Al 7075 합금의 연삭잔류 응력에 관한 연구(I)
A Study on the Grinding Residual Stress of Al 7075 Alloys(I)

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ABSTRACT

Grinding experiments for Al 7075 alloy were carried out to study the influence of grinding conditions and supply methods of grinding fluid on residual stress and surface roughness and grinding force. The residual stress was measured by an X-ray method. The supply method of grinding fluid with a guide nozzle has large decrease value of the tensile residual stress and of grinding force than a normal nozzle. In sparking out state of the grinding work, it is desirable to decrease the depth of cut and the workpiece feedrate for improving surface roughness and mechanical properties.

국문요약

Al 합금 7075에 대해서 공작물 이송속도, 연삭깊이 및 유제 공급방법이 잔류응력에 미치는 영향을 실험적으로 행하였다. 가공 변질층에 형성된 잔류응력을 측정하기 위해 X선 회절법을 사용하였다.

개발된 노즐 공급방법(Guide nozzle)은 인장 잔류응력 및 연삭저항, 표면조도 부분에서 기존 노즐보다 좋은 효과를 가져왔다.

연삭깊이 및 공작물 이송속도를 감속시키고 아울러 스파크 아웃을 행하면 잔류응력 및 표면 조도를 감소시킬 수 있다.

1. Introduction

A machined workpiece has an affected layer which has different characteristics from raw material. The affected layer is generated by external factors such as contamination, compound layer, by the change of organization such as very small crystal working deformation of crystal, recrystallization by friction heat, and by residual

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stress. Especially the residual stress makes the greatest influence to the mechanical characteristics of the workpiece. Decrease of working precision by bending deformation, of fatigue strength, of wear resistance, of anticorrosion, and generation of crack on surface are good examples on the effects of the residual stress.

There are some cases that the residual stress is no problem according to working conditions. But in grinding work demanding high precision, the residual stress is the one of most important factors for the evaluation of the machined workpiece. For minimizing the residual stress the finding of optimal grinding condition is very important research subject in order to provide machine parts having uniform and high precision.

Up to the date, researches for the residual stress in grinding have been analysed the mechanism and the disribution style[1),2)] of the residual stress for ferometals, alloy metals and the relation between plastic deformation and thermal stress in various grinding conditions[3)].

In particular, recently, as Al alloy is used to the newest industries such as VTR cylinder, magnetic disk, polygon mirror, metal mirror, etc, electronic and aerospace fields demanding ultra precision, the researches for the residual stress in grinding of Al alloy are actively progressing.

Kasai[4)] investigated the influence of grinding fluid on surface roughness, loading, grinding force in grinding of ISF as near the pure aluminium. Notaya[5)], and Yonetani[6),7)] researched the influence of grinding condition and of grinding fluid on the residual stress and plastic strain rate in grinding of AC3A as Al-Si chain alloy. Zaima researched the machinability of various Al alloy and the structure deformation at surface layer according to grinding conditions.

In this research, it is analysed empirically that the infuences of grinding conditions and supply methods of grinding fluid on grinding force, surface roughness, and residual stress in grinding of Al 7075 alloy, which is used in airplane and automobile parts because of its excellent tensile strength and light weight.

2. Eepremental Equipments and Methods

Al 7075 specimen being on the market was machined to 6mm × 35mm × 70mm and annealed for stress relief with temperature 154 ± 6℃ at the electric furnace after milling and grinding work. The mechanical properties, the chemical components, the experimental equipments, and the grinding conditions are shown in Table 1, Fig. 1, and Table 2, respectively.

