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ORIGINAL ARTICLE

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Deburring of burrs in spring collets by abrasive flow machining

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Abstract Micro burrs occurring inside the small and large diameters adversely affect the properties of products. Manual deburring of micro burrs in particular damages the processed surface and reduces production efficiency. In this study, spring collets made of chrome-molybdenum are used to test the deburring of the surface of collets including crossed micro grooves by abrasive flow machining.

Keywords Abrasive flow machining · Collet chuck · Media · Micro burrs · Micro deburring

1 Introduction

Precision of 5 μm is required in the shape of internal and external spring collets. For precision processing, the grooves are formed in a crossed pattern; thus, the occurrence of burrs in the internal diameter is extensive. Micro burrs occurring inside the small and large diameter adversely affect the properties of the collets. Manual deburring of micro burrs in particular damages the processed surface and reduces production efficiency. It is almost impossible to remove effectively burrs caused by cutting through general machinery processing in products. Even if the first burrs can be removed, second burrs also pose a problem. Abrasive grain media for abrasive flow processing has been developed by blending a silicon polymer with abrasive grains. It effectively removes edges and burrs by flowing through the interior and micro grooves of the spring collet. This study used a spring collet made of chrome-molybdenum and considers deburring properties of the collet surfaces with crossed micro grooves using abrasive flow machining.

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2 Jig design of spring collet and media viscosity

Figure 1 shows the shape of the spring collet and the direction of abrasive flow. Deburring is executed through the repetitive vertical flow of abrasive grain media in the gap between the workpiece and tooling. This gap should be kept uniform for the maintenance of a constant media supply and pressure so that the deburring will not cause dimensional changes in the workpiece. The tooling fixes the component for processing in the right position and creates a passage for leading the abrasive grain media into the processing target area. The effective viscosity and pressure of the media are determined for surface abrasion or deburring.

Deburring of the internal surface of a spring collet is analysed based on the principles of material removal through media grain impact. The removal rate is calculated as:

$$R = kND^3\mu^{\frac{3}{2}}\left(\frac{\rho_a}{12\rho_y}\right) \tag{1}$$

where

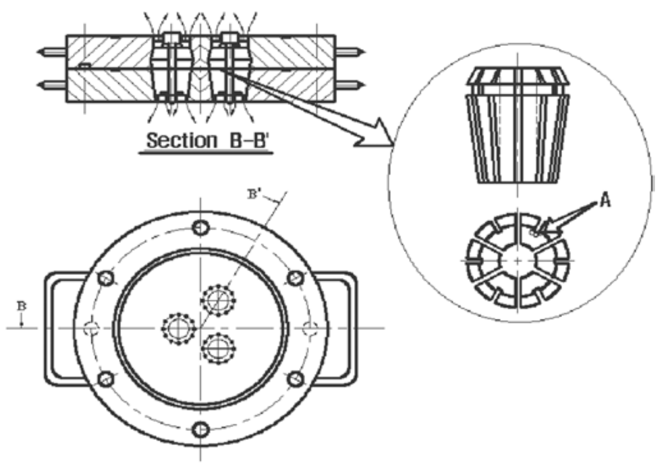


Fig. 1. Deburring process of spring collet

k : Constant
N : Number of abrasive particles making cut at a time
D : Diameter of inner hole (mm)
μ : Velocity of media (ms^{-1})
ρ_a: Density of media (kgm^{-3})
ρ_y: Yield stress of workpiece material (Nm^{-2})

The removal rate R can be represented as $R \propto v^{\frac{3}{2}}$ and, if the abrasive flow pressure (Nm^{-2}) is p, then R is expressed as $R \propto p^{1.75}$.

Generally, the viscosity of the media is determined by its molecular weight. This can be estimated given the known molecular weight of the silicon media in the abrasive media. The relationship between the molecular weight and the viscosity of a media is expressed as:

$$\mu = KM^a \tag{2}$$

where

K, a: Constant
M : Molecular weight

The viscosity of the silicon media used in the abrasive flow system is estimated to be in the range of 10^{-1}–10^4 N sec/m^2 according to the magnitude of the molecular weight. The viscosity of the abrasive media changes with the temperature. The media is sensitive to temperature change; the change in viscosity of the media due to the change in temperature should be considered over the deburring time. In addition, the resistance is proportional to the molecular weight of the media and the shear strength, i.e. a higher resistance places a greater load on the grains of the media, as well as a higher removal rate. Likewise, shear strength is proportional to the viscosity of media. Accordingly, a higher viscosity means a greater load on the media grains, as well as a higher removal efficiency of deburring.

