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# Experimental Study of the Effect of Wire Electrical Discharge Machining on Crack tip Opening Displacement for Compact Tension Specimens of Low Carbon Steel

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**Abstract**

Fracture mechanics approach is important for all mechanical and civil projects that might involve cracks in metallic materials the purpose of this paper is to determine a crack tip opening displacement fracture toughness experimentally, also study the effect of thickness on CTOD fracture toughness of low carbon steel and study the effect of Wire Electrical Discharge Machine (WEDM) to have a pre-crack, instead of fatigue pre-crack by using a CT specimen of low carbon steel with a thickness of (8,10, and15 mm), a width of 30mm, crack length of 15mm, and pre-crack of 1.3mm for all samples, this dimension according to ASTM-E399-13, by pulling the specimen in a 100 KN universal testing machine at a slow speed rate of 0.5 mm/min, the load applied on the specimen is generally a tension load. The crack tip plastically deforms until a critical point $P_C$ at this moment a crack is initiated. The computer-controlled universal testing machine gives the value of the load and the displacement transducer gives a crack mouth opening displacement. Critical crack tip opening displacement CTOD is found with the plastic hinge model (PHM) method. The result showed the stress intensity factor $K_I$ increases with increased loading in the elastic region and the thickness effect refers to the effect of the plastic zone at the crack tip on the stress intensity factor, In a thin specimen, a plastic zone is large at the fracture tip leads to a high-stress intensity factor at the fracture tip but in the thick specimen, on the other hand, has a small a plastic zone and a low-stress intensity factor around the crack tip. The fracture toughness is found to increase with an increase in the thickness of specimens.

Keywords: CTOD, WEDM, Low carbon steel, CFOA, EPFM

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## 1. Introduction

Fundamental concepts of fracture mechanics can be traced back to the late nineteenth and early twentieth centuries. Both experimental observations and theoretical elasticity contributed the creation of the fundamental aspects of the theory of fracture mechanics[1].

Many factors contribute to the failure of an engineering component, i.e. flaw or inclusion in material, cyclic fatigue loading, and residual stresses in the material. One of the most notable failure cases in history is the brittle fracture of Liberty Ships in the 1940s, where 1031 of 2078 ships experienced brittle-related damage. The lack of understanding of fracture at the time did not recognize material strength at low temperatures and the effects due to weld-ments, which led to an expensive lesson in fracture. This incident led to more research in fracture mechanics.

Fracture mechanics is a study of the material's fracture resistivity, consisting of two main parts; linear elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM). Linear elastic fracture mechanics describes the material's fracture resistance within the elastic yielding region, mainly represented by stress intensity factor $K_I$ Stress intensity factor (SIF) is the most important single parameter in fracture mechanics, which can be used to examine if a crack would propagate in a cracked structure

under particular loading condition[2], the elastic-plastic fracture mechanics considers post yielding where the crack deforms plastically, represented by the J-integral and crack tip opening displacement, CTOD [3].In fracture mechanics, when the stress intensity factor in the crack tip is equal to the material fracture toughness, a crack will start to grow. That means the fracture toughness of a material can forecast the remaining strength of a component with an initial crack. Although fracture toughness is a material inherent attribute, for the same material, different fracture toughness values were determined in different tests as test conditions (temperature, loading rate, et al) and specimen size are different. Of all the influence factors for fracture toughness tests, specimen thickness is the most important factor. Stress in crack tip varies as pipe thickness is different. As thickness increases, a stress-strain field in the crack tip starts changing to a plane strain state from a plane stress state, which means the crack tip is in a tension state in all three directions and the plastic zone will be limited in a small scope. So critical fracture toughness will decreases when pipe thickness