (b) show the finite element representation of flowdrilling hole rivet and standard rivet joint. A set of orthogonal axes is defined by the X- and Y-direction, as shown in Fig.2 (a). The X-direction is the radial direction of rivet and the Y-direction is the axis-direction of rivet. The finite elements are axis symmetric with respect to the axis of rivet. These finite element models are composed of the rivet down edge. In boundary conditions, the material end is restricted constrained, and then; the load is applied to the lower side of the rivet in the plus Y-direction. Assuming the load is uniform in the radial direction; this load is applied to the section of the rivet equivalently. In this study, the rivet size used is 4.8X15 or 5X15 [mm] and the material is decided with A2041. The Young's modulus and Poisson's ratio are given 7200 kgf/mm$^2$ and 0.3 as the material conditions. Table 1 also shows the stress analysis conditions.

Table 1 FEM Analysis conditions

| | material | Solid Rivet |
|---|---|---|
| Young's mod. [kgf/mm$^2$] | 7200 | 7200 |
| Poisson's rat. | 0.34 | 0.34 |
| Axial comp. [kgf] | —— | 300 |
| Element No. | 120 | |
| Nodes No. | 423 | |

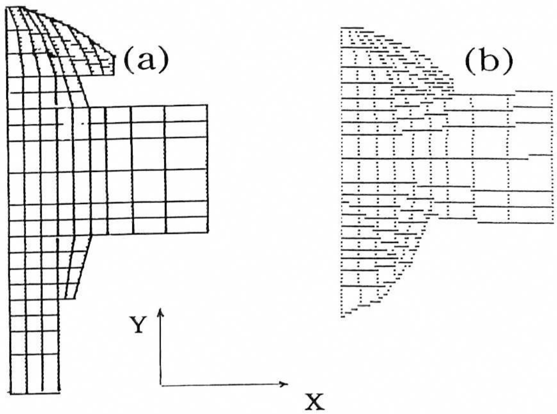



Fig.2 (a) Axis symmetric finite element representation.
Fig.2 (b) Example for deformation of rivet tightening.

An example of deformation of flowdrilling hole rivet under the appropriate compressing force is shown in Fig.2 (b). In the figure, the shape before deformation is shown by the continuous lines, and the shape after deformation is shown by the dotted lines. It is seen that deformation of the lower rivet part is larger than that of top one. From these analytical results, it is considered that the applying stress and the deformation of rivet or material can be controlled by means of flowdrilling bush forming.

## 4. EXPERIMENTAL RESULTS

A few tightening experiments were carried out for rivets with the flowdrilling hole, as compared with the standard rivet. The hole was drilled at the revolution 3150 rpm using an electric driver in dry conditions. And the relationship between the stress and strain was recorded in X-Y recorder. Fig.4 (a) shows an example of the relationship between the stress and strain curves. In this experiment, a maximum force of flowdrilling hole 5 mm rivet was

187.1 [kgf]; and shearing stress was 93.4 MPa; Wb was 8.02 [joule] as shown Fig.4(b). When the flowdrilling hole rivet tightened until broken, the shearing force does not decrease as compared with the standard rivet as shown in Fig.4. Because the relative slip between the rivet head and the tighten material due to the deformation of rivet axis does not produce, and then flowdrilling hole rivet is broken. From the results of this experiment, it is found that the tightening force can be controlled by the hole bush height within this experiment. In Fig.4(a), the relation between the stress–strean curve is shown in the case in which the thickness of the blank t=1.5 mm, the diameter of flowdrill D=5 mm, the clearance between die and the Flowdrill c=0.2mm and baseline is used for non lubrication. It is shown in the figure, Fig. 4(b); the Wb vs. D for the case of blind rivets are shown by taking the matirials(O/H24) as a solid or dotted line. In both curves, the curves are seen similar, and we are to consider hereafter the maximum tensile force in stress vs.strean curve as the representative value of the performance in flowdrilling, respectively. The drawing speed of flowdrill Sf is varied, the stress vs. streain curves become varied. The influence of bush to the Wb is shown in Fig.4(b) with solid line. According to these curves, the Wb value increases of D and the break limits go up with the increment of bush height.