3 Experimental equipment and methodology

Figure 2 shows the abrasive flow processing system developed for the deburring of spring collets. The system was designed in three parts: the main body, the hydraulic system, and the controller. The main body consists of a clamp cylinder, a media cylinder, a hydraulic system, and a system controller. The clamp cylinder in particular is operated by hydraulic cylinders. It locks and releases the spring collet by vertical movement of the upper part of the system. The hydraulic system consists of a hydraulic cylinder for the operation of the media and clamp cylinder, hydraulic motor cooler, the control valve for pressure and velocity, and the solenoid valve for control of the piston in the media cylinder. Likewise, the system controller regulates the extrusion pressure of the media.

The abrasive flow processing system developed in this study was designed to enable control of the extrusion pressure at 7–220 bar, with over 380 litres (100 gallons) of media.

Table 1 shows the silicon polymer that was developed as the media in this study. It is a plastic resin with a very high chemical molecular weight. Media processing consists of two stages, i.e. mixing solid silicon resin material and softener and the blending materials to obtain the correct physical properties. In this study, the media was manufactured using silicon carbide and alumina abrasive grains.

Table 1. Characteristics and application of media

Abrasive / Viscosity	Silicon Carbide (SiC)	Alumina (Al203)
Low Viscosity(LV) (1900 mPa • s)	Hardness : 9.5	Hardness : 9
Medium Viscosity(MV) (2400 mPa • s)	Weight percent Ratio { Abrasive(1) : polymer(1) }	Weight percent Ratio { Abrasive(1) : polymer(1) }
High Viscosity(HV) (2400 mPa • s)	Mesh : 80#	Mesh : 80#

4 Results and discussion

Figure 3 shows the burrs on the cut surface of the spring collet after machining. Analysis indicated that 0.5 mm burrs were formed on the processed surface and curling burrs were formed on the bottom surface. These types of burrs are characteristic of