Table 1 Chemical composition & Mechanical properties of Al 7075 alloy

Material	Cr	Zn	Mg	Cu
%	0.20	5.84	2.44	1.71
Material	Fe	Si	Ti	Mn
%	0.32	0.12	0.04	0.04

Tensile strength (Kg/mm^2)	Elongation (%)	Hardness (Hv)
62.2	17.0	147

Table 2 Grinding condition in experiments

Grinding wheel	C46Kmv (305 × 30mm × 127mm)
Grinding wheel speed	1,150m/min
Dressing condition	20μm × 3time, 10μm × 3time
Feedrate	0.05, 0.10, 0.15m/s
Depth of cut	20μm, 40μm, 60μm
Grinding fluid	wet type

Experiments are carried out at the grinding depth of 20μm, 40μm, 60μm while keeping the workpiece feedrate of 0.1m/s constant, and the workpiece feedrate of 0.05, 0.10, 0.15m/s while keeping the grinding depth of 40μm constant.

Two different supply methods of grinding fluid are compared and investigated. Those are the general nomal nozzle type and the guide nozzle type equipped guide apparatus to the circumferencial plane of wheel, and are shown in Fig. 2.

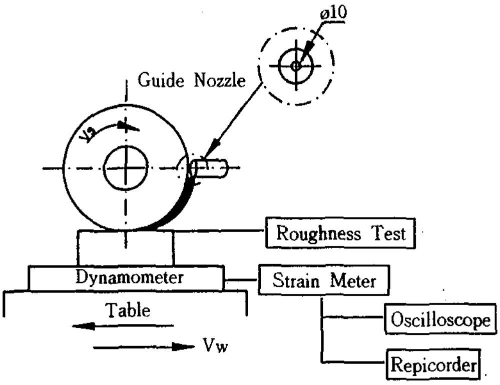
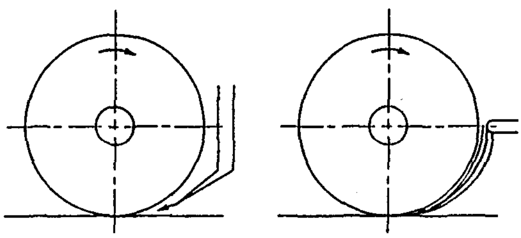


Fig. 1 Schematic diagram of experimental equipment



a) Normal Nozzle b) Guide Nozzle

Fig. 2 Schematic diagram of guide nozzle mothod & normal nozzle mothod

In surface grinding, the zero point of depth of grinding indicates the state when oil ink painted on the workpiece was peeled off more than 90% by grinding.

Grinding type is down cut, two types of grinding are applied, the one pass grinding without cross feed and the complete spark out grinding.

The AST style tool dynamometer is used for measurement of grinding force. Measuring signal is recorded to repicorder after amplified by strain amplifier. Surface roughness values are the Ra and center line average height. In this research, X-ray diffraction method developed recently is used to measure the residual stress generated in the surface and inside of workpiece. This method applied the X-ray diffraction is easy to handle and has short measuring time and high reliability.

Also an etching method is used to measure the residual stress formed at affected layer in the same direction to the grining depth. The chemical components of etching liquid have the volume rate of acetic acid 10%, phosphoric acid 65% and nitric acid 25%.

The residual stresses are measured at every 25 μm removal until 100 μm in depth and every 50 μm removal over 100 μm. Ten times of removal for each speciman and an X-ray measurment is applied at the middle to grinding direction[8]. Measuring conditons of residual stress are shown in Table 3.

Table 3 X-ray measuring conditions of residual stress

Target	Cr target
Voltage	25-30Kv
Current	8-9mA
Area	2 × 4mm^2
Angle of incidence	(0°, 15°, 30°, 45°)

3. Experimental Results and Considerations

3.1 Influence of grinding conditions on residual stress and grinding force

3.1.1 Influence of grinding conditions on distribution of residual stress

In this study, the influence for the workpiece feed rate and grinding depth on distribution of residual stress is analysed.

Fig. 3 shows the values of residual stress according to the supply methods of grinding fluid, which are the normal nozzle type and the guide nozzle type equipped guide apparatus to the circumferencial plane of wheel. These are the results of one pass grinding at various grinding depth of 20 μm, 40 μm, 60 μm while keeping workpiece feed rate of 0.1m/s constant, from these results, one knows that the residual stress is the largest at surface layer and gradually decreases with the increase of depth.

