COMPLETE POLE FIGURE MEASUREMENT USING ONLY BACK-REFLECTION METHOD WITH IMAGING PLATE AND APPLICATION TO THREE-DIMENSIONAL ANALYSIS OF TEXTURE

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ABSTRACT

Complete pole figures were obtained using only a back-reflection method with an imaging plate (IP). Pole density data of them were effectively applied to three-dimensional analysis of texture.

INTRODUCTION

In this study, complete pole figure measurement using only a back-reflection method with an imaging plate (IP) was attempted. In our method, complete pole figures were obtained using only the back-reflection method without the use of a transmission method. In particular, the complete pole figure is theoretically obtained when its diffraction angle $2\theta$ is $90^\circ$. In the cases of other $2\theta$ values, the complete pole figure is obtained by measuring two incomplete pole figures by the back-reflection method and combining them. Such incomplete pole figures could be simultaneously measured by means of the two-dimensional detection ability of IPs. In addition, the correction of X-ray diffraction intensity to compensate the deviation from the pseudo-focusing condition was not needed in our method, unlike Schulz back-reflection method.

Pole density data obtained from our complete pole figures were effectively applied to three-dimensional analysis of the texture of a dual-phase stainless steel sheet, and crystallite orientation distribution functions (ODFs) of the sheet were obtained.

COMPLETE POLE FIGURE MEASUREMENT METHOD USING IP

An entire Debye-Scherrer ring can be measured by means of the two-dimensional detection ability of the IP. In the measurement of some Debye-Scherrer rings, by turning a disk specimen at regular intervals ($\beta$-rotation), as shown in Fig.1, the pole density distribution along the circular paths of loci (locus circles) shown in Fig.2(a) can be obtained. A complete pole figure is theoretically obtained when its diffraction angle $2\theta_{hkl}$ is $90^\circ$, because the radius of the pole figure would be equal to the diameter of the locus circle. For other values of $2\theta_{hkl}$, the complete pole figures is obtained by measuring two incomplete pole figures at two different X-ray incident angles $\phi_1$ and $\phi_2$ and combining them. A specimen was shaped and positioned so that incident
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In a three-dimensional analysis of texture by Dunge's method, pole density data at intersections $P(\alpha_R, \beta)$ of the meridian and latitude lines drawn at intervals of 5° on the pole figure, as shown in fig.2(a), are needed. However, pole density data $I(\alpha_R, \beta)$ at these points are not obtained directly in our method, but are obtained as follows. First, pole density data at the intersections of the latitude lines and the locus circles on the pole figure are obtained. For example, these points along the latitude line $\alpha_R = 85°$ are shown by X's in Fig.2(a). Secondly, the pole density data are approximated by a polynomial curve, and pole density data $I(\alpha_R, \beta)$ at the intersections are obtained from the curve shown in Fig.2(b). Finally, $I(\alpha_R, \beta)$ data are displayed as contour lines, and the pole figure is obtained.

**EXPERIMENTAL PROCEDURE**

**Sample and Specimen**

A ($\alpha + \gamma$) dual-phase stainless steel sheet 6.0mm thick was used. The sample consists of equal quantities of the $\alpha$-Ferrite matrix and $\gamma$-Austenite particles. The specimen was cut from the sheet by a wire-electrodischarge machine and its taper was formed by a lathe. The maximum diameter of the specimen was 12mm. The surface of the specimen was electrolytic polished.

**X-Ray Observation**

Figure 3 shows Debye-Scherrer rings recorded on IPs using Co and Cr characteristic X-rays. The \{211\} and \{110\} pole figures of the $\alpha$-phase and the \{311\} and \{111\} pole figures of the $\gamma$-phase were obtained by Co-K $\alpha$ X-rays. The \{100\} pole figure of
the $\alpha$-phase and the $\{110\}$ pole figure of the $\gamma$-phase were obtained using Cr-K $\alpha$ characteristic X-rays. These six pole figures were used to obtain crystal orientation distribution functions (ODFs) of $\alpha$ and $\gamma$-phases of the dual-phase stainless steel sheet, because pole density distribution data of three or more complete pole figures are usually needed to obtain ODFs. Table 1 shows the diffraction angle $2\theta_{hkl}$ of the (hkl) reflections used to obtain the six complete pole figures. Two incomplete pole figure measurements were needed for each reflection to obtain the complete pole figures because $2\theta_{hkl}$ of each reflection was not 90°. Table 1 also shows the values of X-ray incident angles $\phi_{1}$ and $\phi_{2}$ to obtain the two incomplete pole figures, and the measurable area $\alpha_{R}$ on each incomplete pole figure. Pole density data of the low $\alpha_{R}$ area on the complete pole figure were obtained at $\phi_{1}$, and the data of the high $\alpha_{R}$ area were obtained $\phi_{2}$. In the pole figure measurement at $\phi_{2}$, six incomplete pole figures were simultaneously obtained through two measurements[1].

