CHARACTERISTICS OF INTERNAL SURFACE LAYER OF MACHINE PARTS USING REBOUND SHOTS

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ABSTRACT

In the present study, shot peening process of the internal surface of machine parts in which rebound shots collide with the internal surface was investigated. In this process, the direction of collision of rebound shots perpendicular to the internal surface. In the experiment, an air type shot peening machine was employed. The workpieces were aluminum alloy, carbon steel and coiled spring steel. The jigs used for rebound shot peening were made of alloy tool steel and tungsten carbide. The jigs used for rebound shots have the surface with a slope to the internal surface of machine parts. The internal surface of workpieces can be sufficiently collided by the shots. The distributions of hardness, residual stress and surface roughness in the peened workpieces of the coiled spring steel were measured. It was found from the present study that the present process is suitable for the improving the internal surface of machine parts.

SUBJECT INDEX

Hardness, Residual stress, Surface roughness, Coiled spring, Fatigue

INTRODUCTION

Metals are usually hardened by plastic deformation under forces applied by various tools, especially at low temperatures. Deformation processes are known as forging, rolling and extrusion. As the degree of plastic deformation increases, the strength of a structural or machine part usually increases. It is important when the load is heavy. On the other hand, the surface properties of the machine part is important same as properties of inside the materials. The surface treatments are usually used to improve the surface properties such as wear resistance and corrosion resistance. Shot peening is one of the surface treatments and it is defined as the process of cold working the surface of the structural or machine parts. This process is very useful for the improvement of the surface properties, especially fatigue strength. In this process, the material surface is collided repeatedly with many steel shots, making overlapping indentations on the surface. The material undergoes large plastic deformation near the surface due to the collision of many shots. Because plastic deformation is generated only in the material surface, shot peening imparts compressive residual stresses on the surface, thus improving the fatigue life of the machine parts [1-3]. This process is extensively used on automobile parts such as gears and springs in order to increase resistance to fatigue and stress corrosion failure. In addition, shot peening processed for the inner surface of machine parts such as cylinder and coiled spring is also used. However, it is not easy to collide the shots to inner surface in conventional processing. For example, the inner surface of machine parts was peened by changing the collision direction of shots [4]. In case of a large diameter pipe, the inner surface of pipe was peened by rotating the rubber board with many small balls. However, in these processes the peening effect is low. The operation performance is not good. It is very difficult in case of the inner surface of machine parts such as slender pipe and coiled spring. Therefore, in the shot peening process, the optimum processing for the inner surface of machine parts has been required. In the present study, shot peening process of inner surface of machine parts using rebound shots was investigated. In this process, the collision direction of rebound shots is vertical to the inner surface. The effects of air pressure, shot size, coverage and stress peening on the residual stress, hardness and surface roughness in shot peening using reboud shots are examined.

METHOD OF PEENING USING REBOUND SHOT

In air shot peening process, shots which jetted from the nozzle do not directly collide perpendicular to the inner surface of components. To make the shots collide efficiently with the inner surface, the rebound shots are utilized. In this study, shot peening process of the inner surface for the components using rebound shots was used. In this process, the collision direction of rebound shots is vertical to the inner surface as shown in Figure 1. The shots are accelerated by compressed air. Most of the rebound shots collide perpendicular with the inner surface. If the speed of rebound shots is sufficiently high, the collision energy is also high. The peening effect increases with the increase of the collision energy of rebound shots. Thus the inner surface can be improved by the rebound shots. The present method is available to improve the inner surface of machine parts.

SHOT PEENING EXPERIMENT

In the experiment, the air type shot peening machine SHINTOBRATOR MY-24 was employed. To examine the effect of the working conditions in the shot peening operation using the rebound shots, the peening apparatus shown in Figure 2 was performed. The shots used were high carbon cast-steel (500HV). The shots, which are rebounded by a conical jig (a fixed jig), perpendicularly collide with the inner surface. The rebound jig connects with the end of the air nozzle. The collision direction of the rebound shots was vertical for the inner surface, when an angle of rebound jig was about 45°. The jigs have the surface with a slope of the angle as shown Figure 3. The inner surface of workpieces was sufficiently peened by the rebound shots. The shape of the fixed jig (a) and the pneumatic jig (b) are conical and windmill, respectively. The pneumatic jig (b) is naturally rotated by the compressed air. Both of the jigs are made of the tool steel SKD11 (840HV). Shot diameter and the pressure of compressed air are changed to find an optimal condition. Air pressure, shot size and coverage are controlled in the experiment. The conditions used for this experiment are summarized in Table 1.

