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The Effect of Fine Particle Shot Peening on Carburized Material

1. INTRODUCTION

Shot peening is a process that improves the near-surface properties of metals by impacting the metal surface with small balls called shot that are made of metal or ceramic materials. The main effect is to improve the fatigue strength and it is used for various automotive parts.

The dent is created at the surface due to impact by shot during the shot peening process. The surface roughness characteristics will be modified by the peening process. Changes to the surface are dependent on shot peening conditions and the mechanical properties of metal parts.

In recent years, the demand to reduce fuel consumption of automobiles has led to weight reduction efforts. In a transmission unit for example, the goal of weight reduction is achieved by reducing the total length of the unit. This means that the tooth width will become thinner, and the load on a single tooth will increase. The two fatigue strengths required for transmission gears are the bending fatigue strength at the tooth root and the surface fatigue strength at the tooth surface. It is also important to reduce the surface roughness of the tooth surface in order to reduce noise and vibration. Therefore, the surface roughness after shot peening should be as low as possible. In order to reduce the surface roughness after shot peening, fine shot of 50 to 100 μm has been developed and applied to transmission gears.

In this article, we report on the fine particle shot peening for carburized materials which are widely used for automobile transmissions.

2. ABOUT FINE PARTICLE SHOT

The types of shot media can be roughly divided into cast steel shot, CCW (Conditioned Cut Wire), ceramic shot, and glass beads. The characteristics of each type is summarized in Table 1.

At the current time, the size of conventional shot varies from 30 μm to about 2 mm. For example, CCW is a process to obtain shot by cutting drawn wire at a length approximately equal to its diameter. Therefore, the smaller the wire diameter, the more difficult it is to cut. Currently, the smallest diameter is ϕ0.25 mm.

On the other hand, the diameter of the shot that is produced by casting is much smaller.

The “fine particles” discussed in this article are less than 100 μm.

Table 2 shows the specifications of the currently commercially available fine particle shot for reference.

Table 1 Specification of shot media

	Cast Steel Shot	CCW	Ceramic	Glass
Specification	Lower Cost	Higher Cost	Higher Cost	Higher Cost
	Fragile	High Durability	Durable	Fragile
	Work Hardening	Less Work Hardening	Fine Surface	Fine Surface
	Wide Distribution	Less Hardness Variation	Non-Work Harden	High Disposal Costs
		Narrow Distribution	Wide Distribution	Shallow Influence
Diameter	30 μm~2 mm	0.25 mm~1 mm	30 μm~1 mm	30 μm~0.8 mm

Table 2 Specification of available fine particle shot by SINTOKOGIO

	Ammo Beads	SBM-44T	SBM-100T
Diameter	50 μm~150 μm	45 μm~	100 μm
Hardness	900 HV	1200 HV	700~1200 HV
Specification	Amorphous Higher Young’s modulus	Smallest shot of cast steel	Inexpensive cost among fine particle shot

3. CONFIRMATION OF THE EFFECT OF FINE PARTICLE SHOT ON CARBURIZED MATERIAL

3 • 1 Gas Carburizing and Vacuum Carburizing

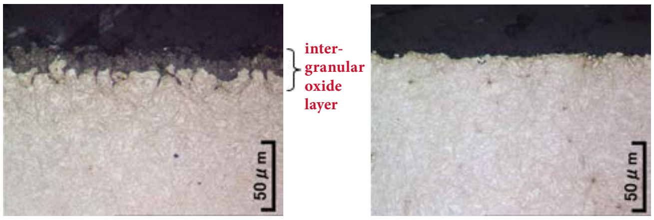
Carburized materials are often used for automotive transmission gears and CVT sheaves. Gas carburizing and vacuum carburizing are two methods currently used in mass production.

In gas carburization, the surface is carburized by the denatured gas containing carbon monoxide. Simultaneously, the surface is oxidized along the grain boundary to form a structure called the inter-granular oxide layer (see Fig. 1 on next page).

The inter-granular oxide layer is softer and less strong than the martensitic layer directly below it. On the other hand, vacuum carburizing produces a very hard martensitic structure from the top surface without oxidation.

3 • 2 Fatigue Strength

Fatigue fracture is a phenomenon in which repeated stresses below the yield stress initiate cracks that propagate and lead to



Gas carburized material **Vacuum carburized material**

Fig 1. Microstructure of carburized material

failure. High-fatigue strength is required for important parts such as transmissions and valve springs. There are two ways to improve fatigue strength: To increase the life until fatigue crack initiation and to increase the life until the fatigue crack propagates to failure.

