Micro Deburring Using Ultrasonic Vibration

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ABSTRACT

The operation of surface and edge finishing is the last and essential process of parts machining, because a product is completed as an assembly. Therefore, the quality of the finished parts has a direct effect upon the performance of the product. Especially, the edge quality depending on the burr control process is very important. A number of deburring processes have been developed for macro burrs such as barreling, brushing, chemical methods, etc. However, micro burr removal when piercing a very thin plate is very difficult, because this badly deteriorates the surface quality of the processed part.

When ultrasonic wave is propagated in liquids, it forms an infinitude of micro bubbles. These bubbles generate extremely strong force, which removes micro burrs. In ultrasonic micro deburring, the problem is that burrs are not removed completely, because only components of the explosive force directly act on the burrs, which is not enough.

An attempt was made to remove the burrs using ultrasonic vibration in water with SiC as an abrasive agent. Because of the abrasive, smoother edges have been achieved. There are many control parameters in ultrasonic deburring such as abrasive size, ultrasonic frequency and amplitude, etc.

This study focuses on how these parameters influence deburring effect. A number of experiments for these parameters have been carried out, and then the effect of each parameter analyzed.

1 INTRODUCTION

Because of rapid development of electronics and computer industry, almost all parts became very small in size which requires extremely high manufacturing precision. Also, many special processing methods are required such as conventional cutting and LCDs in semiconductors manufacturing. As a result of focused R&D efforts, MEMS technology has been introduced for production of ultra-micro parts, but no technique is yet fairly available for ultra-micro parts deburring. Multiple burrs arising in numerous ultra-micro pores in the cylinder of micro hydraulic part is a common problem in industry. As no general technique for micro burrs removal has been developed thus far, engineers mostly rely on expensive equipment.

Generally, burrs are created as a result of plastic deformation such as cutting or punching, or during the casting processing. Whatever the case, the presence of burrs on the part edge is very unwanted, especially because they misshape the part. Broadly speaking, a discrepancy between the designed edge and the obtained edge can be regarded as a burr.

A projected burr may be actually created in a ductile material, but a chamfer resulting from a fracture may be created in a brittle material. In this case, the edge plane is rough and can be easily damaged because of the fractured plane. Therefore, such situation should be avoided. As such, burrs affect the tolerance of the assembling process, and may also cause damage of the contact plane.

Thus, there is a need to study how to inhibit the creation of burrs. It is very difficult, however, to inhibit burrs completely. Because of the fact, so many studies are in progress now. Currently used methods of burrs removal include barreling and brushing by means of abrasives, or additional chemical etching in liquid.

This study deals with efficient removal of burrs using ultrasonic waves. This method requires the control of a great number of experimental conditions. We have used the analysis of variance. To this end, the table of orthogonal arrays was used to check how much each condition affects upon the deburring efficiency. We also tried to find optimum conditions in the planned experiments.

2 Experiment

2.1 Equipment

Fig. 1 shows a piece of equipment used for ultrasonic deburring. The ultrasonic waves have the following characteristics: 1300W/20kHz, and 700W/40kHz, maximum amplitude for both cases is 10μm. Therefore, at the amplitudes of 10μm 100% of power and at 3μm 60% of power was used respectively, so as to get the table of orthogonal arrays on level 2.

Fig. 1 Experimental set-up for ultrasonic deburring

2.2 The table of orthogonal arrays and the results of experiment

We illustrated experimental conditions for ultrasonic deburring in consideration of the importance to establish experiment design using a table of orthogonal arrays, so they correspond to the level 2 respectively. The symbols used in the table of orthogonal arrays are shown in Table 1. Table 2 shows the table of orthogonal arrays we have used. In the table of arrays, 6 factors and 9 factors for individual interaction are shown. As a characteristic value, height difference of the removed burrs was used. Thus, deburred burr height difference as the experimental results by the design of experiment was measured, shown in the last column of Table 2.

