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A Study on Burr Low Frequency Vibratory Drilling

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Abstract

This study deals with effects of the cutting condition, cutting force, shape of chip, cutting phenomenon on burr shape during low frequency vibratory drilling. The cutting characteristics were examined and compared with those during the conventional drilling. From this study, it was found that the application of this method for drilling of aluminum (JIS A1050-0) would be effective to prevent the burrs.

1. Introduction

During drilling, a burr is always formed at the inlet and outlet of a drilled hole. Such burrs are often the cause of various problems [1,2] during automatic machining processes. Therefore, it is very useful to find out an effective method to prevent the burrs during drilling processes. Under such a present situation, the low frequency vibratory drilling [3] was chosen as one of the subjects of our studies, that is, effects of the cutting force, chip shape, cutting phenomenon on burr shape during low frequency vibratory drilling were examined and compared with those during the conventional drilling.

2. Experimental Methods

2.1 Experimental Apparatus

The experimental study was conducted using a vibratory device (electro-hydraulic servo-system, maximum frequency 100Hz), which was made by authors as shown in Figure 1. The vibratory device is attached to the spindle shaft. The drill can be vibrated in the axial direction at the rate of 1～10 times per one revolution of the spindle. Also the vibratory drill was equipped with a quick-stopping device because of examine the behavior for the plastic deformation of burr.

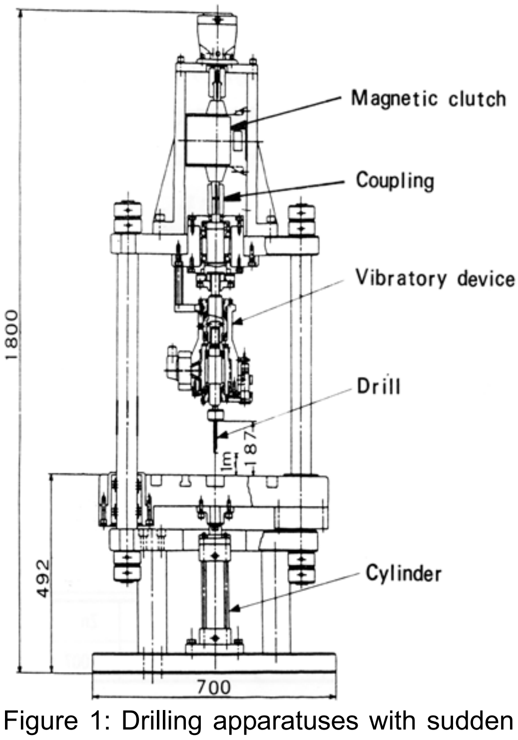

Figure 1: Drilling apparatuses with sudden stop experimental equipment.

2.2 Workpiece and Drill

The workpiece used in this experiment is an annealing aluminum plate of high purity (JIS A1050-0, 99.57%, 100X35X15mm).

Tables 1 and 2 show the chemical composition and mechanical properties of the workpiece (aluminum).

The drills (diameter of 5mm, SKH56) were selected from the same manufacturing lot to remove the possibility of any error due to the manufacturing process. Figure 2 shows the drill dimensions.

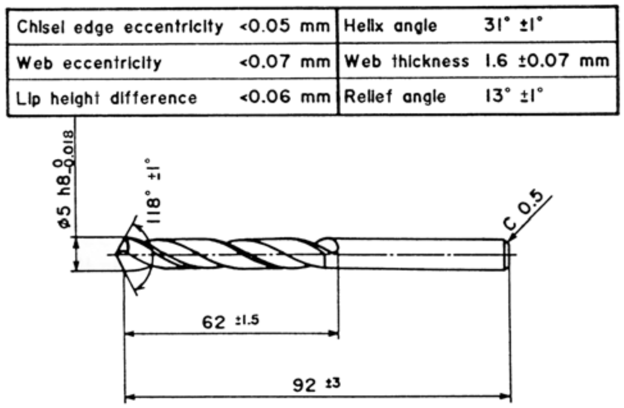

Figure 2: Drill Dimensions.

Table 1 Chemical composition of workpiece.

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.05	0.35	0.0005	0.003	0.002	0.002	0.007	0.0018	99.57

Table 2 Mechanical property of workpiece.

Tensile strength MPa	Yield strength MPa	Elongation %	Vickers hardness Hv
76.3	51.6	56.2	32.4

3. Experimental Results and Discussion

3.1 Relation Between Number of Drilled Holes and Burr Shape

The effect of the number of drilled holes on burr size was examined. The burr size changes as the number of drilled holes increases. Then, the relation between the number of drilled holes and burr shape in cases of W_f=0, 1, 2 was assessed. The relation between the number of drilled holes and the burr shape are shown as an example in Figure 3.

