CRYSTAL TRANSFORMATION OF AUSTENITIC STAINLESS STEEL BY SHOT PEENING AND GRIT BLASTING

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ABSTRACT

This paper describes the influence of shot peening and grit blasting on the strain-induced transformation. Shot peening and grit blasting were performed by steel shot and grit with centrifugal type blasting machine. Obtained factors are strain-induced transformation, surface roughness, hardness distribution accompanied work softening, half-width, austenite volume and residual stress.

1. INTRODUCTION

Austenitic Stainless Steels are widely used in various industries such as mechanical, chemical, atomic, medical and processed food. But recently, SCC and corrosion fatigue of austenitic stainless steel are often reported as accidents. Although it is widely known that shot peening and grit blasting are very effective for them [1][2][3], the relation between these processes and the strain-induced transformation of crystal structure has not so far been clear enough.

This paper describes the influence of shot peening and grit blasting on the strain-induced transformation. Shot peening and grit blasting were performed by steel shot and grit with centrifugal type blasting machine. Obtained factors are strain-induced transformation, surface roughness, hardness distribution accompanied work softening, half-width, austenite volume and residual stress.

2. EXPERIMENTAL PROCEDURES

Table 1. Experimental conditions

<table>
<thead>
<tr>
<th>Shot peening &amp; Grit blasting</th>
<th>Equipment</th>
<th>Centrifugal type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shot &amp; Grit</td>
<td>Material : Steel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P1, G1</td>
<td>D : 0.64 mm</td>
</tr>
<tr>
<td></td>
<td>P2, G2</td>
<td>D : 0.92 mm</td>
</tr>
<tr>
<td></td>
<td>P3, G3</td>
<td>D : 2.2 mm</td>
</tr>
</tbody>
</table>

| Velocity V                  | 35 m/s |
| Peening time                | T : full coverage time |
| Impact angle                | Normal to the peening surface |
| Prestrain                   | Compression & % |
|                             | C1 : 10, C2 : 20, C3 : 35 |
| Specimen                    | Material |
|                             | SUS304 : annealed, 210 HV |
|                             | Size |
|                             | ∅ 16 x 19 mm |
| Residual stress measurement | X-ray diffraction, (220) |
|                             | sin^θ method, iso-inclination method |
Confirmation of strain-induced transformation was treated from the observation by etching with aqua regia and from the change in the X-ray diffraction pattern.

In order to measure the residual stress distribution and confirm of strain-induced transformation in the affected layer, the window (4 x 4 mm) was made by electrolytic polishing.

Residual stresses are calculated from the following equation.

$$\sigma_R = -\frac{E}{2(1+v)} \cot \theta_c \frac{d2\theta}{d\sin^2 \psi}$$

where $E = 192$ GPa and $v = 0.28$

In order to produce the work-softening by shot peening and grit blasting, compressive deformation was performed previously for specimen. Johnson wax #111 was used as the lubricant between the specimen and anvils. This lubricant was dried for 12 hours, and then the specimen was compressed very slowly to avoid the thermal influence.

3. RESULTS

As shown in Fig. 1, the structural transformation under the microscopic observation doesn't appear. Therefore, the confirmation of transformation was detected from X-ray diffraction pattern.

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**Fig. 1. Microstructure of Austenitic stainless steel**  
(Etched by aqua regia)
Fig. 2. Influence of compressive strain on the x-ray diffraction pattern.

Fig. 3. Relation between compressive strain and the intensity (211) on x-ray diffraction pattern.
3.1 Influence of the primary deformation

Figure 2 shows the X-ray diffraction patterns on surfaces of annealed (0), and of compressed (C1, C2 and C3). The peak neighbour on 149° shows that the structure of the annealed is clearly austenite. The height of this peak decreases with increase of compressive strain, and at the same time, another peak arises neighbour on 156° as strain-induced transformation. This is the peak of (211) plain of alpha-Fe and its height increased with the compressive strain.

The influence of compressive strain on the peak intensity of X-ray diffraction is shown in Fig. 3 which shows on logarithmic coordinate. The intensity of (211) peak is in proportion to 1.2 power to the compressive strain.

![Graph showing X-ray diffraction patterns](image)

Fig. 4. Influences of shot peening and grit blasting on the x-ray diffraction pattern (work : annealed)

3.2 Influence of Shot peening and Grit Blasting

3.2.1 X-ray diffraction pattern

Figures 4 and 5 show the influence of shot peening and grit blasting for annealed and for 35% compressed specimen respectively. Strain-induced transformation is confirmed after shot peening and grit blasting. As the height of (211) peak by shot peening was slightly more than by grit blasting, therefore the former transformation was found to be more than the latter owing to the stock removal.
Fig. 5. Influences of shot peening and grit blasting on the x-ray diffraction pattern (work: prestrained)

Fig. 6. Hardness distribution (shot peening)
3.2.2 Hardness distribution

Figures 6 and 7 show the influences of shot peening and grit blasting on the hardness distributions for annealed and for prestrained specimens. The type of hardness distribution changes from work-hardening to work-softening with the increase of the prestrain. The maximum ratio of work-softening was 8.3% obtained from grit blasting.

3.2.3 Half width

Half width means the micro strain of the crystals and its change is similar to the hardness change. Figure 8 shows half width of the surface after compression, shot peening and grit blasting. The influence of the prestrain on half width after shot peening and grit blasting is negligible but the value resulted from shot peening is less slightly than grit blasting. Therefore, this suggests the influence of shot peening on the crystals is also less than grit blasting.

The distribution of half width by shot peening are shown in Fig. 9. The result of grit blasting is also similar. Because the half width of the work-softened zone decreases, the work-softening phenomenon produced by shot peening or grit blasting comes from the relaxation of micro strain of the crystals.
3.2.4 Residual stress

The surface residual stresses after shot peening and grit blasting for annealed and for prestrained specimen are shown in Fig. 10. Although the influence of prestrain on the surface residual stress is small, but the valve after shot peening is remarkably larger than after grit blasting owing to the stock removal.
The residual stress distributions after shot peening for annealed and for 35% prestrained specimen are shown in Fig. 11. Their residual stress distributions are similar as to the surface layer.

Fig. 10. Influence of prestrain on surface residual stress

Fig. 11. Influence of prestrain on residual stress distribution (shot peening)
Fig. 12. Influence of prestrain on the ratio of austenite volume

3.2.5 Ratio of austenite volume

Figure 12 shows the ratio of austenite volume after compression and shot peening. The more the compressive strain the less the ratio.
The distributions of the ratio of austenite volume after shot peening for annealed and for 35% prestrained specimen are shown in Fig. 13. This result is not similar for work-softening phenomenon and is not concerned with the strain-induced transformation.

4. CONCLUSIONS

1. Strain-induced transformation was happened by compressive strain, shot peening and grit blasting, but not confirmed microscopic-structure by chemical etching.

2. The influence of shot peening is effective for the transformation.

3. Hardness distribution shifts from work-hardening type to work-softening type by shot peening and grit blasting with previous compressive strain of austenitic stainless steel.

4. The maximum softening ratio was found to be 8.3% produced by grit blasting in this experiment.

5. Work-softening phenomenon was not concerned with strain-induced transformation.

5. REFERENCES