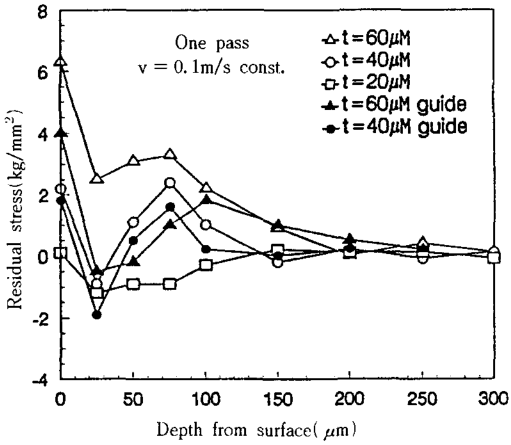


Fig. 3 Variation of grinding residual stress with grinding depth(one pass grinding)

The magitude of tensille residual stress at surface is increased with the increase of depth. It is estimated that these facts are due to the increase of grinding heat accompanied with the increase of tension type residual stress according to the increase of depth. The values generated at from surface to 25 μm depth are rapidly decreased, but are increased at 50~70 μm depth on the contrary.

It seems that the above results appeared are due to the decrease of tensile stress by the compressive stress generated by burnishing effect at shallow depth, and the burnishing effect is disappeared with the increase of depth and only the act of grinding action at deep depth.

One knows from the above results that the compressive stress by the burnishing effect largely acts on the workpiece instead of tensile stress by grinding heat at shallow depth, and the residual stress does not appear for all grinding conditions over 200 μm depth.

The tensile stress fot the supply method of a guide nozzle is less than for the method of a general normal nozzle. The reason is that the efficient supply of grinding fluid between workpiece and wheel increases the grinding efficency and the cooling effect.

Fig. 4 shows the results of one pass grinding at the grinding depth of 40 μm constant and the change of workpiece feedrate as 0.05, 0.10, 0.15m/s. The results are similar to those of Fig. 3.

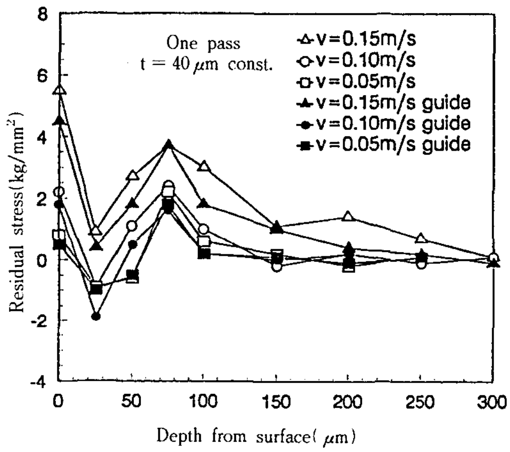


Fig. 4 Variation of grinding residual stress with workpiece feedrate(one pass grinding)

If workpiece feedrate increases, the tensile residual stress generated on surface is increased.

It seems that these results shown are due to the increase of tensile stress by grinding heat generated on surface with the incerease of workpiece feedrate. The residual stress for the guide nozzle type is less than that of the normal nozzle type. This is similar to results of Fig. 3 also.

Fig. 5 and Fig. 6 show the results of the experiment for the complete spark out grinding with the same grinding conditions used in Fig. 3 and Fig. 4, respectively.

In spark out grinding, the tensile residual stress generated on the surface and inside part of workpiece is rapidly decreased than one pass grinding.