In this case, the number of revolution of the drill is 810 rpm. When W_f=0, the drill broke after drilling 13 holes. However, when W_f=1, 2, the drill did not break even after 13 holes had been drilled. Burr height in the case of W_f=1 is uniform. On the other hand, when W_f=2 the burr shape was not as uniform as that when W_f=1. When W_f=0 burr height was large and showed the petal type shape at the first step of drilling and the drill lip became duller as the number of drilled holes increases. In addition, chip ejection was also prevented. Therefore, the chisel edge of the drill sticks out from the drilled hole later due to chip packing.

Consequently, the burr root bulges out largely and burr height become uniform and burr thickness is increased to a great extent. Further, the burr having a conical chip is formed.

As is evident from the above results, the burr shape when W_f=1, 2 is generally smaller than was seen at the other numbers of revolutions.

These results correspond to the tendency of the burr size and area ratio of burrs as mentioned above. Therefore, burr can be more effectively prevented when W_f=1 than when W_f=2.

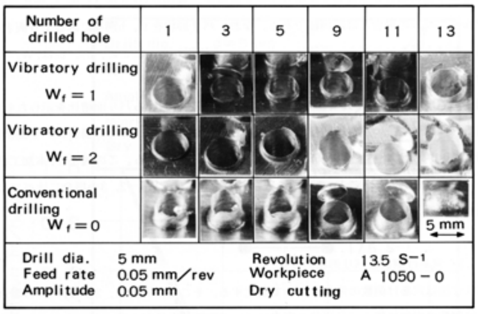

Figure 3: Comparison of the burr shape in the case of W_f = 1,2 with that of W_f = 0.

Next, Figure 4 shows the cross sections of the burrs occurring for 1, 6, 12 drilled holes. From this figure, it can be seen that the burr size when W_f=1 is very small in comparison with that when W_f=0, and the burr size when W_f=1 is hardly affected by the number of drilled holes. On the other hand, the burr size when W_f=0 decreases as the number of drilled holes increases. On the contrary, t and R are reversed, that is, when one hole is drilled h=5.2mm, t=1.1mm, R=0.52mm, when 6 holes are drilled, h=4.6mm, t=1.4mm, R=1.8mm; and when 12 holes are drilled, h=4.1mm, t=1.6mm, R=2.5mm. From these results that of W_f=0, t and R when W_f=0 become gradually larger. Especially, when t and R are large burrs are formed just before drill life due to the chip packing.

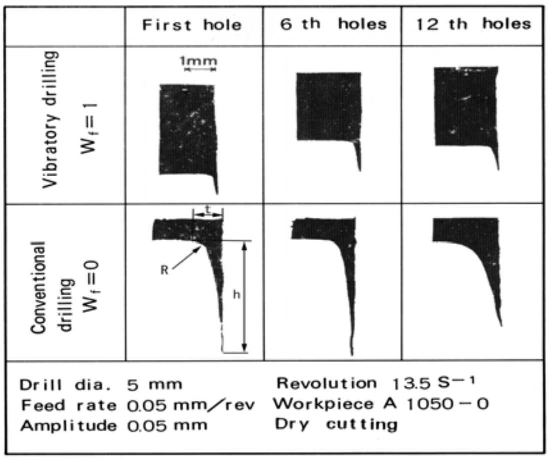

Figure 4: Comparison of cross sectional photographs of the burr in the case of W_f = 1 with those of W_f = 0.

3.2 Metal Flow and Hardness Distribution of a Burr

Figure 5 shows the micro photograph and hardness distribution in the cutting edge division during drilling with quick-stopping device. That is to say, this figure shows to compare the chip generation mechanism of the cutting edge division of drill for W_f=1, 0.

From this figure, it is found that the cutting thickness at the burr root in case of W_f=1 become bigger than that of W_f=0. Also, when W_f=0, the hardening zone occurs in a direction perpendicular to the feed of drill from the inside surface of the hole to the range of 200 μ m, and scattering of hardness is observed. On the other hand, when W_f=1 the hardening zone occurs in a wide range of about 50 μ m from the inside surface of hole and when W_f=1 the zone of metal flow becomes narrower than that of W_f=0. For this reason, it is considered that when W_f=1 the chips are easily and rapidly ejected from the drill flute and the heat at the root of the burr becomes smaller than that of W_f=0.

