X-ray residual stress measuring in actual production process

Kan Aoki, Yuji Kobayashi
SINTOKOGIO,LTD., Japan, ka-aoki@sinto.co.jp y-kobayashi@sinto.co.jp

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Introduction

Shot peening is applied to improve fatigue strength of metal parts such as gears and springs. The effect of improving fatigue strength is mainly produced by residual stress that is induced by shot peening. The residual stress changes with the intensity of the shot peening processing. Therefore, a method to represent the degree of processing was necessary. Dr. Almen of the United States acquired a patent for an evaluation method using Almen strips in 1994 (OS patent 23450440). According to this description, the arc height is the residual stress imparted by shot peening. But it is described that if the material is different for the same shot peening conditions, the residual stress is different. On the other hand, the application range of shot peening is expanding. Therefore, it is not suitable for current materials and applications.

Recently, the Japanese automobile industry uses one piece flow manufacturing, which not only maintains high quality but also reduces the total cost, including quality management. In actual production, some parameters that are required in drawing should be measured for quality checking. In my opinion, residual stress after shot peening should be measured too. Normally, X-ray diffraction analysis is used to measure the residual stress on metal parts. But the measuring time is very long, such as 10 to 15 minutes. Thus, this measuring is difficult to integrate into one piece flow manufacturing. We developed an X-ray residual stress measuring device that can measure stress in a short time. Because the residual stress measurement is fast, it can be applied to one piece flow manufacturing.

In this study, with inspection management by Almen strips, the effectiveness of this X-ray residual stress measuring device in the actual production process was confirmed.

Methodology

Inspection management by Almen strip

For the specimen, Almen strip A pieces (W19.0 x L76 x t1.3 mm), SK85 material, SK85 material decarburized, and SCM420H round bar test pieces were used. SK85 material is a tool steel with chemical composition similar to Almen strips. It was made to have the same hardness as the Almen strip by heat treatment. Table. 1 shows the hardness of the specimen. Table. 2 shows shot peening conditions. Fig. 1 shows a schematic view of a round bar test piece. Shot peening was performed with the Almen strip fixed to the Almen holder. Afterwards, residual stress was measured, fixed to the Almen holder and released from the Almen holder. Also, residual stress was measured using shot peening round bar test pieces with different materials.

Evaluation of residual stress by the developed X-ray residual stress measuring device

The specimens were shot peened under the same conditions. Residual stress was measured with the developed residual stress measuring device (referred to as PSMX II) Fig. 2.

Table. 1 Hardness of the test material

Test pieces	Hardness of surface (HV)
Almen strip A	460～510
SK85	460～490
SK85 (Decarburized)	360～400
SCM420H (Carburized material)	730～800

Table. 2 Shot peening conditions

Media diameter	600μm			
Media hardness	HV500	HV700	HV800	HV900
Air pressure	0.3MPa			
Coverage	300%			
Arc height	0.405mmA	0.484mmA	0.498mmA	0.511mmA

