Fracture Toughness Evaluation for magnetostrictive problem using COMSOL-Multiphysics

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Introduction: Materials with large magnetostriction are broadly used in sensors, actuators, energy-harvesters, and micro electro-mechanical systems. Magnetostriction of ferromagnetic materials describes the change of their shape or dimension in response to the reorientation of magnetization under the influence of externally applied magnetic field.

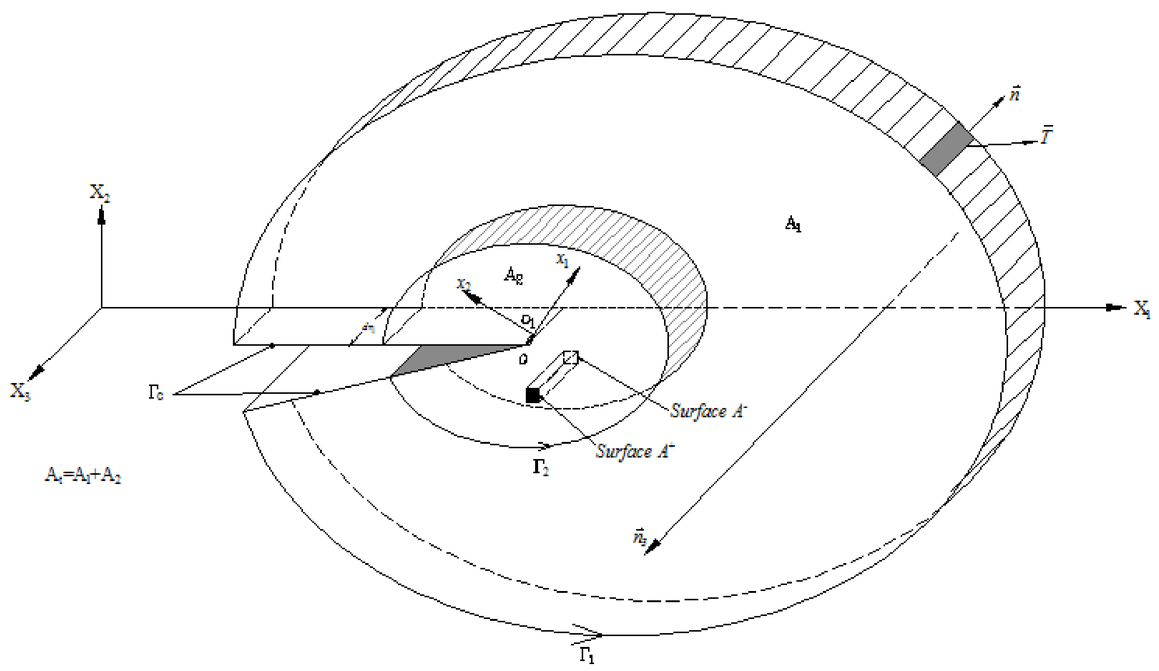

Figure 1. Configuration of crack tip around a region of Infinitesimal thickness enclosing the Crack Front.

Computational Methods:

The path independent integral has been developed to characterize the crack parameter under magnetostriction by following expression [1]:

$$\left(J_k^u\right)_{3D} = \int_{\Gamma_1+\Gamma_c} \{W^e n_1 - T_i \frac{\partial u_i}{\partial X_1}\}\, d\Gamma - \iint_{A_t} (\sigma_{i3} u_{i,3})_{,3}\; dA_1$$

$$+ \iint_{A_1} \sigma_{ij} \frac{3\lambda_s}{M_s^2} M \frac{\partial M}{\partial X_k}\; dA$$

$$K_{Ic} = \sqrt{\frac{\left(J_{kc}^u\right)_{3D} E}{\left(1-\nu^2\right)}}$$

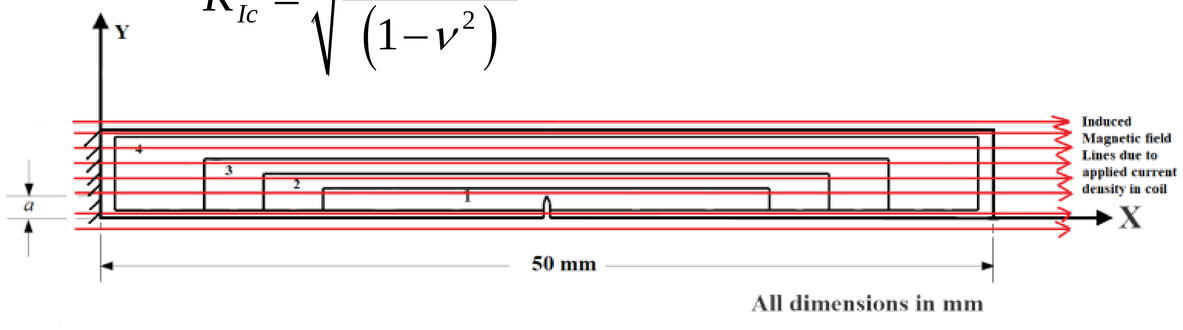

Figure 2. Integrating contours and applied magnetic field

Results: Path independence has been seen from following expression.