The distributions of residual stress and surface roughness in the peened workpieces were measured. The distribution of residual stress in the thickness direction was obtained the X-ray diffraction method by removing the surface layer of the workpiece using electrochemical polishing.

The workpieces were aluminum alloy A6063 pipe, carbon steel STK400 pipe and valve spring steel SWOSC-V coiled spring. The pipe workpieces were annealed for one hour in evacuated silica tube, and the workpieces used for coiled spring were oil-quenched at 920 °C and followed by tempering at 300 °C.

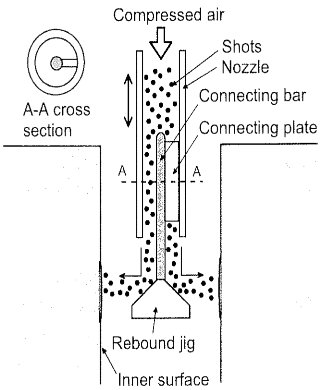


Figure 1 Schematic illustration of the shot peening process of the inner surface using the rebound shots.

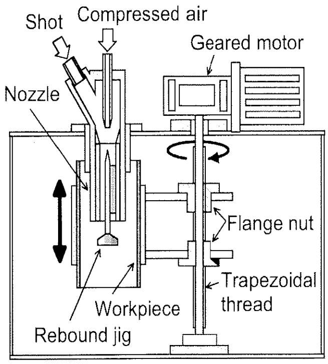


Figure 2 Schematic illustration of shot peening apparatus.

SHOT SPEED AND PROJECTION DENSITY OF REBOUND SHOTS

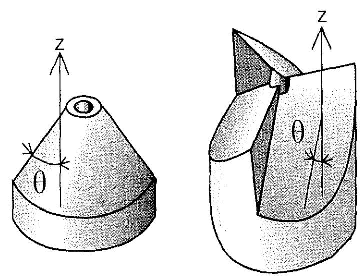
To measure the shot speed of rebound shots, the speed was obtained from the arc height measurement. The N-type almen-strip (t=0.77-0.81 mm) set on the inner surface was hit with the rebound shots, and then the arc height of the test strip was measured by the almen gauge. By changing the air pressure, the arc height, i.e., shot speed was obtained. In this paper shot speed can be determined as follows: $v = 47.5 H$, where v is shot speed, H is arc height of the almen strip. The relationship between shot speed and air pressure is illustrated in Figure 4. Shot speed increases with air pressure. Shot speed of rebound shots is smaller than that of conventional shots. The main reason is that the kinetic energy of shots is lost on collision at the surface of rebound jig (Figure 1).

To examine the effect of the projection density at the inner surface in the air shot peening process using rebound jig, shot peening using two types of jigs was performed. The relationship between the coverage and the collided position to the circumferential direction of rebound shots is shown in Figure 5, where the coverage is defined as the indentation area divided by the area of the inner surface. The workpiece is aluminum alloy A6063(JIS) pipe of 46 mm inner diameter and 2.0 mm thickness. Shot diameter and air pressure are d=1.0 mm and p=0.9 MPa, respectively. The lack of the coverage occurred near the position of 180°. The smaller coverage is attributed to an obstacle to passage of shots, that is, the connecting bar and plate. The coverage was slightly improved by the use of pneumatic jig.