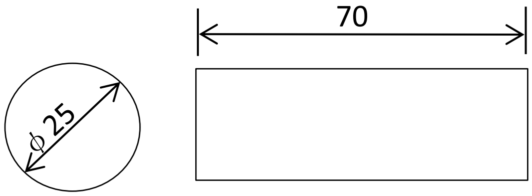
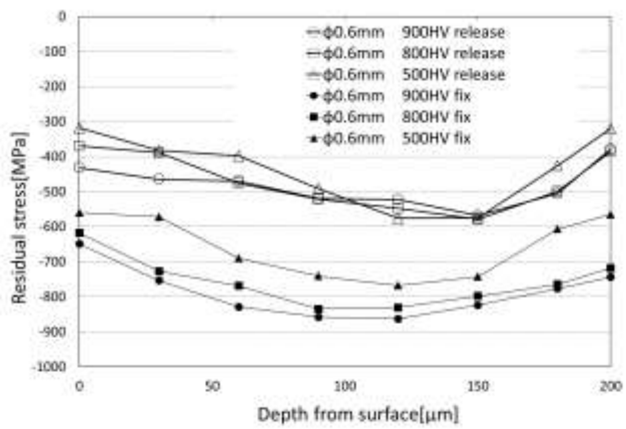
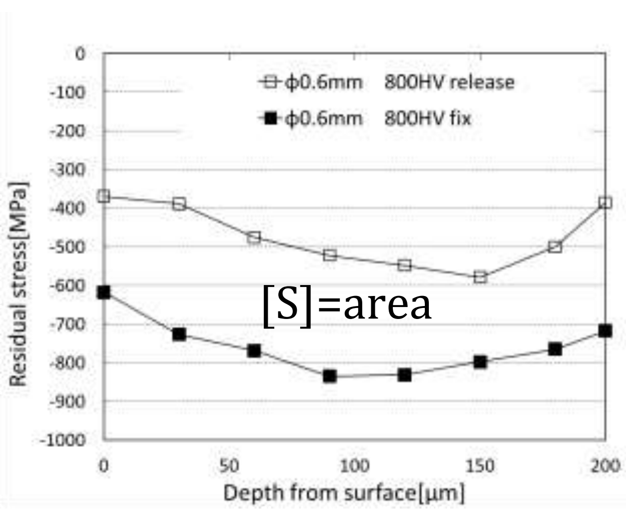


Fig. 1 Round bar test piece

Fig. 2 PSMX II





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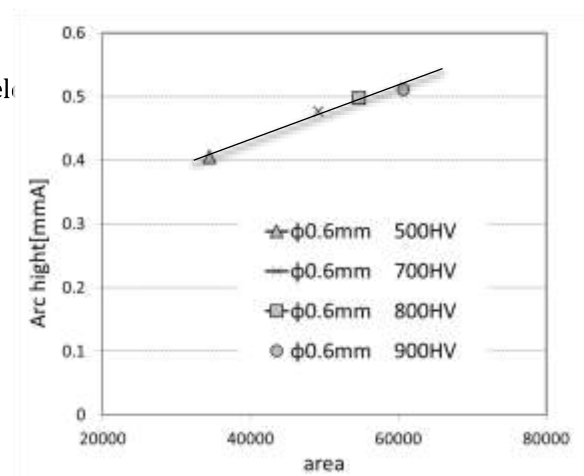

Fig. 4 Amount of change with fixed/released

Fig. 5 Relationship between arc height and area

Results and analysis

Inspection management by Almen strip

Fig. 3 shows the stress distribution fixed to/released from the Almen holder and processed under all kinds of shot peening. The released Almen strip has lower residual stress than the fixed Almen strip. All kinds of shot peening conditions and stress distributions of released Almen strips generally correspond. On the other hand, in the case of the fixed Almen strip, when using a medium with the same hardness as the Almen strip, the residual stress is lower than when using a harder medium.

Fig. 5 shows the change in stress distribution with fixed/released. The vertical axis is the arc height in all kinds of shot peening and the horizontal axis is the area. The area is the amount of change with fixed/released. It refers to [S] from Fig. 4. A good correlation was found between the arc height in all kinds of shot peening and the amount of change with fixed/released.

Fig. 6 and Fig. 7 show the residual stress of the fixed Almen strip compared to the residual stress distribution of SK85 material and SCM420H after shot peening.

The residual stress distributions of the fixed Almen strip and SK85 generally correspond.

