Proceedings of the Eighth (1998) International Offshore and Polar Engineering Conference
Montréal, Canada, May 24-29, 1998

ISBN 1-880653-34-6 (Set); ISBN 1-880653-38-9 (Vol. IV)

Experimental and Analytical Studies on Crack Surface Interference Under Multiaxial Conditions

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ABSTRACT

Fatigue cracks in offshore structures propagate under multiaxial / mixed mode loading conditions. Crack surface interference plays an essential role in rationalizing mixed mode crack growth behavior. Mixed mode crack surface interference is studied by a key-hole notched thin wall tubular specimen. The specimen is pre-cracked under pure mode I loading and then the near-tip strain gauge measurements of the crack surface interference are performed under cyclic mode I and steady mode II loads. The measured strain values are uncoupled into those related to mode I and mode II interference by double gauge and single gauge method. Test results reveal that additional mode I closure and cyclic mode II interference are introduced by steady mode II loads. The mixed mode crack surface interference is also studied by a sliding contact model. The model provides primary explanations to the experimental observations and indicates that mixed mode crack surface interference is closely related to material's characteristics.

KEY WORDS: Tubular Structures, Multiaxial Fatigue, Crack Surface Interference, Effective Stress Intensity Ranges, Sliding Contact Model

1. INTRODUCTION

The geometrical complexity of tubes intersected by tubes and the random loading produced mostly by wave and current actions leads to multiaxial / mixed mode fatigue in offshore structures. To expand our knowledge on multiaxial fatigue crack growth behavior, experimental studies on notched thin wall tubular specimens were carried out under cyclic tension and steady torque by Abel and Yu (1997) and Yu and Abel (1997). It was found that the introduction of steady torque not only reduced crack growth rate but also caused crack path deviation.

Crack surface interference was presumed to be responsible for the observations. However, explicit research on mixed mode crack surface interference have rarely been performed either experimentally or analytically. Although extensive studies have been carried out on mode I crack closure since 1970 (Elber 1970), the knowledge accumulated can not be straight forwardly extended to mixed mode conditions because of the distinct features of mixed mode interference (Baloch and Brown 1993, Gross and Mendelsohn 1989, Tong, Yates et al. 1995, Goulet, Gross et al. 1996).

In the present study, the near-tip strain gauge method is adopted to measure mode I and mode II crack surface interference and a sliding contact model is introduced to rationalize the mixed mode interference behavior.

2. SPECIMEN AND TEST PROCEDURES

2.1. Specimen

A thin-walled tubular steel specimen was used similarly to previous work by Abel and Yu (1997) and Yu and Abel (1997). The tube was manufactured from a hot-finished seamless pipe and the key-hole crack starter notch at the mid length of the tube is introduced by spark erosion, Figure 1. Details of the chemical composition of the material and metallurgical microstructure have been published before (Yu and Abel 1997) and the tensile properties were 400 MPa and 500 MPa yield and ultimate strength repectively.

Two 1 mm strain gauges were used on the outside surface of the specimen with a 45 degrees alignment from the circumference and symmetrically positioned along the expected crack path as shown in Figure 2. The vertical distance from the strain gauges to the expected crack path equals 2 mm.

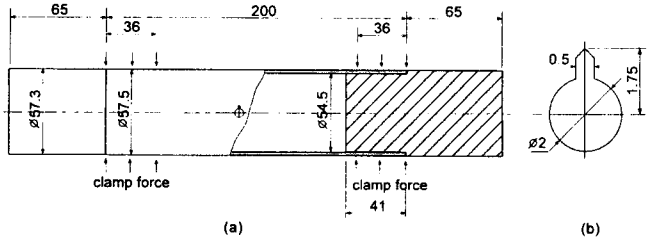

Figure 1. Specimen and details of crack starter notch