Application of X-ray Fourier Analysis to Rolling Contact Fatigue Layer of Rail

Motohide MATSUI
Senior Researcher, Frictional Materials, Materials Technology Division

1. Introduction

Railway rails undergo plastic deformation due to repetitive contact with wheels resulting in the formation of a rolling contact fatigue layer on and underneath the contact surface. Experimental evaluation of the rolling contact fatigue layer has been attempted in a variety of ways. However, none of these past attempts has successfully obtained the consistent quantitative evaluation of the rolling fatigue layer from the contact surface down through rolling contact fatigue layers in the rail. The quantitative evaluation has been particularly difficult on the top surface layer. Thus, we have attempted to apply the X-ray Fourier Analysis Methodology with the objective of quantitatively and consistently evaluating the top surface and downwards through the inner layers of the rolling contact fatigue region of the rail.

2. X-ray Fourier Analysis Method

X-ray Fourier analysis refers to an approach that can determine the plastic deformation state of ferrite grains constituting the rail steel by using X-ray diffraction measurement, and subsequently analyzing the obtained diffraction data including the peak positions, its strength and shapes . From these data, the X-ray crystallite size and dislocation density can be estimated as indicators related to plastic deformation. Fig. 1 summarizes the X-ray diffraction measurement. In our case, we applied the X-ray diffraction method to small test pieces cut out from a rail, and conducted an X-ray Fourier analysis of the resultant diffraction data.

3. Results

Part of the X-ray diffraction data obtained is shown in Fig. 2. In comparison with an unused rail, the test rail (installed rail) data shows diffraction peaks that vary broadly under the influence of the plastic deformation due to rolling contact fatigue. Fig. 3 shows the results of X-ray Fourier analysis of the resultant diffraction peaks at depths ranging from the top surface down through the rail to inner layers displaying rolling contact fatigue. As shown, the X-ray crystallite size increases and the dislocation density decreases at greater depths from the contact surface. This confirms that plastic deformation due to rolling contact fatigue decreases below the contact surface of the rail. Thus, the X-ray Fourier analysis can not only produce a quantitative evaluation of the contact surface of rolling contact fatigue layer, but also can serve as an approach to analyze a broad region below the contact surface of the rail. Further examination of this analysis approach is expected to help determine the formation process in the rolling contact fatigue layer of a rail, thereby contributing to enhance the efficiency of maintenance actions such as rail grinding and replacement.

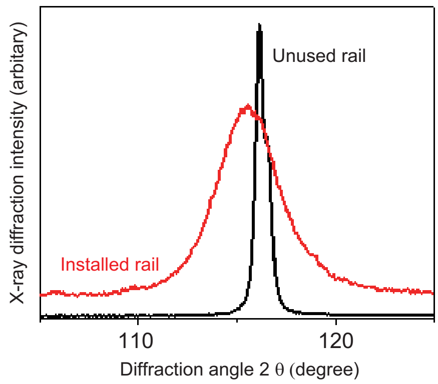

Fig. 2 Variation of diffracted peaks

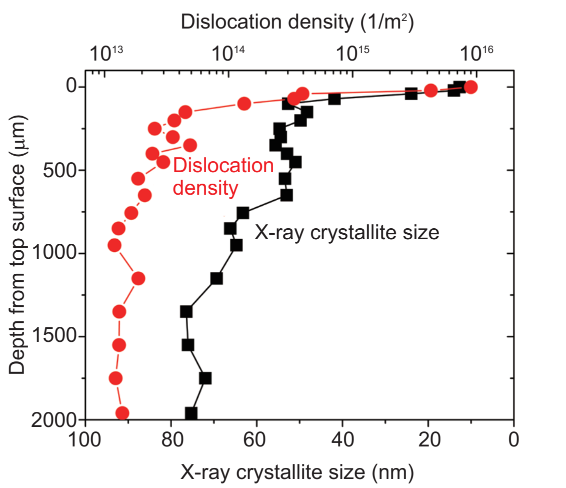

Fig. 3 Results of X-ray Fourier analysis applied to an installed rail (tangent rail, accumulated passing tonnage: 500 MGT(million gross tonnes))

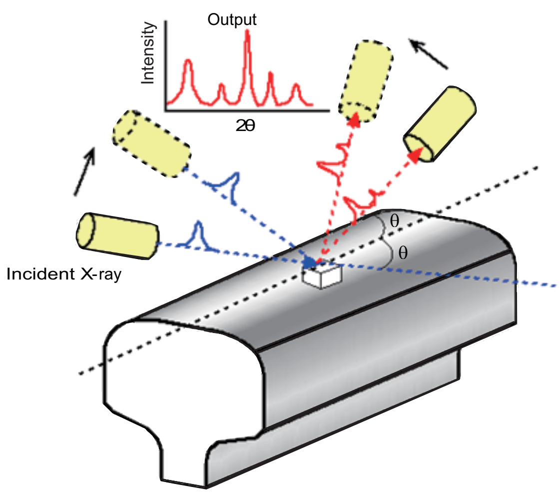

Fig. 1 Overview of X-ray diffraction measurement