Table 1. Experimental design conditions

Factor \ Level	0	1
Water : abrasive(A)	90 : 10	70 : 30
Amplitude (B)	10μm	3μm
Frequency (C)	20 kHz	40 kHz
Distance (D)	1 mm	3 mm
Time (F)	5 min	2 min
Size of abrasive (G)	8000	800

Table. 2 Table of orthogonal arrays

N.of E. \ Col	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	13	**14**	**15**	**Height Difference by Deburring** [μm]
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**38**
2	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	7
3	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	0
4	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	**0**
5	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	**17**
6	0	1	1	0	0	1	1	1	1	0	0	1	1	0	0	8
7	0	1	1	1	1	0	0	0	0	1	1	1	1	0	0	0
8	0	1	1	1	1	0	0	1	1	0	0	0	0	1	1	**0**
9	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	13
10	1	0	1	0	1	0	1	1	0	1	0	1	0	1	0	0
11	1	0	1	1	0	1	0	0	1	0	1	1	0	1	0	**29**
12	1	0	1	1	0	1	0	1	0	1	0	0	1	0	1	**0**
13	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
14	1	1	0	0	1	1	0	1	0	0	1	1	0	0	1	26
15	1	1	0	1	0	0	1	0	1	1	0	1	0	0	1	**15**
16	1	1	0	1	0	0	1	1	0	0	1	0	1	1	0	7
Factor	**A**	**G**	**A*G**	**D**	**F**	**G*D**	**B*C**	**B**	**A*B**	**G*B**	**C*D**	**B*D**	**G*C**	**A*C**	**C**	

2.3 Analysis of the result

Fig. 2 shows the result of the analysis of variance carried out through a confidence interval of 95% with the experimental result in Table 2, and the final result after pooling error terms twice. The amplitude and the abrasive size must be pooled as independent factors, but excluded because it was shown that the factor interaction was significant. As the result of using the design of experiment by means of the table of orthogonal arrays, it was shown that the factors that mostly affect the burr height are the abrasive size, distance, time, amplitude and frequency. The effect of an independent factor was made by the factors such as a distance between the tool end and the specimen, and the processing time. A frequency and abrasive size did not show much effect as an independent factor, but it was known that the amount of removed burrs most significantly depends on the relationship between the abrasive size and the frequency.

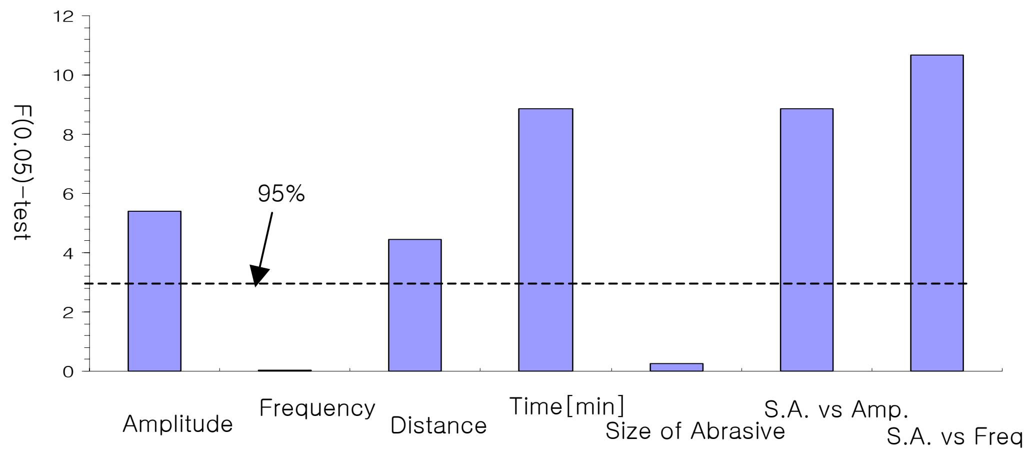


Fig. 2 Result of F(0.05)-test for main factors

Fig. 3 shows the sum of characteristic values to affect individual factors after last pooling. As shown in the graph, the nearer the distance is, the longer time (F) processing is carried out for, the larger the amplitude (B) is and the smaller is the frequency (C), the more processing was achieved if the abrasive size (G) was #8000.

