ADVANCE IN STRESS ANALYSIS TAKING ACCOUNT OF STRESS GRADIENT

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When the x-ray measurement of stress was performed by the $\sin^2\psi$ method, we sometimes observed a curved $\sin^2\psi$ diagram or a ψ-split diagram from a processed surface such as shot-peening process. This means the existence of steep stress gradient within the penetration depth of x-rays and/or of the multi-axial stress state.

Our group begun to challenge to x-ray stress analysis taking into account of the stress gradients within the penetration depth of x-rays under the condition of multi-axial stress state in 1982. Assumptions for the analysis are as follows; 1) the stress gradient with respect to the direction of the depth is linear, and 2) the penetration depth of x-rays is linear to $\sin^2\psi$ within the range of $-45° \leq \psi \leq 45°$. The basic equation was solved by the application of the integral method. Second challenge was to use a polynomial approximation in 1984. The penetration depth was approximated by a quadratic function of $\sin^2\psi$ and then the x-ray lattice strain was expressed as a cubic function of $\sin^2\psi$. Since this function is usable without limitation of the value of $\sin^2\psi$ for measurement of lattice strain and the calculation process is simple in comparison with the integral method.

However, several errors on the stress components were always observed caused by the assumption of the penetration depth at the numerical simulation process and we concluded that the penetration depth of x-rays should not be assumed by the function of $\sin^2\psi$ whether a linear or polynomial function.

In 1985, the penetration depth of x-rays was arranged as a function of $\cos\psi$ without the assumption and x-ray strain was also arranged as a function of $\cos\psi$ and then rearranged as the sum and the difference between stresses or gradients to improve the accuracy of the stress components determined. We called this method $\cos\psi$ method and it was applied to the analysis of residual stress on the shot-peening specimens and others.

In the present stage, lattice strains were measured at two or three kinds of hkl diffraction which differs in wavelength by using synchrotron radiation source, and stress and gradient are respectively calculated on each diffraction data by using the $\cos\psi$ method. Thereafter, distribution of stress with depth is assumed as a quadratic function and then a reliable distribution of stress can be optimized from all of the data by using the quasi-Newton method.