FINITE ELEMENT BASED VIBRATION FATIGUE ANALYSIS OF A NEW TWO-STROKE LINEAR GENERATOR ENGINE COMPONENT

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ABSTRACT

This paper presents the finite element analysis technique to predict the fatigue life using the narrow band frequency response approach. Such life prediction results are useful for improving the component design at the very early stage. This paper describes how this technique can be implemented in the finite element environment to rapidly identify critical areas in the structure. Fatigue damage is traditionally determined from the time signals of the loading, usually in the form of stress and strain. However, there are scenarios when a spectral form of loading is more appropriate. In this case the loading is defined in terms of its magnitude at different frequencies in the form of a power spectral density (PSD) plot. A frequency domain fatigue calculation can be utilized where the random loading and response are categorized using power spectral density functions and the dynamic structure is modeled as a linear transfer function. This paper investigates the effect of mean stress on the fatigue life prediction by using a random varying load. The obtained results indicate that the Goodman mean stress correction method gives the most conservative results compared with Gerber, and no mean stress correction method. The proposed analysis technique is capable of determining premature products failure phenomena. Therefore, it can reduce cost, time to market, improve product reliability and customer confidence.

Keywords: Fatigue, Fast Fourier Transform; vibration; power spectral density function; frequency response; power density function.

INTRODUCTION

Structures and mechanical components are frequently subjected to oscillating loads which are random in nature. Random vibration theory has been introduced for more then three decades to deal with all kinds of random vibration behaviour. Since fatigue is one of the primary causes of component failure, fatigue life prediction has become a major subject in almost any random vibration [1-4]. Nearly all structures or components have been designed using time based structural and fatigue analysis methods. However, by developing a frequency based fatigue analysis approach, the true composition of the random stress or strain responses can be retained within a much optimized fatigue design process.

The time domain fatigue approach consists of two major steps. Firstly, the numbers of stress cycles in the response time history [5-7] are counted. This is conducted through a process called a rain flow cycle counting. Secondly, the damage from each cycle is determined, typically from an S-N curve. The damage is then summed over all cycles using linear damage summation techniques to determine the total life. The purpose of presenting these basic fatigue concepts is to emphasize that the fatigue analysis is generally thought of as a time domain approach, That is, all of the operations are based on time descriptions of the load function. This paper demonstrates that an alternative frequency domain [4,8-9] fatigue approach is more appropriate.

A vibration analysis is usually carried out to ensure that the structural natural frequencies or resonant modes are not excited by the frequencies of the applied load. It is often easier to obtain a PSD of stress rather than a time history [10-11]. The dynamic analysis of complicated finite element models is considered in this study. It is beneficial to carry out the frequency response analysis instead of a computationally intensive transient dynamic analysis in the time domain. A finite element analysis based on the frequency domain can simplify the problem. The designer can carry out the frequency response analysis on the finite element model (FEM) to determine the transfer function between load and stress in the structure. This approach requires that the PSD of the load is multiplied by the transfer function to the PSD of the stress. The main purpose of the present paper is to derive formulas for the prediction of the fatigue damage when a component is subjected to statistically defined random stresses.

THEORETICAL BASIS

The equation of motion of a linear structural system is expressed in matrix format in Equation 1.