RESULTS

Complete Pole Figures

Figure 4 shows complete pole figures of the $\alpha$-phase obtained by plotting pole density data $I(\alpha_{R}, \beta)$ as contour lines. These complete pole figures were obtained by connecting two incomplete pole figures obtained using IPs. Although peak positions on the incomplete pole figures were mutually similar in the same areas of low and high $\alpha_{R}$, there were some differences in the intensity. When the incomplete pole figures were connected, a correction coefficient $a$, used to make the intensity levels of between them as uniform as possible, was calculated by eq.(1). The coefficient was multiplied to the pole density data of the low $\alpha_{R}$ area.

$$a = \frac{\int_{0}^{\pi/2} \int_{0}^{\pi} I_{h,k,l} \sin \alpha d\alpha d\beta}{\int_{0}^{\pi/2} \int_{0}^{\pi} \left[I_{h,k,l}^2 \sin \alpha\right] d\alpha d\beta}$$
Crystal Orientation Distribution Function

Pole figures are generally used for analyses of texture. When the texture consists of a only preferred orientation $(hkl)\{uvw\}$, we can decide it from the pole figures. Here, $(hkl)$ and $[uvw]$ mean the crystal plane and crystal axis parallel to the rolling direction of the sheet, respectively. When the texture consists of multiple preferred orientations, it is difficult to discuss them quantitatively. Bunge proposed a three-dimensional analysis of texture using the series expansion method, which enabled a quantitative analysis of texture [2]. According to his methods, the orientational relation between a sample and crystal coordinate system is described by the Euler angle $\gamma=(\phi_1, \Phi, \phi_2)$, and the density distribution of each orientation $g$ is expressed by the crystal orientation distribution function $f(\phi_1, \Phi, \phi_2)$. $f(\phi_1, \Phi, \phi_2)$, simply called the ODF, is displayed as a density distribution in three-dimensional space consisting of $\phi_1$, $\Phi$, and $\phi_2$ coordinates.

Figure 5 shows the results of the ODF of $\alpha$ and $\gamma$-phases of the dual-phase stainless steel sheet obtained using pole density data of the complete pole figures shown in Fig.4. These results show $\phi_2=0, 45$ and $65^\circ$ sections of Euler space. Figure 6 shows that ideal preferred orientations of cubic materials appear in these sections. From a comparison between Fig.5 and Fig.6, it is judged that the $\alpha$-phase has mainly $(001)[110]$ texture. Similarly, it is judged that the $\gamma$-phase has mainly $(001)[112]$ and $(123)[634]$ texture. Thus, pole density data of our complete pole figures obtained using only the back-reflection method were effectively applied in the three-dimensional analysis of texture.
and changes in the absorption of incident and diffracted X-rays according to the geometrical position of the sample are not fundamentally needed in the pole figure measurement of Schulz's back-reflection method. However, even the method occasionally requires the correction to compensate the deviating from the pseudo-focusing condition. Figure 7 shows an IP image of a random standard sample obtained through our pole measurement method. Figure 8 shows peak profiles of (311) reflection of $\gamma$-phase extracted at a random position X on the Debye-Scherrer rings. Similar peak profiles were obtained at any position. Figure 9 shows the FWHM (full-width at half maximum intensity) and the peak intensity of peak profiles at all X position. They did not depend on the position and remained constant. Even the correction of X-ray diffraction intensity...
Fig. 7 Linear Debye-Scherrer rings of random standard sample.

(a) \(X=100\) pixels.

(b) \(X=500\) pixels.

(c) \(X=900\) pixels.

Fig. 8 Peak profiles of (311) reflection of \(\gamma\)-phase on Debeye-Scherrer ring.

(a) Diffraction intensity distribution.

(b) FWHM distribution.

Fig. 9 Intensity distribution and FWHM distribution along linear Debeye-Scherrer ring.

to compensate the deviating from the pseudo-focusing condition is not needed in our pole figure, because of the characteristic that X-rays were incident on the specimen surface vertically.

CONCLUSIONS

Complete pole figure measurement using only the back-reflection method with an IPs examined. The following is concluded on the results of a series experiments.

1) Complete pole figures could be obtained using only the back-reflection method.

2) Corrections of X-ray diffraction intensity are not needed for the pole figures obtained by our method.

3) Pole density data of the complete pole figures were effectively applied to three-dimensional analysis of texture.

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