Fatigue life of Axially Vibrated Bar using Segmental Steady State Response Time history

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1. INTRODUCTION & OBJECTIVE

Fatigue is associated with the damage of structural components when exposed to long duration cyclic loading resulting in stress reversal. Many metallic structures are seen to be failed by fatigue loading. Practical examples include steel structures in a bridge, subjected to vehicle loading; slender electrical pole or transmission tower exposed to perineal wind flow. Methods adopted to estimate fatigue strength in different code of practice [1] are from the original research work published by Miner [2] and with due honour to the original author, it is popularly known as Miner hypothesis. This hypothesis required experimental stress range vs number of cycles to failure curve for theoretical prediction of fatigue damage. It may be noted that to observe fatigue failure requires application of several cycles of harmonic loading and consumes 3 to 4 days, even more depending on the physical properties of specimen and loading parameters. This incurs heavy operational cost besides the fact that fatigue testing of in-situ structures is prohibited. Noting that there is a need to predict fatigue failure of metallic specimen before approving for construction improving the accuracy of earlier methods. The present work attempts to develop a fatigue damage prediction model that can use a segment of a steady state stress time history without waiting for the physical test or simulation to end. A metallic bar under axial vibration has been considered and closed form expression for steady state time history of stress has been derived. A segment of a time history is now taken to predict fatigue damage in member considering load sequence of loading effect, by splitting loading stage into stages, crack initiation and crack propagation, which is also capable of taking opening stress in crack propagation stage. The results of model have also been validated with experimental observation [3].

2. RESULTS AND MAJOR FINDINGS

The present analytical study yielded steady state response of a metallic specimen of length 100 mm, width 30 mm and thickness 4 mm. This was made of MS whose stress strain curve furnished yield stress 248 MPa, Youngs modulus of elasticity 205 GPa and Poisson ratio was 0.28. Fatigue constants was 250×108 ksi (equivalent to 1.72×1011 MPa) and fatigue power index is taken as 3 [4]. The effect of some of the important parameters-frequency of loading, stress range, effect of damping and number of longitudinal vibration modes are studied.

Peak stresses are found insignificant change with increased loading frequency. Due to increase in loading cyclic frequency, crack propagation becomes slow, thereby lowering damage index and corresponding fatigue strength.

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However, constant low frequency cycles make the specimen vulnerable to undergo accumulation of fatigue stress rapidly. The stress cycles for stress range are more for lower frequency of excitation thus contributing to higher damage. It is also observed that fatigue strength increases with frequency of loading resulting in lower damage index. Due to increase of loading frequency, the slip systems causing crack propagation tend to be less active leading to lower damage index. Fig.1 depicts such observation when simulated with Linear Damage Rule (LDR), Bilinear Damage Rule (BLDR) and Modified Bilinear Damage Rule (MBLDR).

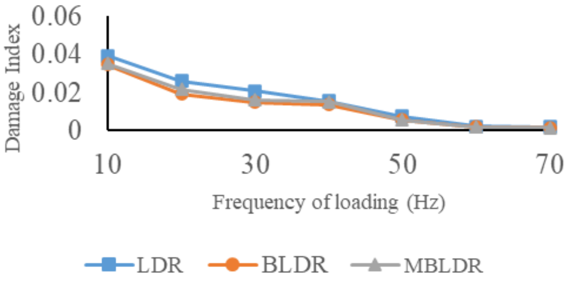

Fig.1 Effect of frequency of loading on damage index

Stress range has found to have reverse trend which accelerates early fatigue growth. The damping of the specimen practically cannot influence fatigue growth since the role of damping in steady state is mainly to limit the amplitude at the time of resonance. In the present case, however, frequency ratio is always kept away from the threshold value.

Experimental results were obtained from three coupon specimen as per ASTM standard tested in INSTRON. Total hours of failure were observed from 24 to 55 hrs. depending on the stress range application during loading the specimen in machine. The fatigue failure of the specimen is presented in Fig.2

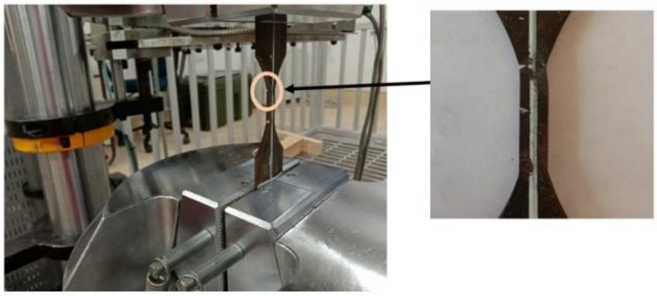

Fig.2 Specimen at failure showing fatigue crack

Prediction of fatigue life with 40 sec time history shows that there is deviation with physical test results by 5% to 7%. Accurate prediction was observed in MBLDR. This method incorporated opening stress in crack propagation stage, which was not considered in existing LDR and BLDR.

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