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Peening Effect on Machining of Steel

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Abstract

Generally, machinery consist of various machined parts. One of the element of the reliability for machinery is endurance limit related to fatigue strength. Fatigue test was performed on various specimens machined with several nose radius tips under the same machining condition and on shot peened specimens with small glass beads after machining.

Experimental conditions are as follows: machined metal is medium carbon steel (0.45%C), tip of cutting tool is cermet (NX33-Mitsubishi), nose radius was varied from 0.2 - 1.6 mm, machined surface roughness was 6 - 24 µm Rmax, glass beads diameter is 0.18 - 0.21 mm, blasting pressure and time is 0.59 MPa and full coverage time respectively, fatigue test was performed with rotary bending machine, residual stress was measured by $\sin^2\psi$ method of Xray diffraction on peripheral and axial direction.

Nose radius of cutting tool affects remarkably surface roughness and residual stress. On one hand fatigue strength was not affected surface roughness but depends upon the surface residual stress of machined or shot peened after machining. Peening effect with small glass beads was excellent on fatigue strength for machined specimens.

Keywords

Reliability of machine, machining, cermet, surface roughness, fatigue strength, residual stress, peening effect, glass beads, Xray diffraction.

Introduction

The relation between the residual stress and machining condition was reported hitherto. The influence on the residual stress from tool geometry, feed rate and cutting force was reported already [1]. In this case, machining was performed on medium carbon steel, (C:0.45%) with various nose radius cermet tips (NX33) under the same machining condition. After machining fatigue tests were performed on machined and shot peened specimens, and peening effect was confirmed for machined steel.

Experiment

The specimen, cutting condition, residual stress measurement and shot peening condition were shown in Tab. 1, Tab. 2 and Tab. 3 respectively. (Table 1 - 3 on page 31.)

Result of Experiment

Surface Roughness and Hardness

Surface roughness is very important factor in machining related to accuracy of products, therefore the first of all, it was measured after turning with various nose radius tips from surface profile records as value of Rmax. The relation between nose radius of tip and surface roughness was shown in Fig. 1. Two lines were drawn in this figure, the one is surfaces after machining and the other is shot peened surface after machining. Surface roughness get better with shot peening, therefore small glass beads peening contributes favorable affect to machined products.

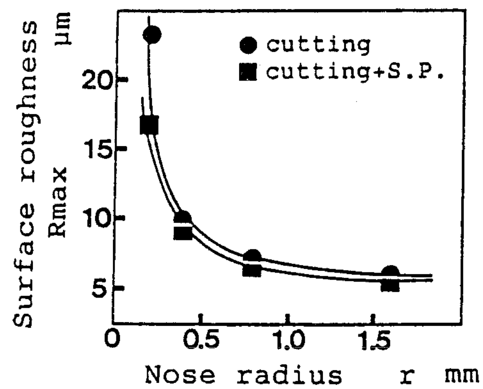


Figure 1. Nose radius of cutting tool and surface roughnesses on machined and shot peened surface after machining.

Shot peening is a process of cold working, then the surface hardness should be increase after shot peening. Generally surface hardening is effective to fatigue strength, therefore surface hardness was measured after shot peening. The results was shown in Fig. 2. Owing to shot peening, hardness of machined surface increases to 18%, therefore shot peening process may be contributes favorable effect to machined products.

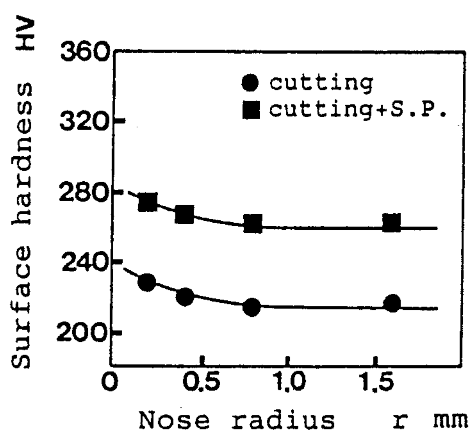
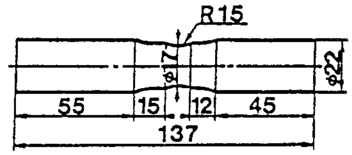
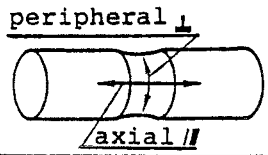


Figure 2. Nose radius of cutting tool and surface hardness on machined and shot peened surface after machining.

Tab.1 Specimen and machining

specimen	
carbon steel 0.45 %C (HV170)	
 	
machining	
nose radius r	0.2, 0.4, 0.8, 1.6 (mm)
cutting speed V	99.0 (m/min)
depth of cut W	0.50 (mm)
feed rate t	0.05 (mm/rev)
machine tool	copying lathe
tip	cermet (NX33 Mitsubishi)
tool geometry	-6, -6, 6, 6, 30, 0, Var.
cutting fluid	dry

Tab.2 Measurement of residual stress

$\sigma_R = -\frac{E}{2(1+\nu)} \cot\theta_0 \frac{\partial 2\theta}{\partial \sin^2\psi}$ $\nu = 0.28$, $E = 206$ GPa	E : Young's modulus ν : Poisson's ratio θ_0 : standard Bragg's angle ψ : incident angle of X-ray
crystal plane (2 1 1)	
X-ray : Cr-Kα	
ψ : 0, 15, 30, 45 deg	
peak : from half width	

Tab.3 Shot peening (S.P.)

shot	glass beads
shot diameter	0.177 - 0.210 (mm)
machine type	compressed air
blasting pressure	0.59 (MPa) (6.0 atm.)
nozzle distance	150 (mm)
blasting time	full coverage time (60 s)

Residual Stress

Surface residual stress is a important factor to fatigue strength. The surface residual stress was measured by Xray diffraction after machining with various nose radius tips under the same machining condition. As shown in Fig. 3, the smallest nose radius tip produced negative axial surface residual stress but other tips were all positive.