Shot peening enhances fatigue strength mainly by inducing compressive residual stress near the surface which prevents fatigue crack growth. As mentioned above, the surface of the gas carburized material has an inter-granular oxide layer, which reduces the hardness. As a result, the material strength is lower and the fatigue and crack initiation life is shorter than that of the martensitic layer below.

When shot peening using fine particle shot is applied to gas carburized material, there is a possibility that the soft inter-granular oxide layer on the surface will be eroded. Therefore, in the case of gas carburized material, it is necessary to change the shot peening conditions to prevent the erosion.

On the other hand, in the case of vacuum carburizing, the top surface is martensite which is hard. Generally speaking, there is little possibility that shot peening will cause erosion.

Poor surface roughness has a negative effect on fatigue strength. Therefore, it is necessary to use shot peening conditions to reduce the surface roughness as much as possible, whether gas carburizing or vacuum carburizing.

The fine particle shot is used in expectation of low surface roughness.

3 • 3 Four-point bending fatigue experiment

SCM420H is typical carburizing steel in Japanese Industrial Standard which is why it was chosen for this experiment. After machining, vacuum carburizing is applied to specimen. Thereafter, shot peening is carried out by four conditions which are described in Table 3. In this table, "HSP" means conventional shot peening condition for gear in Japanese automobile industries. Fig. 2 shows shape of specimen.

Table 3 Condition of shot peening for four-point bending fatigue test

Name	DASP①	DASP②	DASP③	HSP
Shot diameter (mm)	0.05	0.3	0.6	0.6
Shot hardness	900 HV	950 HV	950 HV	700 HV

Fig. 3 shows surface roughness and Fig. 4 shows residual stress after shot peening. In the case of DASP①, which has used fine particle shot, the surface roughness is lowest. On the other hand, residual stress was induced only in the shallowest layer.

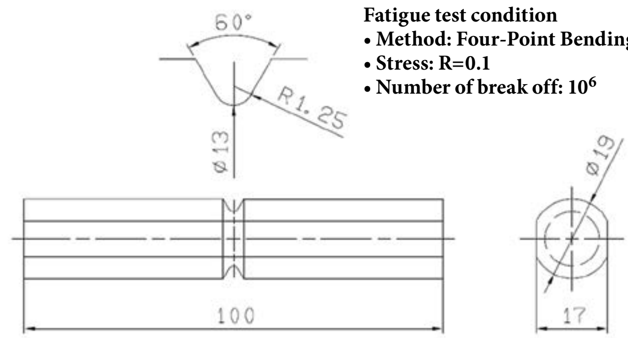


Fig. 2 Shape of specimen for four-point bending fatigue test

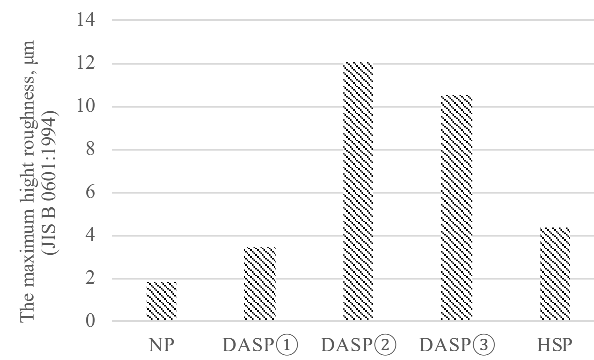


Fig. 3 The maximum height roughness

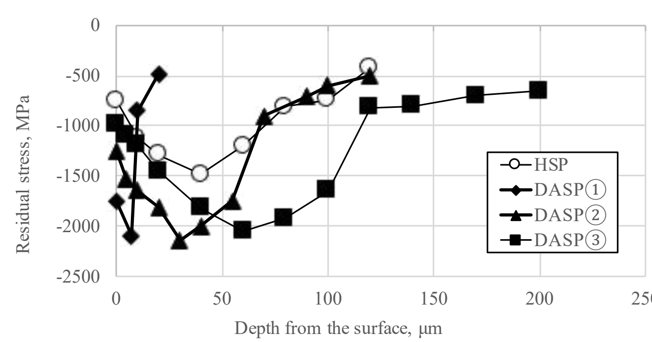


Fig. 4 Distribution of residual stress

Fig. 5 on the next page shows the result of the four-point bending fatigue test. DASP① obtained the best fatigue result. The results show that the best fatigue properties were obtained by fine particle shot peening conditions where the peening effects are only limited to a limited area of the surface which may have reduced the early fatigue cracks.