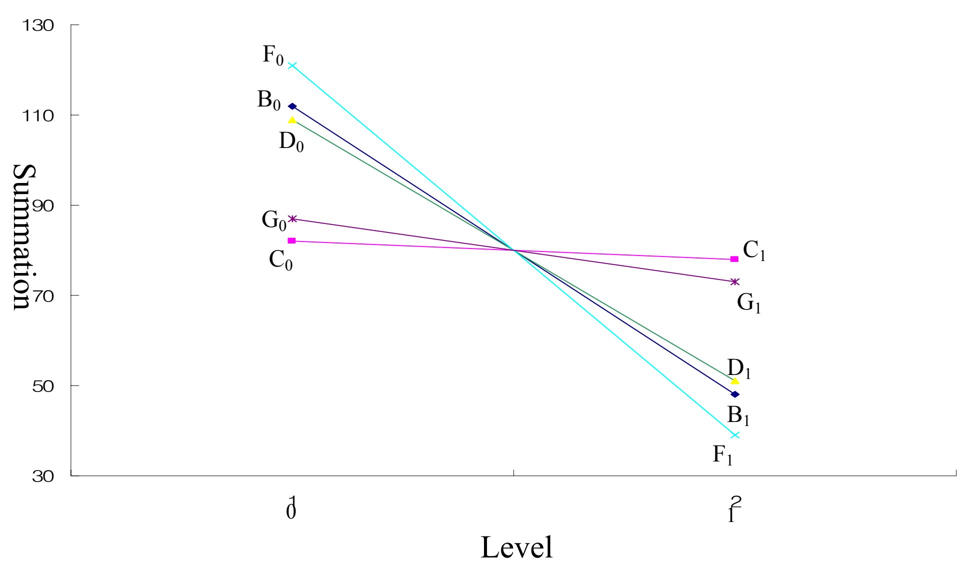


Fig. 3 Characteristic value sum for main factors

Fig. 4 shows the relationship for each level change about abrasive size (G), frequency (C), and amplitude (B), which have a very significant effect. As a result of the experiment it was shown, if the abrasive size was #8000, the frequency was 20kHz and the amplitude was 10μm, or the abrasive size was #800, the frequency was 40kHz and the amplitude is 3μm, many burrs tended to be removed. Consequently, the optimum deburring condition for removing the most burrs was the abrasive size of #8000 and the amplitude of 10 μm.

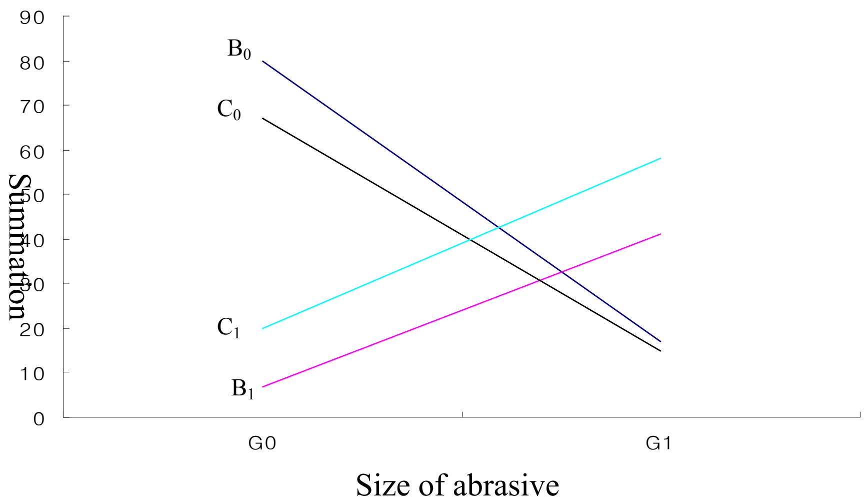


Fig. 4 Result of characteristic value summation for interaction factors

2.4 SEM measurement of burrs before and after the deburring process

Fig. 4 shows a SEM picture of a rectangular hole after punching a steel material of 100μm thickness. As shown in the figure, the part marked with a red circle was checked before/after the deburring process. Deburring conditions are shown in Table 3 and the optimum deburring conditions analyzed in the previous section were applied in the experimental. Fig. 5 shows the picture of the processing result. The size of actual burrs is not definite but seems to be 50μm. A significant change is not indicated in burr height before/after the deburring process, but the overall smoothed shape as well as smoothed burrs can be seen. Therefore, we can learn that the abrasive moves by means of ultrasonic vibration and burrs are removed little by little by means of the abrasive movement in the deburring process using ultrasonic waves. As a result, deburring using ultrasonic waves is suitable for deburring micro burrs because a considerable time is needed to remove a large burr. A reason to cause such burr movement is considered to be the movement by the impulsive force due to cavitation and direct impact of the horn, but we think further study about the result is required.

