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An Observation of Brittle Crack Propagation in Coarse Grained 3% Silicon Steel

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Abstract

Brittle fracture in carbon steel affects serious impact for the safety of fracture of in steel. Especially, the arresting technology of crack propagation is the last stand for the structure. It is so important issue that the conditions which can be stopped reliably crack propagation should be clarified thoroughly. On the background of such social importance, lots of experimental and theoretical researches have been conducted from both mechanical and microstructural viewpoints.

Though it has been reported that the limit speed of brittle crack propagation is the Rayleigh wave speed and the speed is about 2,900 m/s in steels, the real speed of brittle crack propagation in steels is about 1,000 m/s and lower. The reason for that is considered braking effects with crack propagation, for example unevenness in the facet, tear ridge, microcrack, twin deformation and side ligament, namely the elements that dominate the arresting toughness.

In this study, the 3% silicon steel where microstructure is ferrite single phase and its grain size is 4-5mm of very large is used. It is assumed that the brittle crack propagation speed in single crystal grain is very fast because there is no need to consider tear ridge between crystal grains. In this experiment, it is succeeded in shooting of brittle fracture of steel by high speed camera. As a result of that, it was revealed that the brittle crack propagation rate of 3% silicon steel is much lower than ordinary carbon steel. Also, twin deformation and unevenness in the facet are observed by scanning electron microscope (SEM).

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Keywords: Steel, Brittle crack propagation speed, High speed camera, Observation of fracture surface, Twin deformation

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1. Introduction

In the previous study, the formula (1) and (2) shows propagation speed of the longitudinal wave and the transverse wave in the two dimensional infinite flat plate considering that E is changed by the stress state. Also, Rayleigh wave is related to the transverse wave and is shown the formula (3) [Broberg et al(1999)]. Rayleigh wave is surface wave and the wave transmitting along the interface between different media. It is well known that the speed of Rayleigh wave is about 2,900 m/s in steels. In addition, it is said that saturation speed of brittle crack propagation is nearly the speed of Rayleigh wave when crack proceeds in only stress domination [Eshelby et al(1949)]. However, the real speed of brittle crack propagation of steels is about 1,000 m/s and very slow. Correspondingly, it is reported that the experimental value of brittle crack propagation speed is 0.3 and 0.6 times the speed of Rayleigh wave in tungsten single crystal [Hull et al(1966)] which has BCC structure as well as α-iron. The reason for that is considered braking effects with crack propagation, for example unevenness in the facet, tear ridge, microcrack, twin deformation and side ligament, namely the elements that dominate the arresting toughness. In relation to unevenness in the facet, it is said that the phenomenon in glass and resin fibers, called Mirror-Mist-Hackle, is self-suppression mechanism that irregularity of fracture surface is severe so that crack propagation rate is not too high. As crack proceeds, the crack increases the branching and the crack propagation speed approaches the upper limit speed [Zhang et al(2006)] [Yoffé et al(1948)].

$$C_p = \begin{cases} \sqrt{\dfrac{(1-\nu)E}{(\nu+1)(1-2\nu)\rho}}\ (plane\ strain) \\ \sqrt{\dfrac{E}{(1-\nu^2)\rho}}\ (plane\ stress) \end{cases} \tag{1}$$

$$C_s = \sqrt{\frac{E}{\rho}}\ (plane\ strain\ and\ plane\ stress) \tag{2}$$

$$C_r \approx C_s\left(1-\frac{0.135}{3-k^2}\right)\ (plane\ strain\ and\ plane\ stress) \tag{3}$$

$$k = \begin{cases} \sqrt{\dfrac{1-2\nu}{2(1-\nu)}}\ (plane\ strain) \\ \sqrt{\dfrac{1-\nu}{2}}\ (plane\ stress) \end{cases}$$

Nomenclature

ρ	density
E	Young's modulus
ν	Poisson's ratio
C_p	propagation speed of longitudinal wave
C_s	propagation speed of transverse wave
C_r	Rayleigh wave speed

Observation of high speed crack propagation with high speed camera has been conducted much on resin materials. It is because the crack propagation speed is relatively small and the degree of difficulty of shooting is low in resin materials [Ravi-chandar et al(1984)]. However, example that Steel of large propagation speed was observed directly