3 • 4 Rolling contact fatigue test

In order to evaluate the rolling contact fatigue characteristics of fine particle, shot peening was carried out on vacuum

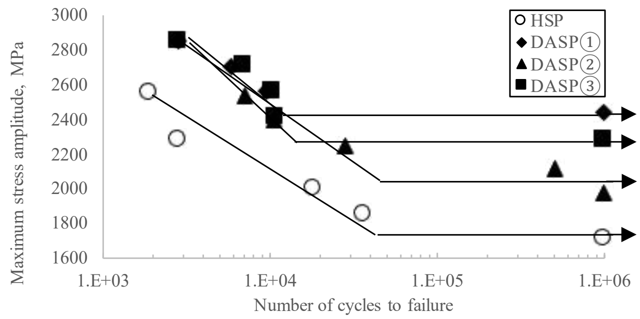


Fig. 5 Result of four-point bending fatigue test

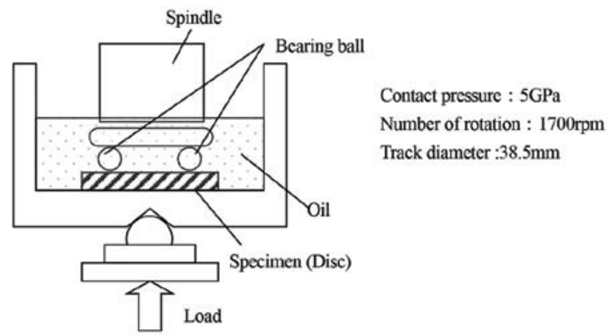


Fig. 6 Method of contact rotating fatigue test

carburized material. After machining, the specimen was polished before vacuum carburizing. The surface hardness is approximately 800HV. The conditions were selected so that surface roughness after shot peening is smaller than that of the untreated material. Two types of shot were used: Fine particle shot and conventional shot. In the case of fine particle shot peening condition, the air pressure are 0.1MPa, 0.3MPa, 0.5MPa. Also, in the case of conventional shot peening condition, the air pressure are 3MPa, 0.5MPa. Table 4 shows the shot peening conditions. In this table, F means Fine, C means Conventional.

Table 4 Shot peening condition for rolling contact fatigue test

Mark	F0.1MPa	F0.3MPa	F0.5MPa	C0.3MPa	C0.5MPa
Diameter of shot (mm)	0.05 (Amorphous)	0.05 (Amorphous)	0.05 (Amorphous)	0.03 (CCW)	0.03 (CCW)
Shot hardness (HV)	900	900	900	800	800

Fig. 6 shows shape of specimen and method of experiment are described. Fig. 7 shows result of surface roughness. In the case of fine particle shot peening condition which uses 0.5mm diameter shot, the surface roughness is improved slightly due to increased air pressure. This was also the same in the conditions using conventional shot.

Fig. 8 shows the distribution of residual stress after shot peening. In the case of fine particle shot, the maximum residual stress is increasing when air pressure is increasing. On the other hand, in the case of conventional shot peening condition, the maximum residual stress is almost the same when air pressure changed. In addition, the compressive residual stress value near the surface is smaller than that of the condition using fine particle shot.

Fig. 9 shows result of rolling contact fatigue test. Best rolling fatigue properties were obtained when fine particle shot was processed at an air pressure of 0.5 MPa. On the other hand, the fatigue properties of conventional shot peening condition is almost same as the non-peened specimen.