EFFECTS OF AIR PRESSURE AND SHOT DIAMETER ON RESIDUAL STRESS

To examine the effect of air pressure on the residual stress, shot peening using the fixed jig was performed. The distributions of the measured residual stress along the depth from the surface for the different air pressure are given in Figure 6. The workpiece made of carbon steel pipe SKT400 is 46.2 mm inner diameter and 2.0 mm thickness. As the air pressure increases, the compressive residual stress increases. The residual stresses of the workpieces have peaks inside the workpieces. The distributions of hardness in the thickness direction from the inner surface for the different pressures were also measured. As the air pressure increases, hardness increases. The hardness at the surface was maximum.

The distributions of the measured residual stress in thickness direction from the inner surface for the different shot sizes are illustrated in Figure 7. The values of compressive residual stresses at the surface are similar for shot size used in this experiment, but the compressive stress inside is different. The residual stress for d=1.0 mm is higher than that for other size, because the increase in the shot size leads to the increase in amount of plastic deformation.



(a) Fixed jig (b) Pneumatic jig

Figure 3 Schematic illustrations of the rebound jigs.

Table 1 Working conditions used for shot peening using rebound shots.

Equipment	Air peening (suction type)
Shot material	High carbon cast steel (500HV)
Shot diameter d (mm)	0.3 - 1.0
Air pressure p (MPa)	20 - 80
Coverage (%)	100
Rebound jig material	Tool steel SKD11 (840HV)
Workpiece	Pipe (t=2 mm) Aluminum alloy A6063-O Carbon steel STK400 Coiled spring Valve spring SWOSC-V
Processing temp. T (°C)	Room temperature
Atmosphere	Air

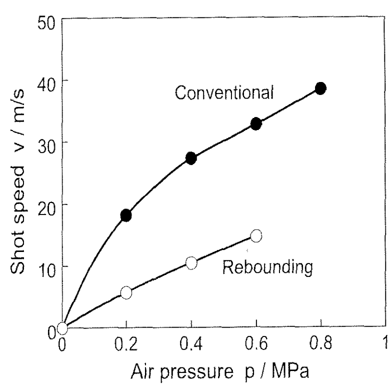


Figure 4 Variations of shot speed with the air pressure. (d=1.0mm)

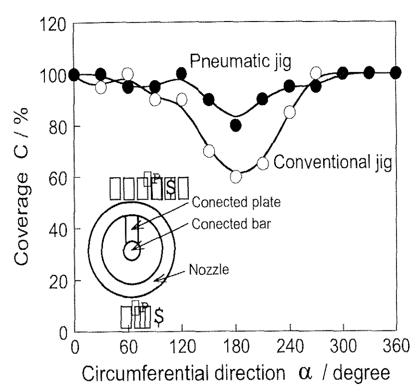


Figure 5 Distributions of the coverage on the inner surface after peening using rebound shots. (d=1.0mm, p=0.9MPa)

EFFECT OF STRESS PEENING

The inner surface of coiled spring was peened by rebound shots. The distributions of the measured residual stress from the inner surface for different air pressure are illustrated in Figure 8. The workpiece is coiled spring of 16mm inner diameter, and the diameter of the wire used is 2.7mm. As air pressure increases, the residual stress increases. The effect of shot size on the residual stress was also examined. The residual stress for d=1.0 mm was higher than that for other size. These results are similar to those obtained in the above Session for carbon steel pipe.

The spring properties are usually improved by shot peening, especially the coiled spring has the best fatigue life for the stress peening process. In this study, the shot peening for the inner surface of coiled spring was carried out under the compressive stress. The initial compressive stresses are 306 and 712 MPa. The distributions of the measured residual stress in the diameter direction from the inner surface for the different initial stresses are shown in Figure 9. For the comparison, the result of the as-received spring is reproduced. The residual stresses of the peened workpieces have peaks near the inner surface. As the initial stress increases, the residual stress considerably increases.