On the other hand, the residual stress distribution of the fixed Almen strip and the SCM420H are different. Fig. 8 shows the hardness distribution of SK85 and decarburized K85 material after shot peening. Fig. 9 shows the residual stress distribution of SK85 and decarburized K85 material after shot peening. The hardness of the decarburized specimen was decreased on the surface (Fig. 8). Lower compressive residual stress for the decarburized specimen compared to the correct specimen was confirmed (Fig. 9). The residual stress depends on the mechanical properties of the material. Therefore, residual stress on the surface of the decarburized specimen will be expected to decrease. There is a correlation between arc height and stress value only for materials with chemical composition similar to Almen strips. However, when shot peening is performed under the same conditions for different materials, the residual stress is different. Additionally, in the case of shot peening for the same material, residual stress differs if there is some error in the material itself. Thus, arc height is effective for process control, but it is not effective for quality management of shot peened parts.

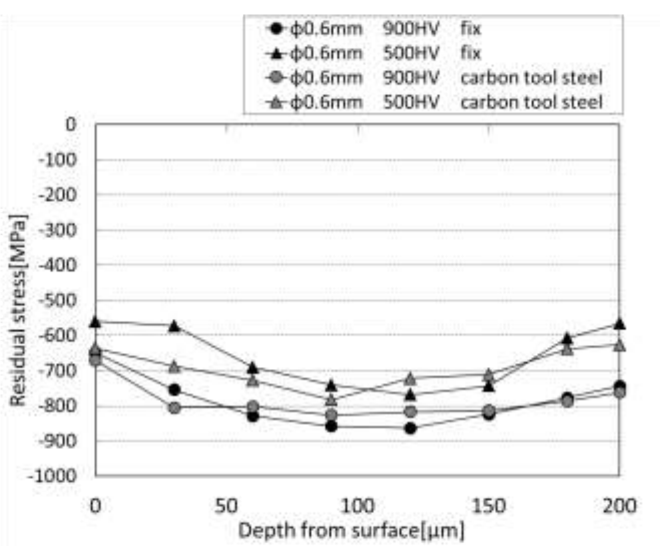

Fig. 6 Fixed Almen strip and SK85 material

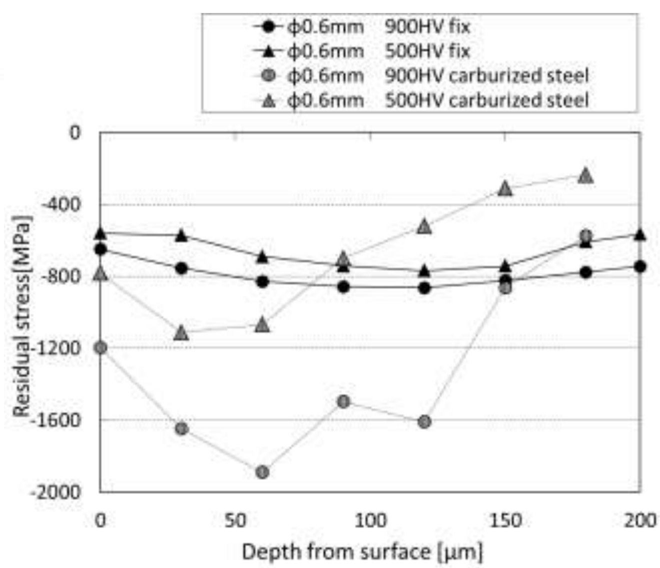

Fig. 7 Fixed Almen strip and SCM420 material

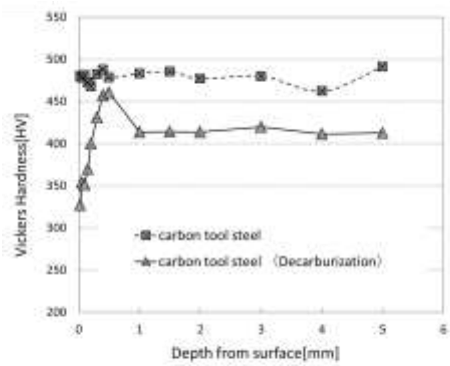

Fig.8 Hardness distribution of SK85 and decarburized K85

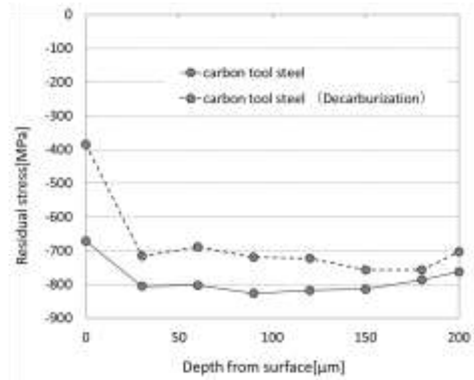

Fig. 9 Residual stress distribution of SK85 and decarburized K85

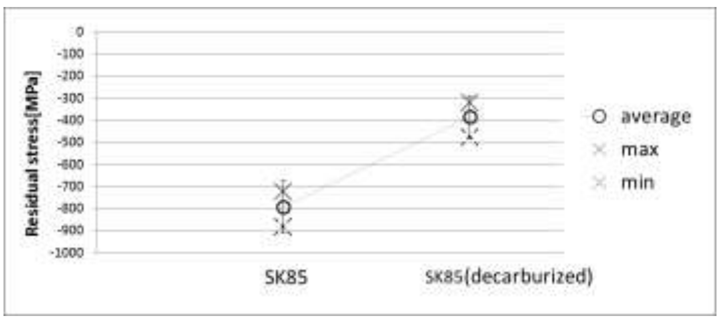

Fig. 10 Residual stress of surface that is measured with PSMX II