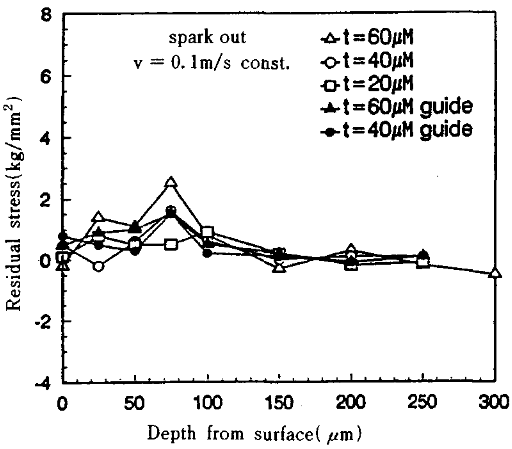


Fig. 5 Variation of grinding residual stress with grinding depth(spark out grinding)

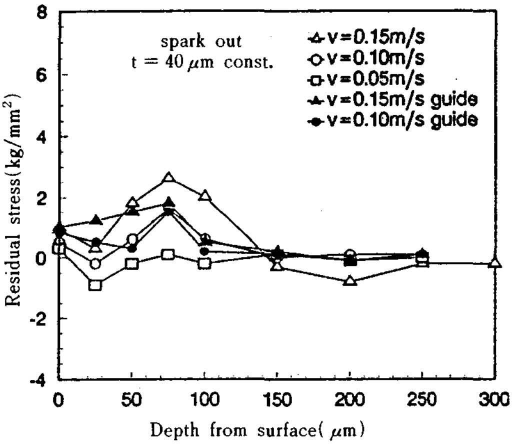


Fig. 6 Variation of grinding residual stress with workpiece feedrate(spark out)

The difference of residual stress is comparatively small for the change of grinding depth in the sparkout grinding, these facts seem to be due to the offset compressive stress by continuous burnishing effect to the tensile stress by grinding heat and grinding action and due to the results of decrease of grinding heat with the dearease of remainded small volume.

Therefore, in grinding of Al-7075 alloy, small grinding depth and low workpiece feedrate and sufficient sparkout are needed for small residual stress.

3.1.2 The influence of grinding condition on maximum residual stress and maximum grinding force.

Fig. 7 shows the results of maximum grinding force for one pass grinding at various grinding conditions. The horizontal and vertical component of maximum grinding force increases with the increase of the workpiece feedrate and the grinding depth. Also, in supply methods of grinding fluid, the guide nozzle type has lower value of grinding force than the normal nozzle type. This seems that the guide nozzle type has high efficiency and usefulness.

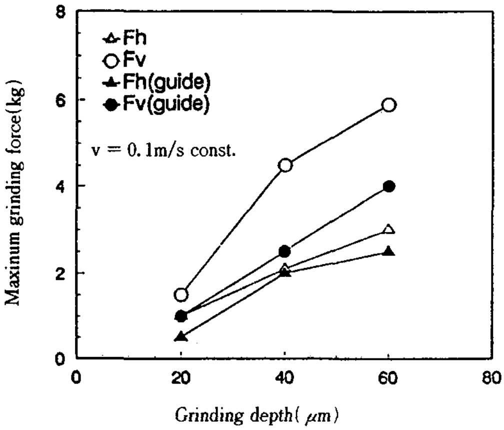


Fig. 7 Variation of maximum griding force with grinding depth(one pass grinding)

From the relationships between the results for maximum residual stress and for maximum grinding force, it is assumed that the more grinding force by related to grinding heat is increased, the more residual stress of tension type is increased.

In the same grinding volume per unit time, it is generally known facts that the large grinding depth has large grinding force than large workpiece feedrate. It is assumed that the larger grinding force gererates more grinding heat.

Fig. 8 and Fig. 9 show the magnitude of grinding force obtained at every grinding pass time up to 5 passes. We know that if the grinding depth and the workpiece feedrate are decreased, the grinding force is decreased.

