LOAD HISTORIES AND SPECTRA AND PREDICTION

OF FATIGUE STRENGTH IN FORKLIFT STRUCTURES

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The paper describes a method of forming representative load spectra of forklift truck metal structures.This method comprises substitution of cyclic loads having a constant or changing to a specified law of distribution amplitudes for the random loads caused by transport operations.Handling operations loads are then added to obtain a schematized load history which is used to get a representative load spectrum by two-parameter schematization.This spectrum is used to predict fatigue strenght of forklift truck metal structures.

1.Introduction

Stress analysis is an effective method of proving forklift metal structure service life and fatigue strength.It generates reliable quantitative data about structural component states of strain and stress in critical points under service loading.The statistical analysis of experimentally obtained load histories and respective load spectra leads to formation of representative load histories,covering one or more working load cycles,which can also be defined as representative ones.This is possible on the assumption that the service load can be considered a stationary ergodic process which is close to the real situation with forklift trucks.The division of working cycles into operations makes possible their separate study during truck travel and stacking. Main methods of obtaining the representative load spectrum from experimental spectra are : approximation to an appropriate distribution law followed by an extrapolation to reach a specified probability addition and multiplication of partial spectra (1) and application of the stress modulation phenomenon (2).Changing of load mass (utilization of truck load capacity),varying of load centre location in handling and transport operations,and dynamic

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loading under various travel speeds and road conditions (asphalt, pavement, potted road) (3), (4), (5) are taken into account. As regards utilization of truck load capacity and road conditions of loading could be classified as heavy, medium and light. An appropriate combination of those conditions must be chosen when forming representative load histories and spectra.

2. Problem statement

A method is presented of forming representative load histories and spectra in forklift trucks, which is used to predict service life and fatigue strength of load-bearing structures. By this method empirical and theoretical load spectra for transport operations are obtained through one-parameter rain-flow schematization (counting). These spectra serve as a basis for constructing schematized partial load histories with constant mean stress and an equivalent amplitude which is constant or varying to the Weibull law or binomial law. These histories are then added to the partial load histories of handling operations.

3. Partial schematized load histories

When the equivalent amplitude σ_{ae} at equivalent frequency n_e of occurence is a constant value they are defined by the following set of equations (5) :

$$\sigma_{ae}^{m_1} . n_e = \Sigma \, \sigma_{ai}^{m_1} . n_i \qquad (1),$$

$$\sigma_{ae}^{m_2} . n_e = \Sigma \, \sigma_{ai}^{m_2} . n_i$$

where : $m_1 = 3...3.5$ for welded structures .
$m_2 = 6...6.5$ for base material.

The solution of (1) is given in ref. (5). The procedure is analogical when assuming a Weibull distribution or a binomial amplitude distribution, where the frequence (number) of occurence of separate new spectrum orders is rounded to an integer. This constructed, the partial schematized load histories of transport operations with a constant mean stress are added to load histories of the handling processes to obtain partial schematized load histories. When these histories are subjected to one-or two-parameter rain-flow schematization, a partial load spectrum will be obtained, which can be used to predict fatigue strength and service life, e.g. to the requirements of DIN 15018 and FEM.

4. Representative histories and load spectra

Two coefficients are defined in order to take into account the impact of modulation (superposition) on loading : q_k-related to the influence of kinematics and load location ; q_t - for usage of the rated truck load capacity.Both coefficients represent ratios of real operating cycle mean stress to the mean stress in a cycle under rated load location.Depending on the values of amplitudes σ_{ai} and mean static stress σ_{mi},relative frequence of occurance p_i for each partial spectrum are defined.For the j-th and l-st load history operating cycles,characterized by coeficients q_{kj} and q_{tl} and relative frequences of occurence p_j and p_l,the equivalent load amplitude q_{ijl} and its equivalent frequency of occurence p_{ijl} will be determined by the equations :

$$q_{ijl} = q_i \cdot q_j \cdot q_l \qquad (2);$$

$$p_{ijl} = p_i \cdot p_j \cdot p_l \qquad (3);$$

$$\Sigma p_i = \Sigma p_j = \Sigma p_l = \Sigma p_{ijl} = 1 \qquad (4).$$

These equations are true when there is zero correlation among load conditions in regard to truck capacity utilization,type of road and influence of kinematics.A three-parameter matrix is obtained in contrast to ref.(1),where it is a two-parameter one.In some cases it manifests as adding of individual loads.The representative loading spectrum is received from several successive operating cycles,covering the major locations of load mass centre and some extreme loading as well.With the purpose of using a computer,we select a maximum of 16 to 24 working cycles (max.1 hour of operation) with various lengths and surface conditions,possibly different loads,observing the requirements of multivariate analysis.After schematization the number of amplitude occurences for the individual orders will be extrapolated over the complete truck life.

5.Prediction of fatique strength

The procedure of fatigue strength prediction as described in DIN 15018 and FEM/1-12-1970 comprises comparison between equivalent stress (a sum of equivalent amplitude and mean stress) and allowable stress.It is expedient when converting into equivalent cyclic load with constant or changing to binomial distribution law amplitude,to take into account also the ψ coefficient of the impact of mean stress in accordance with the known equation of equivalent amplitude σ_{aie} and the Smith-Goodman diagram :

$$\sigma_{aie} = \sigma_{ai} + \psi . \sigma_{mi} \qquad (5).$$

Instead of amplitudes σ_{ai},we use the equivalent stress amplitudes σ_{aie} to solve the set (1).With DIN 15018 and FEM standards these amplitudes are determined as follous :

$$\sigma_{aie} = \sigma_{ai} . \frac{6 - 4r_i}{5 - 5r_i} \; ; \; \psi = 0,2 \text{ for } \sigma_{ai} > 0 \text{ and } r_i < 0 \qquad (6);$$

$$\sigma_{aic} = \sigma_{ai} \quad : \psi = 0 \quad \text{for } \sigma_{mi} < 0 \text{ and } r_i < 0 \qquad (7);$$

$$\sigma_{aic} = \sigma_{ai}\{18\sigma_B(1-r_i)+40[\sigma_{-1}]r_i\}/15\sigma_B(1-r_i) \quad \text{for } \sigma_{mi} > 0 \qquad (8);$$

$$\sigma_{aic} = \sigma_{ai}\{9\sigma_B(1-r_i)+20[\sigma_{-1}]r_i\}/9\sigma_B(1-r_i) \quad \text{for } \sigma_{mi} < 0 \qquad (9).$$

The asymetry r_i is defined in compliance of DIN 15018 requirements.After solving equation (1) in a reverse manner the amplitude will be converted into mean stress σ_{mi} to predict fatigue strength.

6.Application

This method has found an application for predicting the service life and fatigue strength of forklift trucks made in Bulgaria. It is equally suitable for static stress measurements and finite-element calculations.Data from previous field and laboratory performance tests carried out as per Balkancar factory standard are used in both cases.

SYMBOLS USED

σ_{ai}, n_i- amplitudes and frequencies (number) of their occurence for the i-th order of the partial load spectrum

m_1, m_2- exponents of the Woehlers' curve

σ_B- material fracture strength

$[\sigma_{-1}]$- allowable fatigue strength to table 17 of DIN 15018

r_i-asymmetry of the i-th order of the load spectrum

σ_{mi}- mean stress of the i-th order of the load spectrum

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