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The number of measurements was 100
Error bar shows 3σ

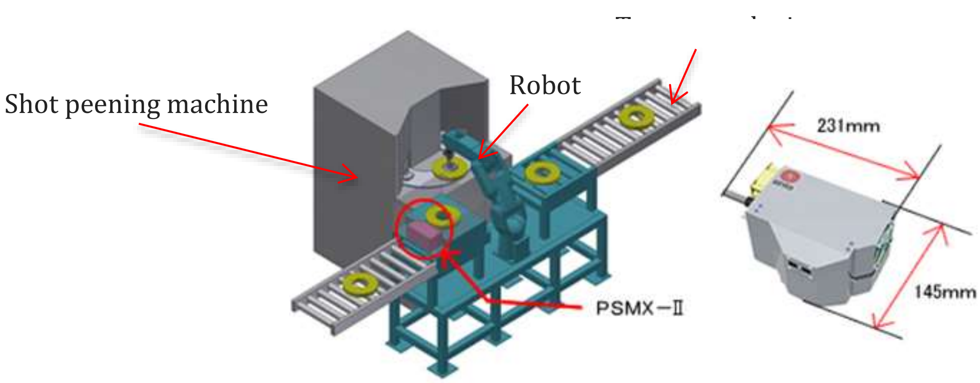

Fig. 11 Model of shot peening line incorporating PSMX II

Evaluation of residual stress by the developed X-ray residual stress measuring device

Residual stress on the surface of the specimen shot peened was measured with PSMX II. Fig. 10 shows the residual stress of the surface that is measured with PSMX II. The naked eye cannot judge the decarburization, but because PSMX II can judge the difference in residual stress on the surface, it is possible to find a decarburized product. Therefore, residual stress should be measured with one piece flow manufacturing.

Conclusion

Shot peening under the same conditions for materials with different properties results in different residual stress. Even with the same material, the residual stress differs if there is some error in the material itself. Therefore, the evaluation of quality after shot peening should not be arc height. Rather, the change that occurs in the target product by shot peening should be evaluated by residual stress. One piece flow manufacturing is applied in the shot peening process, and it is expected that the number of parts with specified residual stress values will increase in the production drawing. Therefore, we think that the need for X-ray stress measuring devices that can be applied to one piece flow manufacturing will increase. For example, the cycle time of gear production is about 20 seconds to 1 minute. PSMX II can measure in about 10 seconds. Therefore, measurement within the cycle time can be achieved. Fig. 11 shows a model of a shot peening line incorporating PSMX II.