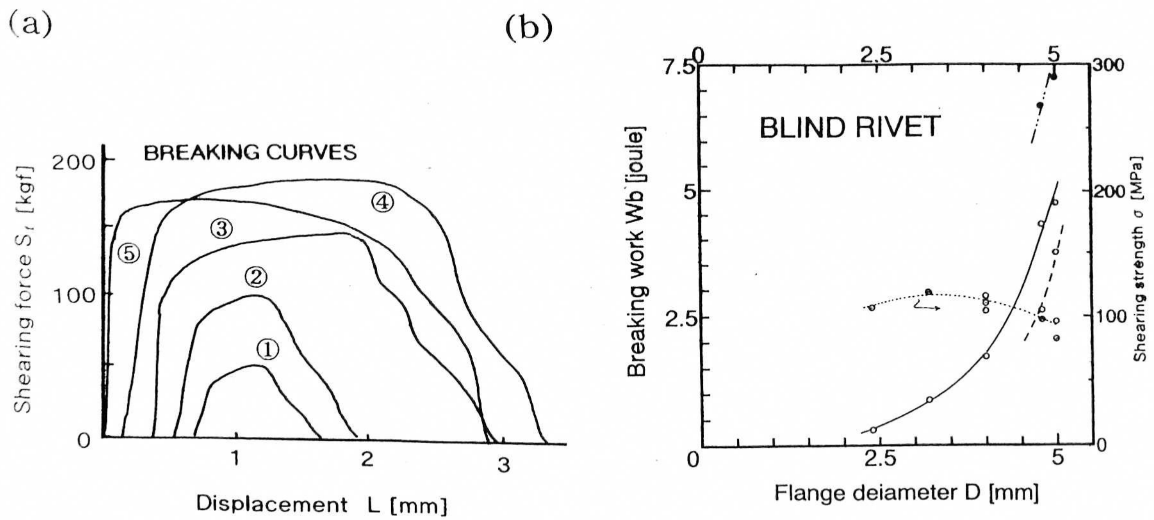



Fig.4(a) Stress strain curves of blind rivet, ①blind rivet φ2,② φ3,③ φ4,④ φ4.8 ⑤ Standard rivet φ5; Fig.4(b) Relation between shearing work Wb and rivet diameter D for H24, ●; indicate shearing strength of flowdrilling + blind rivet operation.

## 5. CONSIDERATIONS

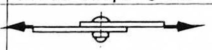
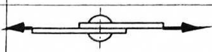
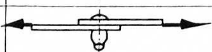
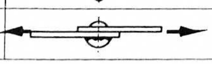
The estimate value of breaking work Wb for each rivet joint obtained by the following equation:

$$Wb = \Sigma F_i \Delta X_i \quad (1)$$

where, $F_i$ is shearing force at i-th, and $\Delta X_i$ is strain width at i to (i+1)th point. In the simple rivet joint for $\phi$5, namely, in the first stage of experiment, obtained, the result is Wb=5.3 [joule].

In the case of flowdrilling hole and standard riveting joint, it is found that the shearing strength of rivet is 20～30% greater than that of the blind rivet because of Bush-effect. It is considered that work hardening at rivet hole by cold working and the relaxation of stress concentration to arise from the change of engagement state of rivet axis and material affects to the strength. In opposition to the above-mentioned example, the case of drilling hole and blind riveting has little effect on the shearing strength when the force less than maximum load at pure tension is given to the present test.

Table 2 Values of maximum shearing strength $F_m$, Wb, maximum shearing force $F_o$
Illustrations are indicated of each riveting shape.

| | $F_m$ MPa | $W_b$ | Rivet shape 5 mm | Fo kgf |
|---|---|---|---|---|
| BLIND RIVET | 71.8 | 6.45 |  | 143.9 |
| RIVET | 76.4 | 5.30 |  | 153.0 |
| BLIND RIVET+FD | 86.8 | 7.29 |  | 174.0 |
| RIVET +FD | 93.4 | 8.02 |  | 187.1 |

## 6. SUMMARY

The results of FEM analysis about rivet joints and a few shearing experiments may be summarized as follow:

(1) The deformation of flowdrilling+rivet is larger as compared with the standard rivet.

(2) The stress distribution over the yield strength was observed over a wide range in flowdrilling+rivet.

(3) According to the stress distribution on the rivet, the tightening force can be controlled by the bush with flowdrill operation.

(4) Therefore, it is considered that a rivet joint by means of the flowdrilling hole is a useful method for the increase of tightening force.

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