On the contrary, as mentioned above, when W_f=0 the burr enlarges due to the increase of the chip packing and the zone of metal flow. Therefore, it is considered that when W_f=0 the burr is larger than When W_f=1.

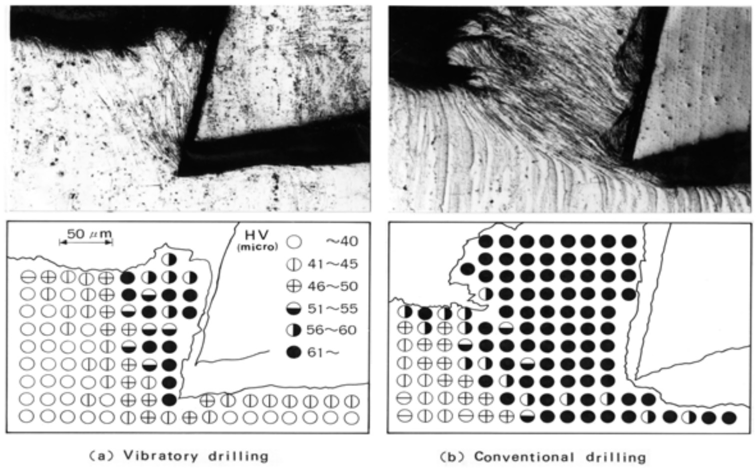

Figure 5: Micro photograph and hardness distribution in the cutting edge division by quick-stopping device.

3.3 Effect of Cutting Force on Wlongation

Next, in order to examine information of hardness difference (relation between cutting force and prestrain), a static tensile test was carried out using universal test machine (30t maximum load). That is to say, the change of hardness was adopted by giving the elongation (prestrain) of test piece. In this case, the test piece (JIS) No.5) was made from the A1050-0 material and elongation of 10%, 20%, 30% and 40% were respectively given to each test piece.

Figure 6 shows the relationship between hardness and elongation percentage. That is to say, the hardness of the test piece of normal structure of 0 elongation percentage becomes 32Hv (micro), and it becomes 42Hv (micro) in case of the 40% elongation percentage. Therefore, the hardness of the 40% elongation percentage increased about 29% in comparison with that of 0 elongation percentages.

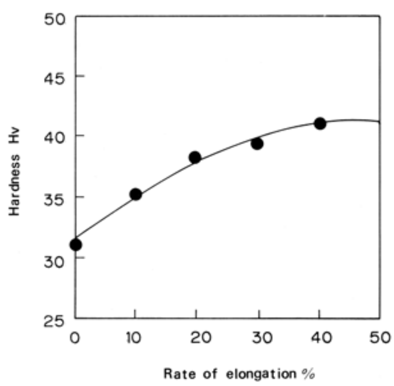

Figure 6: Relationship between hardness and elongation.

Figure 7 shows the relationship between cutting force (thrust, torque) of W_f=1, 0 and elongation percentage. Figure (a) is in case of 0% elongation percentage, and figure (b) is in case of 40% elongation percentage. From these figures, it is found that the cutting force (thrust, torque) of 0% elongation percentage increase with the hole deepening. In the vibratory drilling (W_f=1), the dynamic component with the width thrust and torque almost fixedly produces to the hole penetration. That is, the static component of thrust and torque of W_f=1 tends to drastically lower than that of conventional drilling (W_f=0). And, when W_f=0, the dynamic component of cutting force (thrust, torque) of 40% elongation percentage unstable appears in comparison with that of W_f=1. Then, the tendency increases with the increase until drilled hole penetration. On the other hand, when W_f=1, dynamic component of cutting force (thrust, torque) of 40% elongation percentage is shown almost similar tendency such as the case of the 0% elongation percentage.