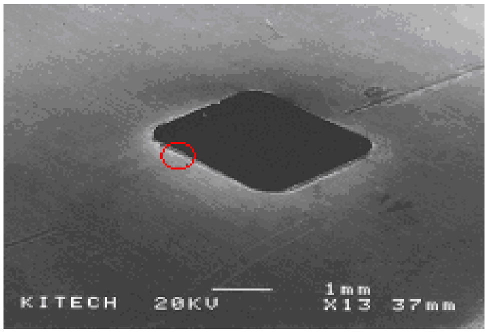
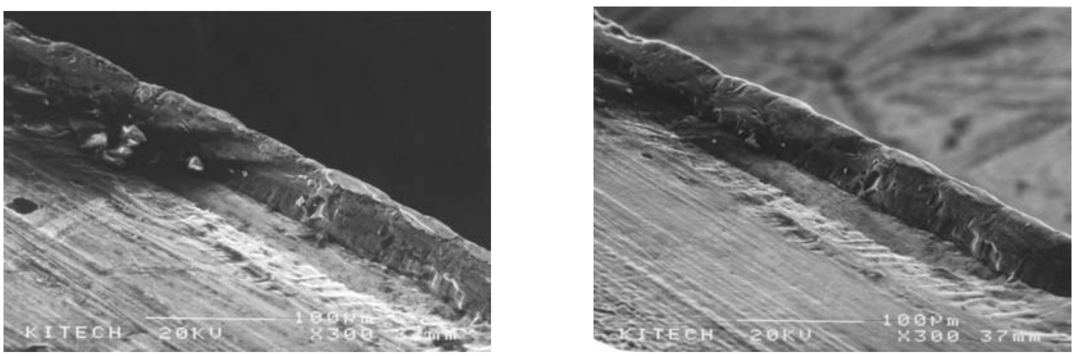


Fig. 4 Photograph of SEM of hole

Table. 3 Experimental conditions

	conditions
Water : abrasive(A)	90 : 10
Amplitude (B)	10μm
Frequency (C)	20 kHz
Distance (D)	1 mm
Time (F)	5 min
Size of abrasive (G)	8000



(a) Before deburring process

(b) After deburring process

Fig. 5 Photographs of SEM of the burr

3 Conclusions

We performed experiments and analysis to which the design of experiment was applied to check how much effect the experimental conditions that must be considered for efficient deburring using ultrasonic waves have on deburring, and obtained the following conclusion.

1. Main independent factors, which affect deburring, are: amplitude, distance between the tool end and the specimen, and the processing time. However, frequency and the abrasive size do not have much effect as independent factors, but it was learned that the amount of the removed burrs most significantly depends on the relationship between the abrasive size and the frequency.

2. As the result of analysis shows, the nearer the distance is, the longer time processing is carried out for, the larger the amplitude is and the smaller is the frequency, the more processing was obtained if the abrasive size was #8000.

3. For a burr of 50 μm, no big change was shown in height when SEM pictures for a specimen before/after processing were compared, but it was learned that the overall shape as well as the smoothed burr was smoothed.

REFERENCE

[1] Park, Seong-Hyun: Method of Modern Design of Experiment, published by Minyoungsa, 1997.

[2] Goh, Seong-Rim: Study on efficient deburring of micro burrs created in blanking, Workshop on Precision Surface Finishing and Deburring Technology, pp 19-45, 1998.

[3] Im, Han-Seok, An, Joong-Hwan : Tendency of created burrs and characteristics of ultrasonic deburring in micro groove processing for optic parts , Workshop on Precision Surface Finishing and Deburring Technology, pp 157-166, 1998.

[4] YOSHIHIDE SHIBANO : Ultrasonic Micro Deburring Application, 3rd International Conference on Precision Surface Finishing and Burr Technology, 1994.