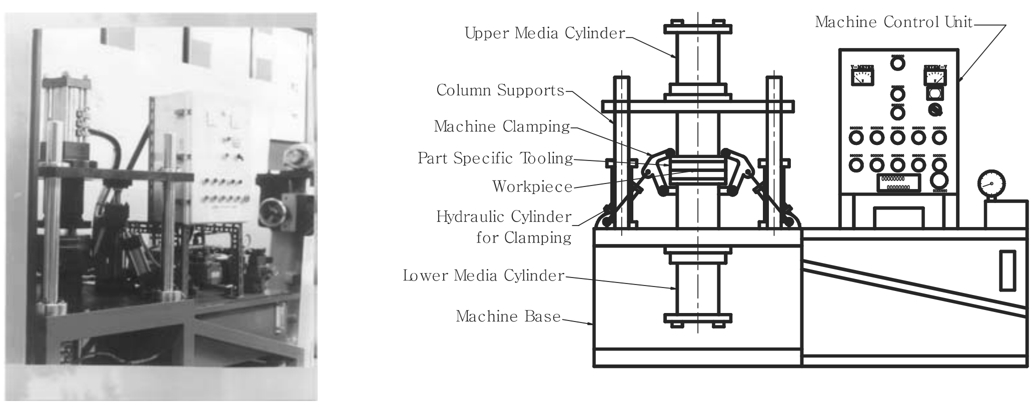


Fig. 2. Abrasive flow machine system

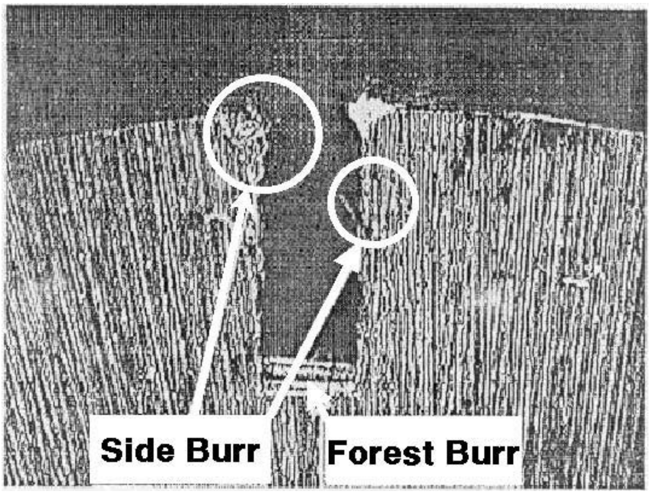


Fig. 3. Burr phenomenon of inside part

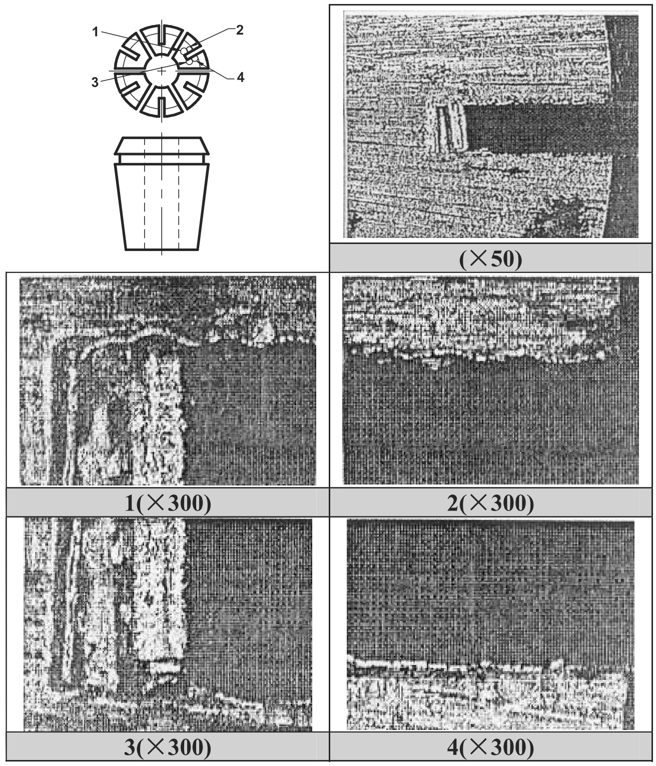


Fig. 4. Burr phenomenon of inside part

machined SCM steel. However, the size of burrs varies according to the kind of cutting process.

Figure 4 shows the grooves in four parts of the external diameter of the spring collet after processing. These were analysed as general burrs and curling burrs. The extensive curling burrs in particular occurred in the bottom of the groove where the cutting ended.

Table 2 presents the results of 45 abrasive flow cycles using SiC #80 grains. Although the deburring differed with the position of the burrs, in general they were effectively removed. The upper part of the spring collet in particular had perfect deburring (100% removal rate), with the surface roughness improved from 1.7 μm to 0.5 μm in the exterior and 0.9 μm to 0.7 μm in the interior.

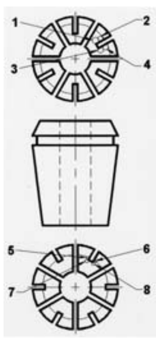
The experiment analysed the change in shape of the spring collet under varying pressures of 30, 35, and 40 kg cm^2. As expected, the design of the jig for fixing the spring collet was critical. Abrasive particle flow with uniform distribution was achieved, and there was no change in circularity and concentricity. The circularity or concentricity of the internal and external diameters generated during the processing of the spring collet were unchanged after abrasive machining.

Round ness Concentricity \ Pressure		Pressure(kg/cm2) 30		35		40	
Concentricity	X(μm)	2.8		25		2	
	Y(μm)	4.1		7		1	
Roundness	X(μm)	In	Out	In	Out	In	Out
		4	2	3	4	2	3
	Y(μm)	3	2	2	3	2	3
	D(μm)	8	3	6	7	4	6

Figure 6 shows the results of deburring using SiC media Al_2O_3 media. The media viscosity was HV (2900 mPa s) and the processing pressure was 40 kg cm^2. Processing was executed for 10, 20, 30, and 45 cycles. Generally, the SiC media was superior to the Al_2O_3 media for deburring.

Figure 7 presents the result of deburring using SiC media which showed perfect deburring over the entire area. The de-

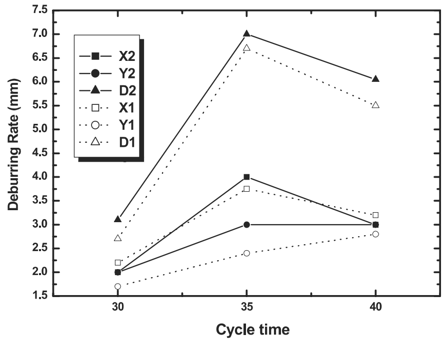
Table 2. Result of burr removal rate and surface roughness (HV : 2900 mPa s)