In Fig. 3 (page 32), white marks show residual stress after machining, axial stresses are round, peripheral stresses are square. After small glass beads peening, all these stresses coincide with the value -323 MPa. Black marks in Fig. 3 are the stresses after shot peening.

Fatigue Strength

Rotary bending test was performed on various specimens machined with different nose radius tips which are triangular throw away type cermet.

Fatigue strength of machined specimen with the smallest nose radius tip was increased 39% compare with annealed one. Other specimens were also increased from 9% to 28% as shown in Tab. 4 (on page 32).

Increasing ratio of machined specimen was arranged in axial residual stress order. The largest positive axial residual stress corresponds the minimum increasing ratio. After shot peening, these machined specimens were coincided with one another and get to the maximun strength as shown in Fig. 4 (on page 32).

The reason why shot peened specimens get to maximum fatigue strength is owning mainly to the increase of surface compressive residual stress.

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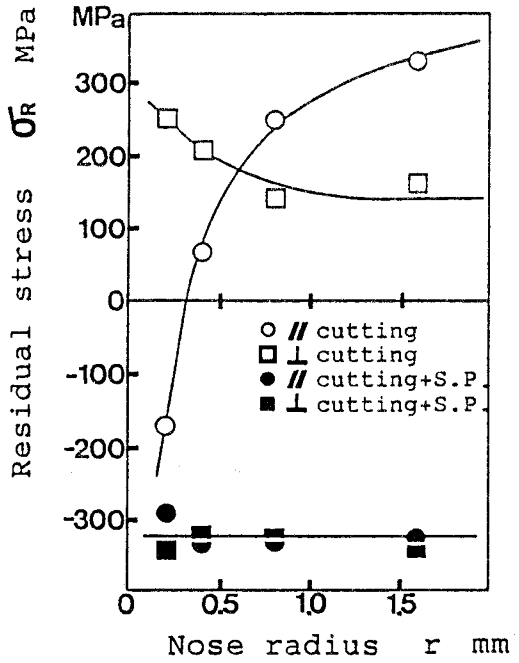

Figure 3. Surface residual stresses were varied with nose radius of cutting tool and were almost positive after machining but coincided after shot peening.

nose radius mm		0.2	0.4	0.8	1.6
annealed	A	230			
machined	B	320	295	265	250
shot peened after machined	C	330			
C/A %		43			
C/B %		3.1	12	25	32

Table 4. The change of fatigue strength with machining and shot peening after machining for carbon steel (C:O.45%)

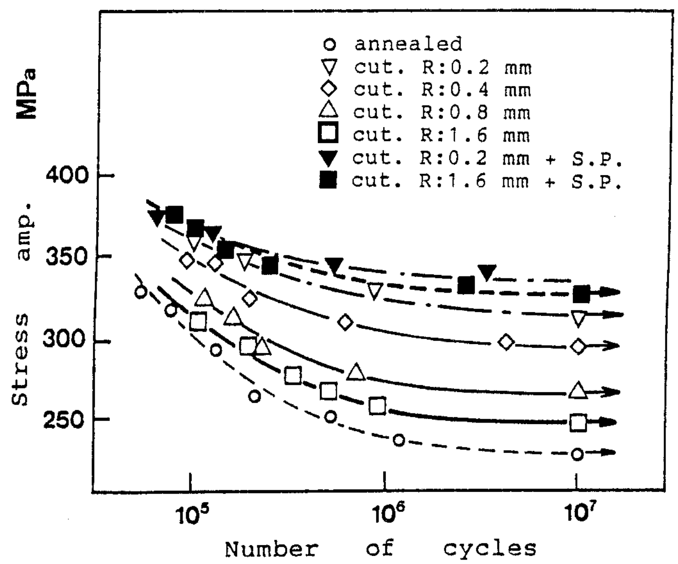

Figure 4. Fatigue strength increase with machining and shot peening.

Conclusion

1. Surface tensile residual stresses are induced on machined steel.
2. Shot peening with small glass beads is effective for the change of surface residual stress on machined surface from tensile to compressive.
3. Fatigue strength, surface hardness and roughness of machined steel get better by shot peening with small glass beads.
4. Fatigue strength was increased with small glass beads peening 43% for annealed steel and 3.1 - 32% for machined in this experiment.
5. Shot peening even with small glass beads has favorable effect on the increase of reliability of or lightening of machinery.

Reference

[1]. K. Iida, T. Yamamoto, "Residual Stress Induced by Machining of Steel" reported at International Conference on Residual Stress, Los Angeles, USA (1989.8), Metal Behavior and Surface Engineering, I.I.T.T. International, (1989) 329.