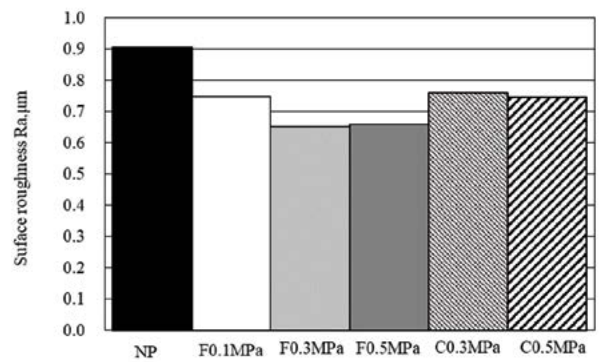


Fig. 7 Surface roughness after shot peening

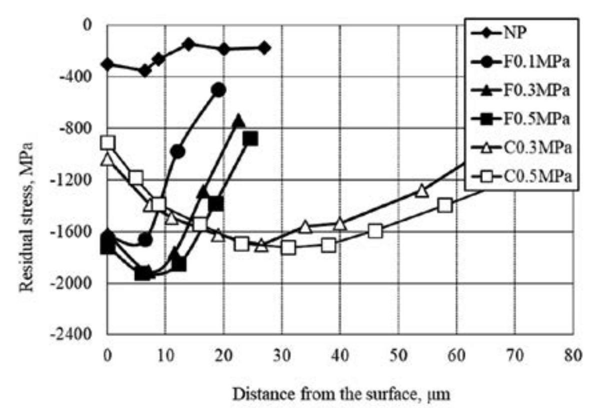


Fig. 8 Distribution of residual stress

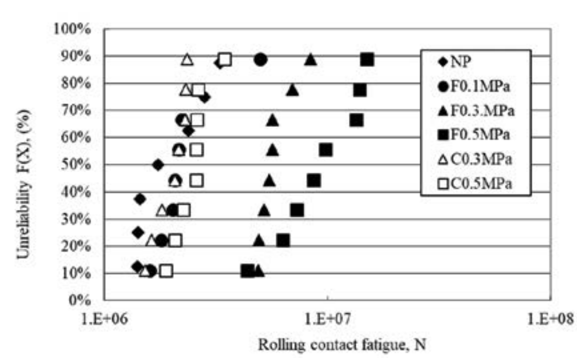


Fig. 9 Result of rolling contact fatigue test

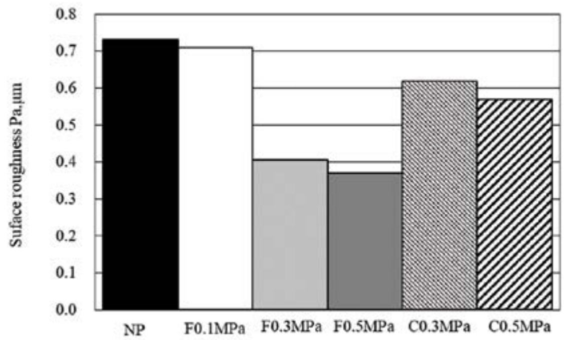


Fig. 10 Surface roughness after rolling contact fatigue test Pa (µm)

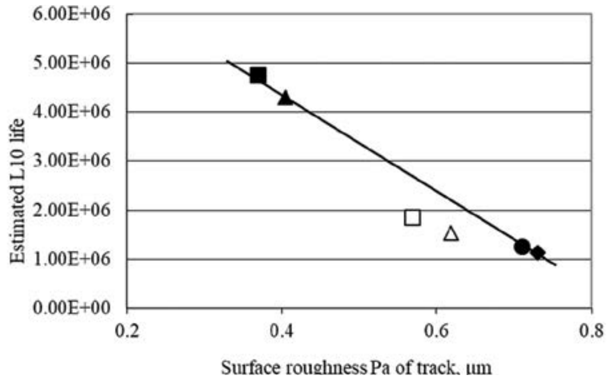


Fig. 11 The relationship between surface roughness of track after fatigue test and L10 life

Fig. 10 shows surface roughness Pa after rolling contact fatigue test. In the case of fine particle conditions, the surface roughness is reduced when the air pressure is high. On the other hand, under conditions of conventional shots, the roughness of the track increases as the air pressure increases.

The primary regression equation was obtained from the Weibull plots obtained from each shot peening condition. The obtained regression equation was used to estimate the rolling contact fatigue life L10 life N at unreliability F(X)=10%. Fig. 11 shows the relationship between surface roughness Ra and 0 N. Fig. 11 shows the relationship between surface roughness Ra and L10 life N.

From Fig. 11, it can be observed that under the condition of direct pressure, the L10 lifetime N increases with decreasing surface roughness. However, in the gravity type, the L10 life N was lower even though the surface roughness was lower.

4. CONCLUSION

In order to evaluate the fatigue strength characteristics of fine particle shot peening condition, a four-point bending fatigue test and a rolling fatigue test were conducted on vacuum carburized material.

This is due to the peening effect of the residual stress introduced near the surface by fine particle shot.