15th International Conference on Fracture (ICF15)
June 11-16, 2023 Atlanta, GA USA

FRICTIONAL CRACK GROWTH INITIATION IN A NATURAL ORTHOTROPIC QUASI-BRITTLE SOLID

Sailendu Biswal*, Gaurav Singh

Department of Applied Mechanics, Indian Institute of Technology Delhi, New Delhi , India
** Presenting Author email: sailendu.biswal@am.iitd.ac.in*

Abstract

The frictional crack is extensively observed in natural phenomena like earthquake fracture, fracture at rock fault line and in fracture of other geological materials.The contact between the flaw faces alters the stress field in comparison to the stress field in an open condition or when not in contact. The crack growth initiation in an open condition have been investigated sufficiently in literature. However, the frictional crack or closed crack in an anisostropic medium has hardly been addressed. The naturally occurring biological materials such as bone, wood, cartilage, etc. are anisotropic as well as quasi-brittle in nature. Considering the vital application of these naturally occurring composites, it calls for a thorough investigation. The current research work performs compression test on wood with an embedded central pore for different contact surface conditions and orientation of pore. In addition to that, it carries out numerical simulation of crack growth initiation and propagation using cohesive zone model (CZM) considering quasi-brittle nature of wood. Further, it verifies the applicability of classical fracture criteria for friction crack propagation in wood.

1. Introduction

A large segment of naturally occurring materials such as bone, teeth, wood, cartilage, shell etc. are composite materials. Often, flaws are formed due to natural causes or artificially introduced for an additional functionality. For instance wood which is widely used as construction and building material, holes are introduced for architectural reasons. Further, in wood, micro-pores or cracks occur due to the process of bio-degradation, mainly due to the act of fungus and termites. Similarly, micro-pores are formed in bone due to degradation in bone density (Osteoporosis). Under remote compression, the flaw or crack faces comes in contact. The frictional contact between the faces influences not only the overall strength of the structure, but also the crack growth initiation and propagation from the existing flaw.

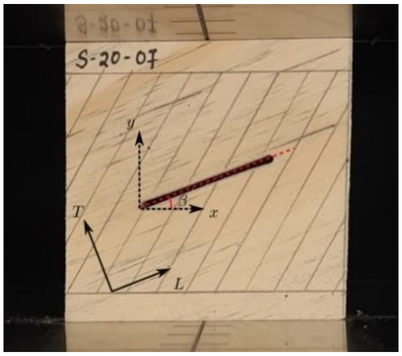

Fig. 1 – A representative specimen of New Zealand Pine wood under compression illustrating the orientation of an embedded pore with respect to loading direction (y-direction) and material orthotropy (L-T system)

In the current experimental investigation, New Zealand Pine wood was considered with a centrally embedded pore as show in Fig. 1. Wood, being an orthotropic material, possesses three planes of symmetry: longitudinal plane, radial plane and tangential plane. The longitudinal direction (L) is parallel to the grain orientation, radial direction (R) across the growth rings and tangential direction (T) is tangent to growth rings but perpendicular to the longitudinal direction. Further, wood is quasi-brittle in nature due the fracture process zone (FPZ). The FPZ in wood exhibits the presence of fibre bridging and micro-crack formation.

The compression tests were carried out for six different orientation (or angle of inclination β) of the pore with respect to loading direction. In each test case, the major axis of the pore is oriented along the grain or longitiudinal (L) direction. At each orientation of the pore, three different surface conditions (or coefficient of friction μ) were introduced to understand its role in peak stress determinaton. The coefficient of friciton (μ) values for each surface condition i.e. primer painted, enamel painted and normal conditions was separately measured.

2. Results

From the compression test results shown in Fig. 2, it is observed that

a. The peak stress increases with an increase in angle of inclination β.
b. In case of lower angle of inclination, the surface condition through μ, seems to have lesser influence on peak stress. The inclination angle in the range of 0^0 to 20^0 shows a close a range of peak stress values. Further, for a higher degree inclination i.e. > 30^0 enamel painted surface gives a lower upper extreme. The average peak stress for an inclination angle > 30^0 the normal surface exhbits highest value.
c. A representative stress-strain plot is shown in Fig. 3 exhibits an initial linear elastic region followed by a kink due to gradual contact between pore faces. Then it attains peak stress and gradually descends due to crack growth initiation and propagation.

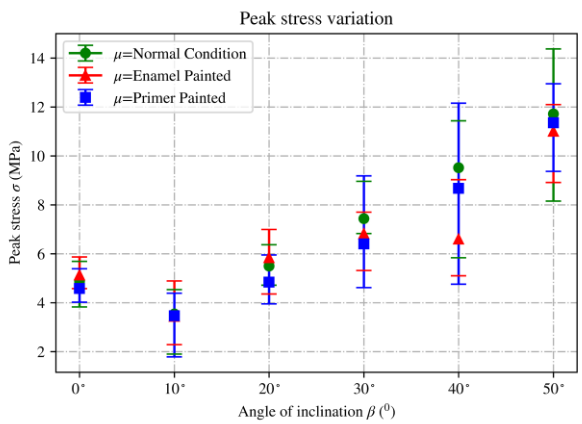

Fig. 2 – Variation of peak stress with respect to orientation of pore as well as pore contact interface μ

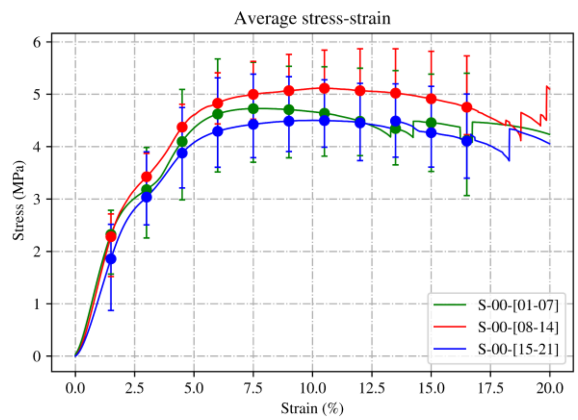

Fig. 3 – A representative stress-strain plot for 0^0 orientation of pore for various pore contact surface conditions [green, red and blue curve represents normal, enamel and primer painted pore surface respectively]

3. Conclusions

The criteria for the onset of the crack growth initiation is broadly based on either stress/strength or fracture energy. However, these fracture criteria were originally laid out for an open crack or flaw condition in an linear elastic isotropic medium. Thus the current work aims at establishing a suitable approach through numerical simulation for frictional crack problem in wood. The approach considers both strength and fracture energy simultaneously through the cohesive zone modelling. It also, investigates the applicability of classical linear elastic fracture criteria such as maximum tangential stress, maximum principal stress and maximum energy release rate criterion.