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Study of Elastic-Plastic Fatigue Crack in Functionally Graded Materials

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Abstract : Composite materials emerged in the middle of the 20th century as a promising class of engineering materials providing new prospects for modern technology. Recently, a new class of composite materials known as functionally graded materials (FGMs) has drawn considerable attention of the scientific community. In general, FGMs are defined as composite materials in which the composition or microstructure or both are locally varied so that a certain variation of the local material properties is achieved. This gradual change in composition and microstructure of material is suitable to get gradient of properties and performances. FGMs are synthesized in such a way that they possess continuous spatial variations in volume fractions of their constituents to yield a predetermined composition. These variations lead to the formation of a non-homogeneous macrostructure with continuously varying mechanical and / or thermal properties in one or more than one direction. Lightweight functionally graded composites with high strength to weight and stiffness to weight ratios have been used successfully in aircraft industry and other engineering applications like in electronics industry and in thermal barrier coatings. In the present work, elastic-plastic crack growth problems (using Ramberg-Osgood Model) in an FGM plate under cyclic load has been explored by extended finite element method. Both edge and centre crack problems have been solved by taking additionally holes, inclusions and minor cracks under plane stress conditions. Both soft and hard inclusions have been implemented in the problems. The validity of linear elastic fracture mechanics theory is limited to the brittle materials. A rectangular plate of functionally graded material of length 100 mm and height 200 mm with 100% copper-nickel alloy on left side and 100% ceramic (alumina) on right side is considered in the problem. Exponential gradation in property is imparted in x-direction. A uniform traction of 100 MPa is applied to the top edge of the rectangular domain along y direction. In some problems, domain contains major crack along with minor cracks or / and holes or / and inclusions. Major crack is located the centre of the left edge or the centre of the domain. The discontinuities, such as minor cracks, holes, and inclusions are added either singly or in combination with each other. On the basis of this study, it is found that effect of minor crack in the domain's failure crack length is minimum whereas soft inclusions have moderate effect and the effect of holes have maximum effect. It is observed that the crack growth is more before the failure in each case when hard inclusions are present in place of soft inclusions.

Keywords : elastic-plastic, fatigue crack, functionally graded materials, extended finite element method (XFEM)
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