Abstract Title

Tension of a Soft Ferromagnetic Strip with a Single Edge Crack in a Uniform Magnetic Field

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Abstract body

INTRODUCTION

There are many devices that operate in magnetic fields. Such devices include magneto hydro dynamics (MHD) structures and magnetically levitated vehicles, etc. If a ferromagnetic material is used in a magnetic field, the effect of induced magnetization should be considered. The stress and strain state in a magnetizable elastic body is caused not only by mechanical forces but also by magnetic forces. The strength of the ferromagnetic materials is weakened by the presence of defects such as voids and cracks. Therefore, it is important to understand the degradation phenomena of the ferromagnetic materials. In the theory of brittle fracture in the magnetic field, we must consider linear magnetoelastic solutions of crack problems [1]. Recently, Shindo et al. [2,3] confirmed theoretically and experimentally the fact that the applied magnetic field tends to intensify the stress intensity factor. Also, the excellent agreement between calculations and measurements of the stress intensity factor established the validity of the linear theory for magnetoelastic interactions in a cracked soft ferromagnetic material. This paper examines theoretically and experimentally the effects of magnetic fields on the fracture mechanics parameters of a soft ferromagnetic strip with a single-edge crack subjected to tensile load and uniform magnetic field.

METHODS

Theoretical analysis

Consider a soft ferromagnetic isotropic linear elastic strip of width h which contains a single-edge crack of length a aligned with its plane normal to the free edge. The strip is in the plane stress or plane strain state, and is subjected to a uniform normal stress σ_0 and a uniform magnetic field of magnetic induction B_0. Fourier transform techniques are used to formulate the mixed boundary value problem as a singular integral equation. The stress intensity factors are obtained for several values of material and geometrical parameters, and magnetic field.

Experiment

Tensile tests were performed on nickel-iron soft ferromagnetic materials. The specimen geometry was a plate specimen containing a single-edge crack. The edge-cracked specimen has a length of 140 mm, a thickness of 1 mm, a width, h, of 40 mm, and a crack length, a, of 4,10,15 mm. An initial through-the-thickness notch was machined using electro-discharge machining. The specimen was fatigue precracked and then annealed to obtain the optimum magnetic properties. A simple strain gage method is very suitable to determine the magnetic stress intensity factor. A five element strip gage was installed along the 90-deg line and the center point of the element closest to the crack tip was 2 mm.

Tensile load and a magnetic field were simultaneous applied to the edge-cracked plate specimens at room temperature. A 10 T (T:Tesla) cryocooler-cooled superconducting magnet with a 100 mm diameter working bore was used to create a static uniform magnetic field of magnetic induction B_0 normal to the crack surface. The specimen was loaded by P = 29.4 N load that consisted of weight.

RESULTS AND DISCUSSION

(1) The variations of calculated $k_{h1}/\sigma_0 a^{1/2}$ against a/h for a TMC-V soft ferromagnetic material under various values of B_0 in the plane stress case are compared with the experimental data in Fig. 1. The magnetic field increases the stress intensity factor, depending on the strip-width to crack length ratio. (2) A larger value of the specific magnetic permeability trends to increase the magnetic stress intensity factor. (3) The applicability of the strain gage method for magnetic fracture testing is established. (4) A comparison between theoretical and experimental values of the stress intensity factor shows good agreement.

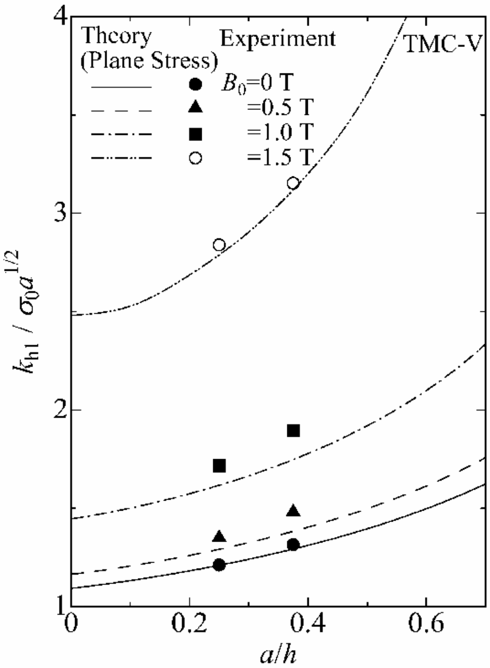

Fig.1 Stress intensity factor vs a/h

Keywords

Elasticity, Fracture mechanics, Magnetoelastic analysis, Singular integral equation, Tensile testing, Strain gage method, Soft ferromagnetic materials, Stress intensity factor

References

1. Y. Shindo. The linear magnetoelastic problem for a soft ferromagnetic elastic solid with a finite crack. *ASME J. Appl. Mech*. 44, pp. 47-51, 1977
2. Y. Shindo, D. Sekiya, F. Narita and K. Horiguchi. Tensile testing and analysis of ferromagnetic elastic strip with a central crack in a uniform magnetic field. *Acta Mater*. 52, pp. 4677- 4684, 2004
3. Y. Shindo, D. Sekiya, F. Narita and K. Horiguchi. Magnetic stress intensity factors for two symmetric edge cracks in a soft ferromagnetic elastic strip under tension. *JSME International Journal, Series A*. 48, pp. 7-13, 2005.

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