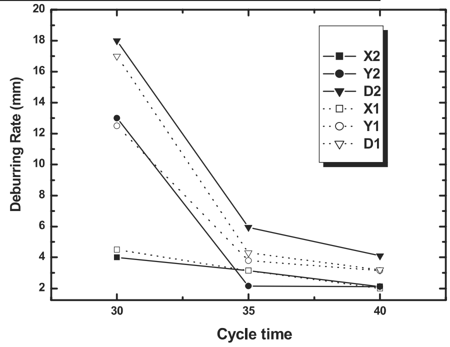


Burr NO.		Original Burr (mm)	Deburring Size (mm)	BRR (mm)
Top Outside	1	0.052	0	0.052
	2	0.060	0	0.060
	3	0.052	0	0.052
	4	0.034	0	0.034
Bottom Outside	1	0.103	0.017	0.086
	2	0.069	0.052	0.017
	3	0.069	0.035	0.034
	4	0.069	0	0.069

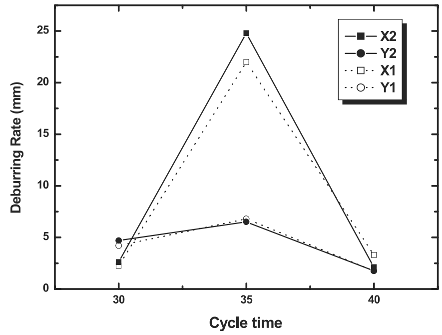
Fig. 5. Relationship between accuracy and deburring pressure (HV)

	D(μm)	8	3	6	7	4	6





X : Max Error
Y : Normal Error
X1, Y1, D1 : Before Deburring
X2, Y2, D2 : After Deburring
$D = \sqrt{D_1^2 + D_2^2 + D_3^2 + D_4^2}$
(D_1, D_2, D_3, D_4 : Measurement points)



X, Y : Error
X1, Y1 : Before Deburring
X2, Y2 : After Deburring

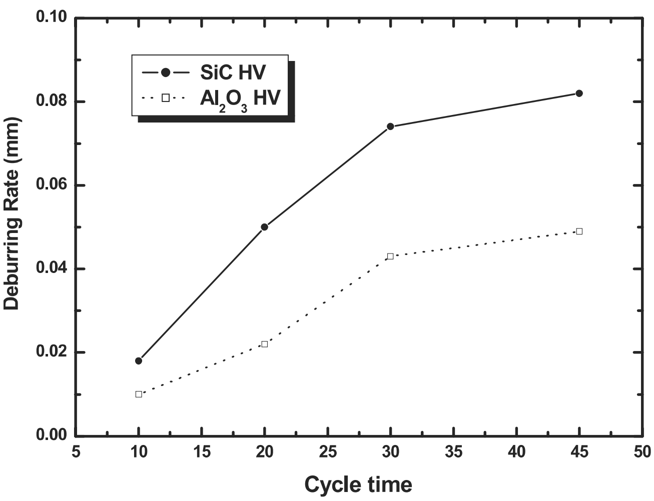


Fig. 6. Relation between deburring rate of SiC and Al_2O_3

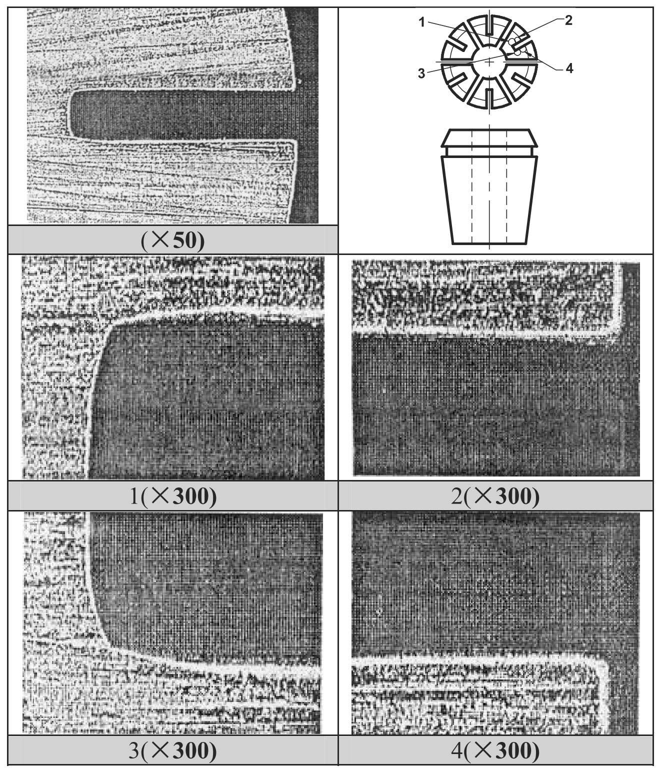


Fig. 7. Result of deburring

burring was done for 45 cycles at $40\,kg/cm^2$ g pressure and achieved zero burrs.