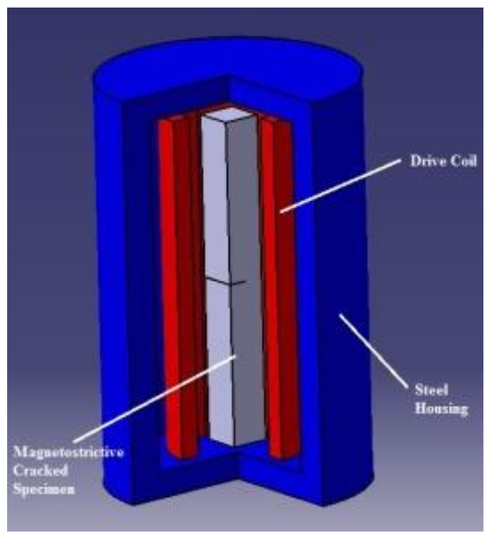

Figure3. Arrangement of Parts

Variable	Value	Units
saturated magnetization	15E5	A/m
saturated magneto-striction	.0002	
Poisson Ratio	0.3	
Modulus of Elasticity	60	GPa

Table 1. Material Properties

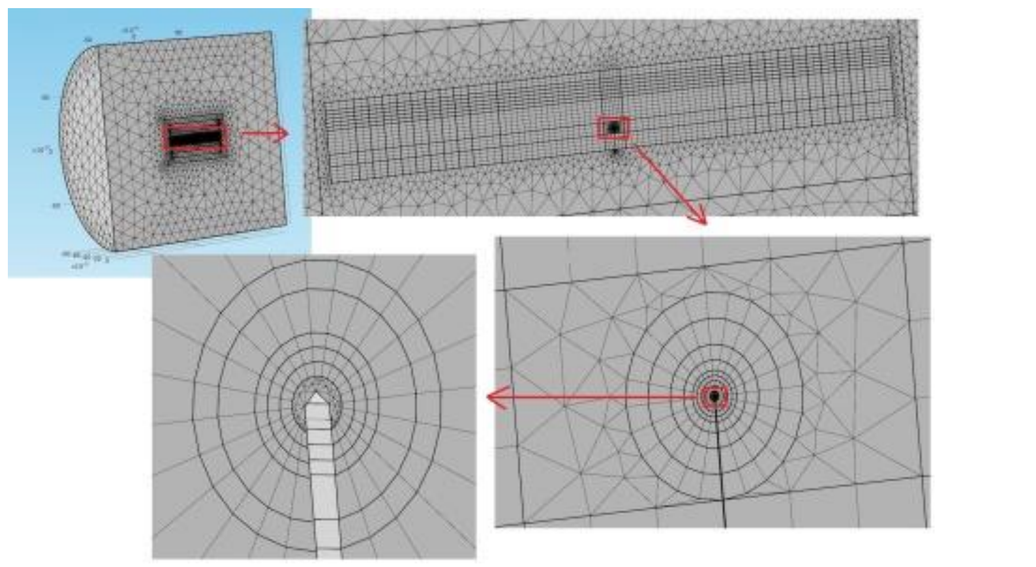

Figure 4. Mesh distribution around the crack

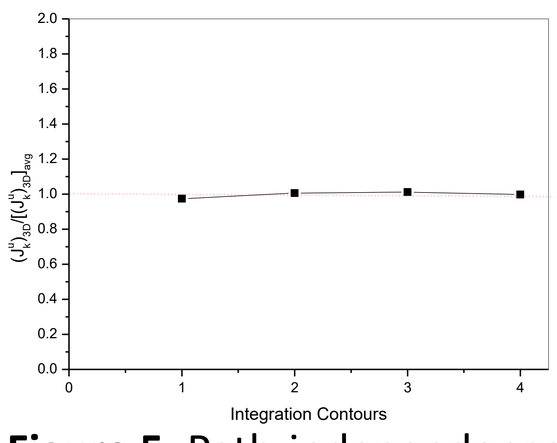

Figure 5. Path-independence

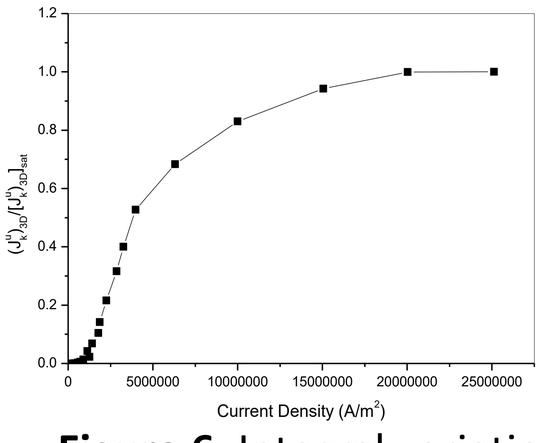

Figure 6. Integral variation

Conclusions: The integral operated over magnetostrictive environment is found to be path independent. The variation of integral is saturated at saturated magnetization.

References:

1. Bhushan, A., Panda, S. K., Singh, P. K., Kartheek, P., Kumar, R., and Mittal, Y., 2018, “3D Path Independent Integral for Thermoelastic and Magnetostriction Problem,” Mechanics Research Communications (accepted).

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