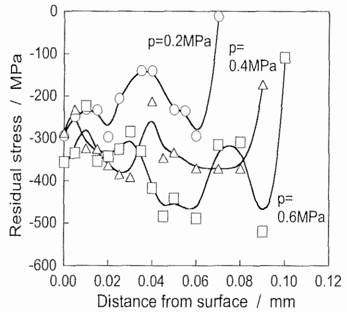


Figure 6 Distributions of residual stress near the inner surface after shot peening. (d=1.0mm, SKT400 pipe, fixed jig)

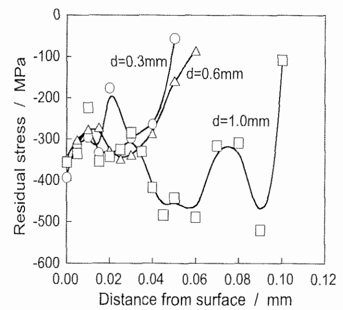


Figure 7 Distributions of residual stress near the inner surface after shot peening. (p=0.6Mpa, SKT400 pipe, fixed jig)

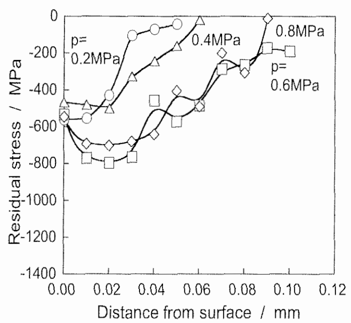


Figure 8 Distributions of residual stress near the inner surface after shot peening. (d=1.0mm, coiled spring, fixed jig)

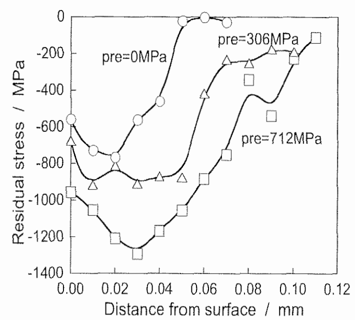


Figure 9 Distributions of residual stress near the inner surface after stress peening. (d=1.0mm, coiled spring, fixed jig)

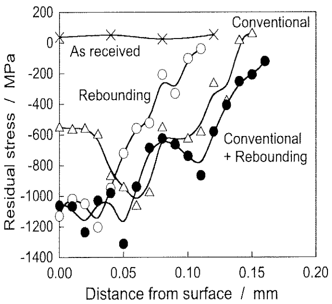


Figure 10 Distributions of residual stress near the surface of spring after three types of shot peening. (p=0.8MPa, d=1.0mm, coiled spring)

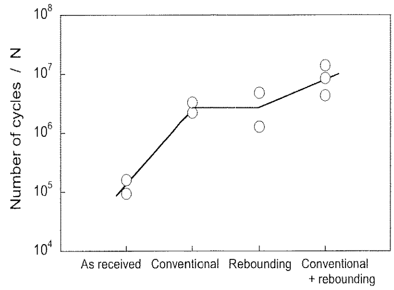


Figure 11 Critical number of cycles of spring after shot peening. (p=0.6MPa, d=1.0mm, coiled spring)

FATIGUE STRENGTH

To measure the distribution of residual stress of coiled spring workpiece (SWOC-V) used in the fatigue test, the three types of shot peening were carried out. The distributions of the measured residual stress from the inner surface are shown in Figure 10. The initial compressive stress are 306 MPa for conventional shot peening and 712 MPa for rebound shot peening. In this shot peening, the residual stress of workpiece is increased using the combination of the rebound shot peening and the conventional peening.

The fatigue failure of coiled spring occurs after many millions of cycles of satisfactory operation. To examine the fatigue strength of peened workpiece, fatigue test was performed by using the fatigue testing machine. The critical number of cycle for the three types of shot peening is given in Figure 11. The initial compressive stress are same as working condition in Figure 10. The critical number of cycle for rebound shot peening is almost equal to the conventional process, although the outside surface of coiled spring was not peened because of the rebound shot process.

CONCLUSIONS

In the present study, shot peening process using the rebound shots was investigated. In this process, the shots rebounded on the jig and collide with the inner surface of machine parts. The inner surface was successfully peened by the rebound shots. The distributions of residual stress in the peened workpieces were measured. The stress peening using rebound shot was effectively for the improvement of spring properties. The results of a fatigue test showed that the fatigue life of the spring was improved. It was found that the present process is suitable for the improvement of the inner surface of machine parts.

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