SIMULTANEOUS MEASUREMENTS OF SEVERAL POLE FIGURES USING AN IMAGING PLATE

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ABSTRACT

Several pole figures of a stainless steel sheet were simultaneously obtained from a single X-ray measurement by using an imaging plate (IP). Computer smoothing of the Debye-Scherrer rings produced excellent pole figures.

INTRODUCTION

An IP [1] has been used, in recent years, to make X-ray experiments. Since the IP is a two-dimensional X-ray area detector, information about several Debye-Scherrer rings can be simultaneously obtained. When more than two Debye-Scherrer rings are simultaneously recorded on an IP, several pole figures can be obtained from a single X-ray measurement. Diffraction data recorded on an IP is digital data, so it is easy to analyze them with a computer. In an earlier paper [2,3] we proposed the use of an IP to simultaneously obtain multiple pole figures. In this paper, this method was applied to a textured dual phase stainless steel sheet with some coarse grains. Excellent pole figures were obtained and showed at preferred orientation.

POLE FIGURE MEASUREMENT METHOD USING AN IP

The specimen was cut from a sheet as shown in Fig.1(a), and placed on the specimen holder of the pole figure goniometer as shown in Fig.1(b). X-rays diffracted at the diffraction angle 2θ, and produced Debye-Scherrer rings on the IP. Perpendicular lines to the {hkl} crystal plane are shown as a cone with a vertical angle 2θ in Fig.1(b). When a cylindrical X-ray camera is used for pole figure measurement, a liner Debye-Scherrer ring is recorded on IP. A semicircle of the Debye-Scherrer ring is recorded on the IP by the cylindrical X-ray camera which has a window of central angle 180°. The specimen was shaped and positioned so that incident X-rays could strike the specimen surface vertically, and diffracted X-rays were not interrupted with the specimen.

The locus of the axial direction of perpendicular lines to {hkl} crystal planes can be shown as a circle on the pole figure as shown in Fig.1(c). We shall call this circle a locus circle in...
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(a) Shape and sampling position of the specimen

(b) Direction of diffracted X-rays by the specimen and Debye-Scherrer ring recorded on IP.

(c) Normal direction of the diffraction plane (locus circle) on pole figure.

Fig.1 Pole figure measurement method using IP.

\[ \psi - (90^\circ - \theta_{\text{HKL}}) \leq \alpha_{\text{R}} \leq \phi + (90^\circ - \theta_{\text{HKL}}) \quad \cdots \quad (1) \]

EXPERIMENTAL PROCEDURE

Sample and Specimen

A (\(\alpha + \gamma\)) dual phase stainless steel sheet 6.0mm in thick was used. The sample consists of equal quantities of \(\alpha\) matrix and \(\gamma\) particles. The specimen shown in Fig.1 (a) was cut from the sheet by an electrodischarge machine. The maximum diameter of the specimen was 12mm.
Fig. 2 Changes of locus circle.

(a) Changes due to diffraction angle.
(b) Changes due to angle of incidence X-ray.

Fig. 3 Measurement of multiple pole figures on a dual phase stainless steel sheet.

Table 1 2θ angle and measurable area of pole figures for given hkl's.

<table>
<thead>
<tr>
<th>Diffraction plane</th>
<th>Diffraction angle 2θ, deg.</th>
<th>Measurable area on αk, deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>α 211</td>
<td>99.0</td>
<td>14.7~90</td>
</tr>
<tr>
<td>γ 311</td>
<td>110.3</td>
<td>20.3~90</td>
</tr>
<tr>
<td>γ 222</td>
<td>118.3</td>
<td>24.4~86.1</td>
</tr>
<tr>
<td>α 220</td>
<td>122.7</td>
<td>26.6~83.9</td>
</tr>
</tbody>
</table>

X-Ray Observation

Four Debye-Scherrer rings of (211), (220), (222) and (311) reflections were recorded on an IP as shown in Fig.3(a) using Co characteristic X-rays. (211) and (220) are reflections from the α matrix particles, and (222) and (311) are from the γ particles. We adjusted ψ to 55.2 degrees so that the locus circle of the (311) reflection could touch the outer circle (basic circle) of the pole figure as shown in Fig.3(b), because its 2θ is in the middle of the measurable 2θ area of the pole figure measurement device. Table 1 shows 2θ and the measurable area of each (hkl) reflection used in the simultaneous pole figure measurement. Tube voltage, tube current and exposure time were 30kV, 10mA and 300sec, respectively. The pinhole diameter of the collimator was 1.0mm. The specimen was rotated at intervals of 6 degrees, and 36 exposures were done in total.

RESULTS AND DISCUSSION

Debye-Scherrer Ring Recorded on an IP

Figure 4 shows an X-ray diffraction image recorded on an IP at β = 324°. There are four
linear Debye-Scherrer rings of (211), (220), (311) and (311) reflections. The rings contain spots and arcs because there is preferred orientation and coarse grains.

Figure 5 shows results of the diffraction intensity distribution analyzed by a computer. Diffraction intensities along the Debye-Scherrer rings were obtained by computing the $2\theta$ of peak profiles of 1024 pixel lines which perpendicularly crossed it using the FWHM middle point method (upper). Results of a random sample are also shown as a comparison in the figure (lower). Peaks correspond to dark spots of the linear Debye-Scherrer rings. Remarkably high intensity peaks appeared on parts of the spot.

Results of {311} Pole Figure and Effect of Computer Smoothing Processing on Spotted Debye-Scherrer Ring

Figure 6 shows {311} pole figures. The diffraction intensity distribution data was smoothed in Fig.6(b) by computer analysis and not smoothed in Fig.6(a). Figure 7 shows the example of a smoothed diffraction intensity distribution with a computer. Excellent pole figure was not obtained with the condition of Fig.6(a). The X-ray experiment using the IP was not suitable for coarse-grained materials because of the pinhole optics system. However, the computer smoothing processing produced a excellent pole figure shown in Fig.6(b), and the pole figure was similar to a {311} pole figure obtained by the Schulz reflection method with mechanical oscillation shown in Fig.8.
The smoothing processing of the diffraction intensity distribution data with a computer supplemented the weak point of the optics system of the X-ray measurement using the IP.

\{110\} Pole Figures Obtained at Different $\phi$

Figure 9 shows simultaneously and individually obtained \{110\} pole figures. In the individual measurement, $\phi$ was adjusted to 61.4 degrees so that the locus circle of (220) reflection could touch the basic circle of the pole figure. Broken lines in these pole figures indicate a non-measurable and measurable area of the pole figure. These areas were calculated by using equation (1). The pole density distribution of these pole figures showed a similar tendency in a common measurement area. These \{110\} pole figures were also similar to \{110\} pole figure.
Fig. 11 Pole figures obtained by present method and Schulz reflection method.

obtained by the Schulz reflection method shown in Fig. 10 in a common measurement area. Even if $\phi$ is changed, similar pole figures are obtained. We can also freely change the measurable area on the pole figure ($\alpha_R$-direction) by adjusting $\phi$.

**Remaining \{111\} and \{211\} Pole Figures**

Figure 11 shows other simultaneously obtained pole figures. These pole figures were also similar to pole figures obtained by the Schulz reflection method in a common measurement area.

**CONCLUSION**

Simultaneous pole figures can be recorded from a single measurement by use of an imaging plate (IP). Four pole figures of a textured dual phase stainless steel sheet with some coarse grains were measured by this method. By applying a computer smoothing process to intensity diffraction data containing spotty Debye-Scherrer rings, excellent pole figures which clearly show the state of preferred orientation were obtained.

**REFERENCES**