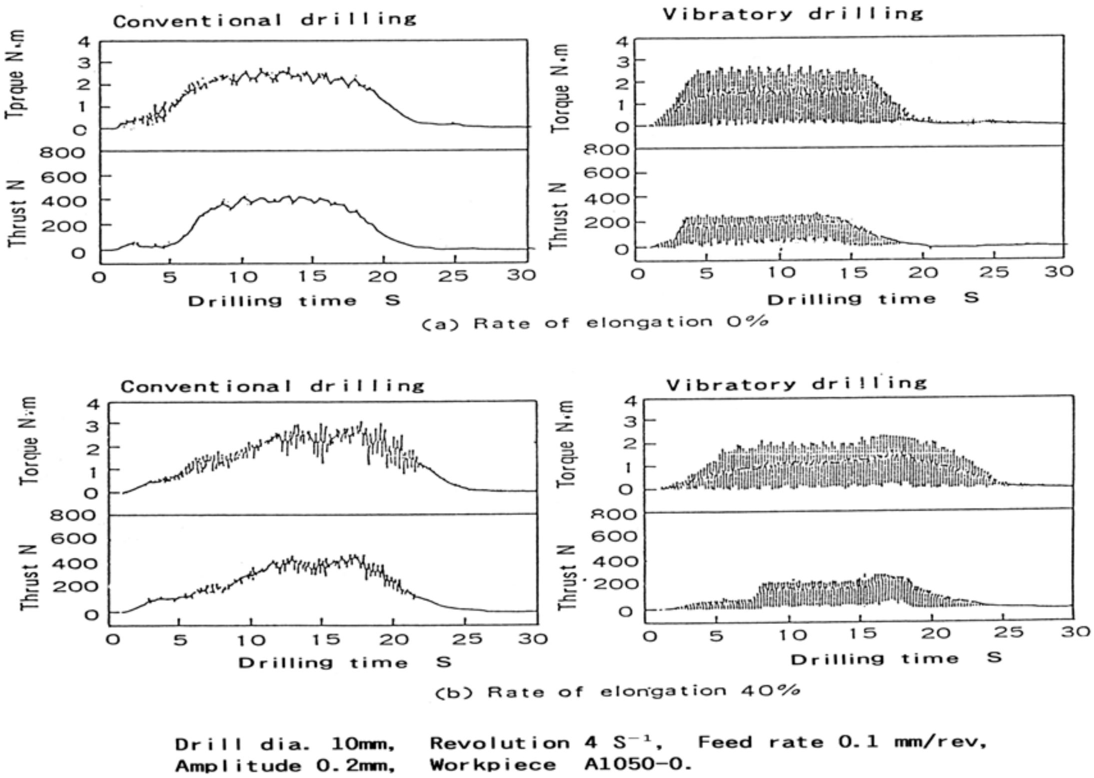

Figure 7: Effect of the processing strain on cutting force.

Figure 8 shows relationship between prestrain (elongation) and cutting force against to the static component. From these figures, it is found that the cutting force of vibratory drilling (W_f=1) generally lowers in comparison with conventional drilling (W_f=0). That is to say, the cutting force of W_f=0 in case of 0 elongation percentage becomes respectively thrust about 360N, torque about 2.4Nm. On the other hand, the cutting force of W_f=1 in case of 40% elongation percentage, the thrust becomes about 150N and torque become about 1.6Nm. Therefore, the cutting force of W_f=1 shows the decrease of thrust 58% and torque 33.3% in comparison with that of the W_f=0.

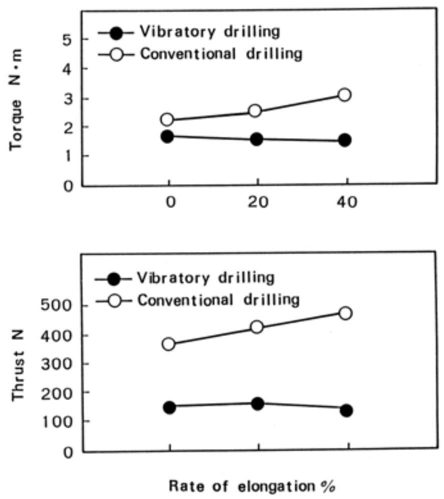

Figure 8: Relationship between processing strain and cutting force (static component).

From the results mentioned above, it has been proved that the burr shape depends upon the chip ejection and that the application of this method for drilling of materials such as aluminum (JIS A1020-O) would be effective in preventing burrs.

4. Conclusions

The formation of the burr at the circumstance of drilled hole in low frequency vibratory drilling was examined. The following properties become clear from the experimental results.

(1) The burr size produced by the low frequency vibratory drilling of aluminum is smaller than that produced by conventional drilling.
(2) In case of low frequency vibratory drilling, the burr size is not influenced greatly by the increase in the number of drilled holes, but the burr size in case of conventional drilling becomes larger as the number of drilled holes increases.
(3) The zone of metal flow in case of vibratory drilling becomes narrower in comparison with that of conventional drilling.
(4) The cutting force (dynamic component of thrust, torque) in case of low frequency vibratory drilling larger than that of conventional drilling and the static component is small. When dynamic component is large, burrs could be effectively prevented and the burrs shape becomes larger as the static component becomes larger.

References

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