Figure 8 shows the changes in surface roughness relative to the number of cycles measured for HV, MV, and LV respectively. Surface roughness improved with increasing number of cycles. The best result was evident for HV compared to LV or MV. Likewise, the surface roughness Rmax improved in proportion to the number of cycles with HV SiC media and grain size of 80#.

Figure 9 shows the ratio of deburring to the number of cycles. Deburring was executed and measured with varying viscosity of SiC media of HV, MV, and LV. The best result was observed when HV media was applied. The deburring ratio increased rapidly to 30 cycles, but from that point the rate of increase in deburring ratio slowed down.

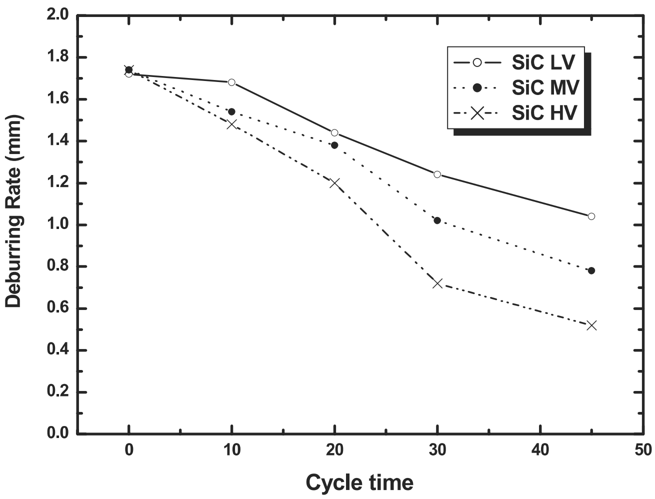


Fig. 8. Surface roughness according to cycle time

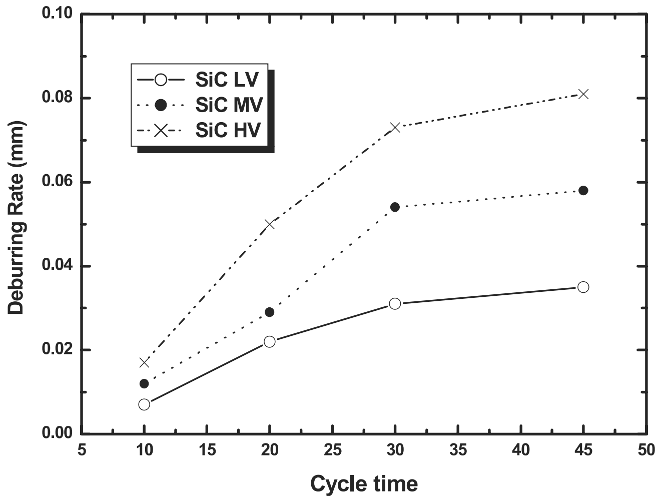


Fig. 9. Deburring rate according to cycle time

5 Conclusion

The following conclusions were drawn regarding abrasive flow deburring of spring collets:

(1) Abrasive flow processing is an effective system for the deburring of spring collets for the burrs generated during machining.
(2) SiC media is superior to Al_2O_3 media in terms of removal rate of the burrs.
(3) Circularity and concentricity of the spring collet are not related to deburring pressure.
(4) High viscosity media shows superior deburring effects compared to MV media or LV media.
(5) The abrasive flow processing system not only removes burrs inside and outside the spring collet, but also improves surface roughness.

References

1. Kim JD, Kim BH, You JU, Choi HY (1998) Deburring Chracteristic of Frame Hole in Finishing Trackle Reel. Spring Conference KMMA, pp203-208
2. Resnick R (1998) Advanced Abrasive Flow Technology, Deburring and Surface Finishing. 5th International Conference, CA, USA, pp16-27
3. Rhoades LJ (1986) Abrasive Flow Machining and its use. Conference Proceedings, pp111-120
4. Rhoades L (1991) Abrasive Flow Machining: A Case Study. J Mater Process Technol 28:107-116
5. Loveless TR, Williams RE (1994) A Study of The Effect of Abrasive-Flow Finishing on Various Machined Surface. J Mater Process Technol 47:133-151
6. Willams RE, Rajurkar KP (1992) Stochastic Modeling and Analysis of Abrasive Flow Machining. Trans ASME 144:74-81
7. Rhoades LJ (1998) Abrasive Flow Machining. Manuf Eng Nov:75-78
8. Kurata M, Tsunashima Y (1989) Viscosity and Molecular Weight Relationships and Unperturbed Dimensions of Linear Chain Molecules. Wiley, NY, ch.VII pp1-28
9. Brydson JA (1970) Flow Properties of Polymer Melts. Iliffe, London, pp16-20, pp142-143