RELAXATION BY ANNEALING OF RESIDUAL STRESS DISTRIBUTION PRODUCED BY SHOT PEENING

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1. INTRODUCTION

Residual Stress affects remarkably on fatigue strength [1] and stress corrosion cracking. Residual stresses do not keep initial distributions under loading or heating.

In order to clarify the change of residual stress distribution by heat treatment, shot peening was performed on plain carbon steel (0.45%C), austenitic stainless steel (SUS304) and carburized steel (SCM415), and then residual stress distributions were measured by X-ray diffraction. The influences of temperature (200 - 700°C) and heating time (15 - 240 min.) on the distributions are discussed.

2. EXPERIMENTAL PROCEDURE

Table 1. Experimental conditions

<table>
<thead>
<tr>
<th>Shot peening</th>
<th>Equipment</th>
<th>Centrifugal type</th>
<th>Direct pressure type (3 atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shot</td>
<td>Material: cast steel (900 HV)</td>
<td>D: 0.92 mm</td>
</tr>
<tr>
<td></td>
<td>Velocity V</td>
<td>35 m/s</td>
<td></td>
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<tr>
<td></td>
<td>Peening time</td>
<td>T: full coverage time</td>
<td></td>
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<tr>
<td></td>
<td>Impact angle</td>
<td>Normal to the peening surface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>45C</td>
<td>0.45%C, Annealed (180 HV)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Size: 25 x 25 x 12 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCM415</td>
<td>Carburized steel (800 HV)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Size: fatigue specimen (sheet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUS304</td>
<td>Austenitic stainless steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annealed (210 HV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Size: Ø 18 x 18 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td>Temp. (Time)</td>
<td>200 - 700°C (15 - 240 min)</td>
<td></td>
</tr>
<tr>
<td>Residual stress measurement</td>
<td>X-ray diffraction, (220) plane, sin²ψ method, iso-inclination method</td>
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</tbody>
</table>
Specimen, shot peening, heating and residual stress measurement are shown in Table 1.

Residual stress distributions were measured by window method with x-ray diffractometer, the size is 4 mm square and etched chemically.

3. RESULTS

3.1 Surface Residual Stress

Figure 1 shows the influence of residual stress on the deformation of plain carbon steel ring which was cut after shot peening. (a) non-peened and no deformation. (b) shot peened on the outside of ring, and the gap closed. (c) shot peened on the inside of ring, and the gap expanded.

(a) As annealed (b) Outside peened (c) Inside peened

**Fig. 1. Deformation of peened ring after cutting (S45C)**

![Deformation of peened ring after cutting](image)

**Fig. 2. Influence of peening time on surface residual stress**

![Influence of peening time on surface residual stress](image)
The influence of peening time on surface residual stress for plain carbon steel and for austenitic stainless steel are shown in Fig. 2. Compressive residual stress increases much before full coverage and reaches saturated values at full coverage time (Tf).

![Fig. 3. Influence of heating on surface residual stress](image)

![Fig. 4. Influence of heating on surface residual stress](image)
Figure 3, 4 and 5 show the influence of temperature and heating time on surface residual stress produced by shot peening for plain carbon steel (S45C), carburized steel (SCM415) and austenitic stainless steel (SUS304).

As shown in Fig. 3, surface residual stress does not change with the increase of heating time under 200 - 300°C. The more the temperature rise, the more the surface residual stress relax. Its critical time is 60 min. on 400°C and is 20 min on 600°C.

The relaxation of surface residual begins at low temperature for carburized steel owing to the previous heat treatment as shown in Fig. 4.

The relaxation of surface residual stress of austenitic stainless steel is similar to plain carbon steel as shown in Fig. 5, but the relaxation at 400°C - 500°C is less than plain carbon steel.

3.2 Residual Stress Distribution

Figure 6, 7 and 8 show the relaxation by heating on residual stress distributions for three specimens.

As shown in Fig. 6, the relaxation of residual stress hasten by heating from 600°C, and the decreasing ratio at surface is more than inside.

Carburized steel shows S type distribution produced by shot peening as shown in Fig. 7, and the maximum residual stress decreased rapidly by heating.
The influence of heating for austenitic stainless steel which shows C type distribution is similar to carbon steel as shown in Fig. 8.

The decreasing ratio of residual stress by heating at 300°C, 30 min are shown in Fig. 9. The depth where residual stress changes rapidly is the shallow layer...
for the specimens of C type distribution such as plain carbon steel and austenitic stainless steel, but for carburized steel which shows S type distribution is changed more on surface than inside.

![Graph showing residual stress distribution](image1)

**Fig. 8. Influence of heating on residual stress distribution**

![Graph showing decreasing ratio of residual stress](image2)

**Fig. 9. Influence of heating on the decreasing ratio of residual stress**
4. CONCLUSIONS

The relaxation by heating on residual stress distributions for carbon steel and stainless steel are little under 200°C - 300°C.

Residual stress produced by shot peening almost vanished above 600°C for carbon steel, austenitic stainless steel and carburized steel.

The relaxation by heating on residual stress distribution is different from each other, much at shallow on carbon steel and austenitic stainless steel (C type), and at deep on carburized steel (S type).

5. REFERENCES