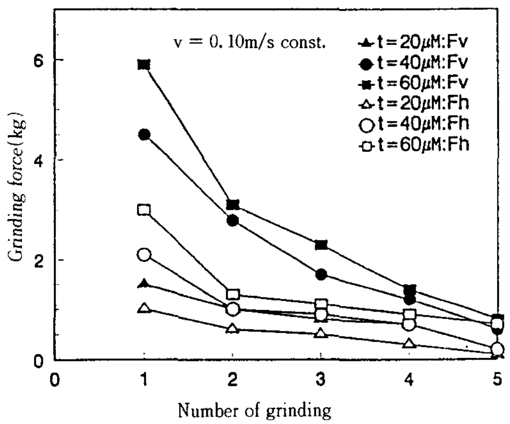


Fig. 8 Variation of grinding force with depth and number of grinding

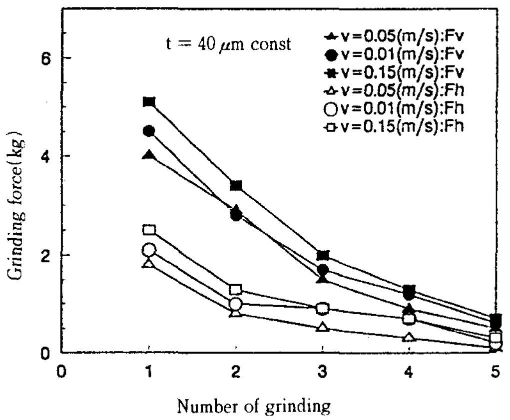


Fig. 9 Variation of grinding force with workpiece feedrate and number of grinding

However, the workpiece feedrate gives the larger influence to the grinding force than the grinding depth, and the vertical component of grinding force is larger than the horizontal component.

The grinding force is rapidly decreased after one pass, has almost uniform value over 2 passes, and is not appeared after 5 passes. These facts are in accord with general grinding theory on the remained quantity of grinding.

Consequently, the maximum grinding force and the maximum residual force are influenced by the grinding depth and the workpiece feedrate.

But from the above results, it is difficult to estabilish clear relationship between the maximum grinding force and the maximum residual force with grinding conditions. The reason is that complex relationship of residual stress for grinding force is largely influenced by a kind of grinding liquid and its quantity.

3.2 The influence to surface roughness on grinding conditions

Fig. 10 shows the surface roughness values obtained at workpiece feedrate of 0.10m/s constant and the various grinding depth at guide nozzle type and the normal nozzle type for the supply method of grinding fluid. From the results, as the grinding depth increase, the surface roughness become worse.

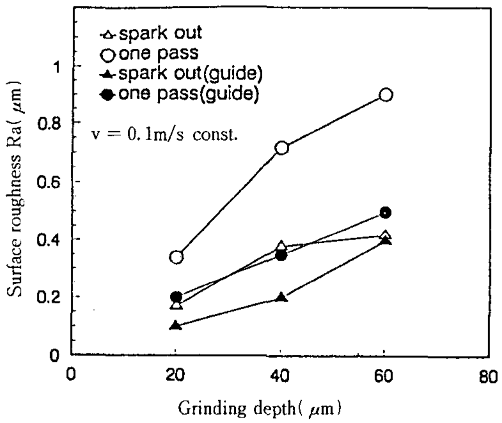


Fig. 10 Variation of surface roughness with grinding depth

The surface roughness with spark out grinding was improved about twice more than that with the one pass grinding. Also, the surface roughness was improved about twice much better with the guide nozzle type of grinding fluid than with the normal nozzle type.

4. Conclusions

The grinding experiment for Al 7075 alloy was carried out in order to measure the influence of the grinding conditions and the supply method of grinding fluid on residual stress and surface roughness and grinding force. The results are summarized as follows :

1) It is known that small grinding depth, low workpiece feedrate and sufficient spark out grinding are needed for small residual stress.
2) The maximum value of the grinding force and the residual stress increase with the increase of grinding depth and workpiece feedrate.
3) Grinding depth has largely influenced on maximum residual stress than workpiece feedrate in same amount of grinding volume per unit time
4) The tensile residual stress increases with the grinding force related to the grinding heat increases.
5) The more grinding depth and workpiece feedrate increase the worse surface roughness. Specially, when the sparkout grinding was performed, the surface roughness was improved about twice much than the one pass grinding by averaged effect.
6) The supply method of grinding fluid with the guide nozzle has the large decrease value of tensile residual stress and grinding force than the normal nozzle.

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