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A NUMERICAL ANALYSIS BY THE FINITE ELEMENT METHOD ABOUT THE WIRE ROPES LIFETIME CALCULATION

VÎLCEANU Lucia *, BABEU Tiberiu Dimitrie **

* Lecturer dr. eng., ENGINEERING FACULTY OF HUNEDOARA, ROMANIA, e-mail: vilceanu63@yahoo.com
** Prof. dr. eng. Eur. eng., MECHANICAL ENGINEERING FACULTY OF TIMIŞOARA, ROMANIA, e – mail: tbabeu@mec.utt.ro

ABSTRACT

The paper presents a numerical analysis by the Finite Element Method regarding the deterioration of wire ropes subjected under variable traction loading. The FSTAR modulus, part of the COSMOS/M 2.5 software, and the PLM criterion for cumulative deterioration, has been used in order to perform the analysis. The specific and total cumulative deterioration coefficients for every loading range have been obtained after the program running.

KEYWORDS*: finite element method, cumulative deterioration, fatigue.*

1. Introduction

In order to perform a numerical analysis by the Finite Element Method regarding the wire deterioration in traction wire ropes, the FSTAR modulus, part of the Cosmos/M 2.5 software, has been used. The PLM criterion for cumulative deterioration has been considered as valid. The phenomenological definition of the deterioration process under a variable loading may be formulated as follows: the state of deterioration is considered as global state of the material, which for the initial lifetime is modified. If under a repeated loading until the crack appearance, the amplitude of cycles is non-continuous variable between the levels i = 1,…, q, the analytical expression of the PLM criterion for cumulative deterioration is:

$$\sum_{i=1}^{q}\frac{n_i}{N_i}=1 \qquad (1)$$

where: n_i – the number of loading cycles for the **i** level;
N_i - the number of loading cycles until the crack appearance (the life-time) for the **i** level.

The tests under a variable loading with single non-continuous amplitude between the σ_1 and σ_2 stress values, the succession of the loading cycles has an important effect. So, the PLM criterion became:

$$\frac{n_{11}}{N_1} + \frac{n_{22}}{N_2} = 1 \qquad (2)$$

If the higher loading amplitude is applied at first (**$\sigma_1 > \sigma_2$**), the amount in relation (2) is less than **1**, respectively higher than **1** if the loading order is reversed.

The only logical opportunity to evaluate the safety of a machine part subjected under a variable loading consists in the introduction of the probabilistic methods: *the method of the guaranteed lifetime* **D.G** (safe-life) and *the method of the controlled deterioration* **D.C** (fail–life).

According to the **D.G** *method*, a metallic structure subjected under repeated loading, is designed for a low total or partial failure probability during the guaranteed working lifetime. When the guaranteed working lifetime is reached, the metallic element or structure must be substituted, even a perceptible deterioration may not be observed. A **D.G** designed structure is the traction chain where the working lifetime is imposed by the working lifetime of the weakest ring in the chain.

According to the **D.C** *method*, there is permitted to reach an enough low partial deterioration, which is easy to be observed and which has an enough low propagation velocity between two technical inspections, so that the loading capability of the structure (subjected under static and variable loading) will not be alterated. A classical example of a machine part, which has been designed according to the D.C conception, is represented by a wire rope composed of wires and strands. That is because when the fracture of a wire takes place, the loading capability is transferred to the other wires. The ending boundary wires, which have been fractured, represent a sign of the extension of the deterioration.

2. The lifetime calculation of wires by Finite Element Analysis

The data storage is obtained by using the NSTAR modulus, part of the Cosmos/M 2.5 software. The contact between two wires with the same diameter of 1,25 mm loaded with a pressing force of (3,6…327,5) N has been analyzed.

Nine working on loading cases have been studied for a wire rope. The loading cases have been accidentally considered both as number and amplitude of cycles. According to the same calculus model, it may be paired any number of cycles with any maximum stress.

The fatigue phenomenon induced by the maximum stress σ_{ymax}, which are not perpendicularly on the contact patch, has been simulated by accidental fatigue loading blocks (σ_{ymax} – number of cycles), see Fig. 1.

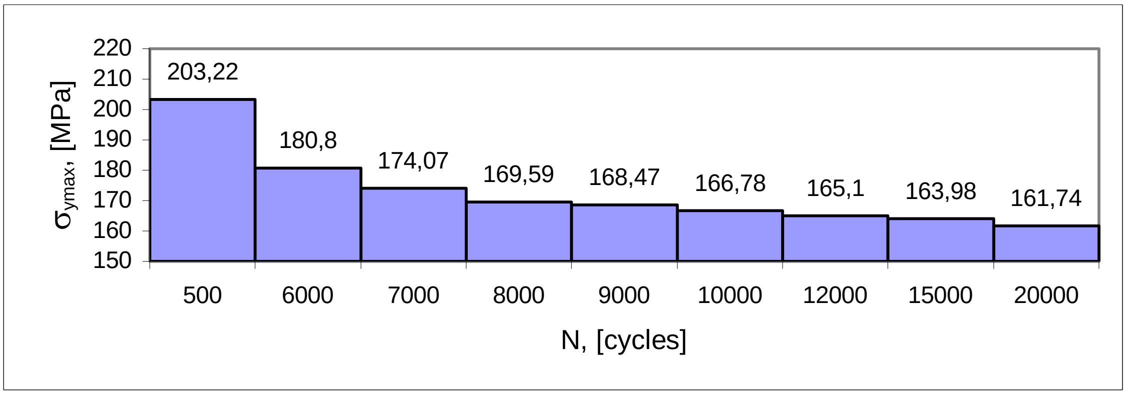

Fig.1 *Loading fatigue block σ_{ymax} – N*

The fatigue limit curve (Fig.2 – curve 1) for an alternative-symmetrical loading cycle of a non-torsion wire, which is blended on a roll with the diameter of 40 mm, has been plotted according to the experimental data [3] obtained on a fatigue contact compression test on the [NB] testing machine which belongs to the Laboratory of Strength of Materials from the Mechanical Engineering Faculty of Timisoara.

The stages to be followed to introduce the data and to use the software [5] are:

1) – The running of the Finite Element software for the contact between two wires with equal diameters of 1,25 mm, for the testing cases.

2) – The 9 testing loading steps and the associated number of cycles are entered.

3) – The central surface contact node (where the maximum stress σ_{ymax} is present) is prescribed.

4) – The fatigue limit curve (7 points on the curve 1, Fig.2, according to Table 1) is introduced. The curve followed an alternative-symmetrical loading cycle with a non-symmetry coefficient of $\mathbf{R_s = -1}$.

5) – The prescription for the results calculation is accurately defined.

6) – The software is running on according to the orders *Analysis > Fatigue > Run Fatigue Analysis*.

The particular values of the fatigue limit curve **Table 1**

N [cycles]	2000	3000	6000	20000	60000	200000	7000000
σ_{cmax} [N/mm^2]	3900	3550	3350	3100	3050	2948	2900

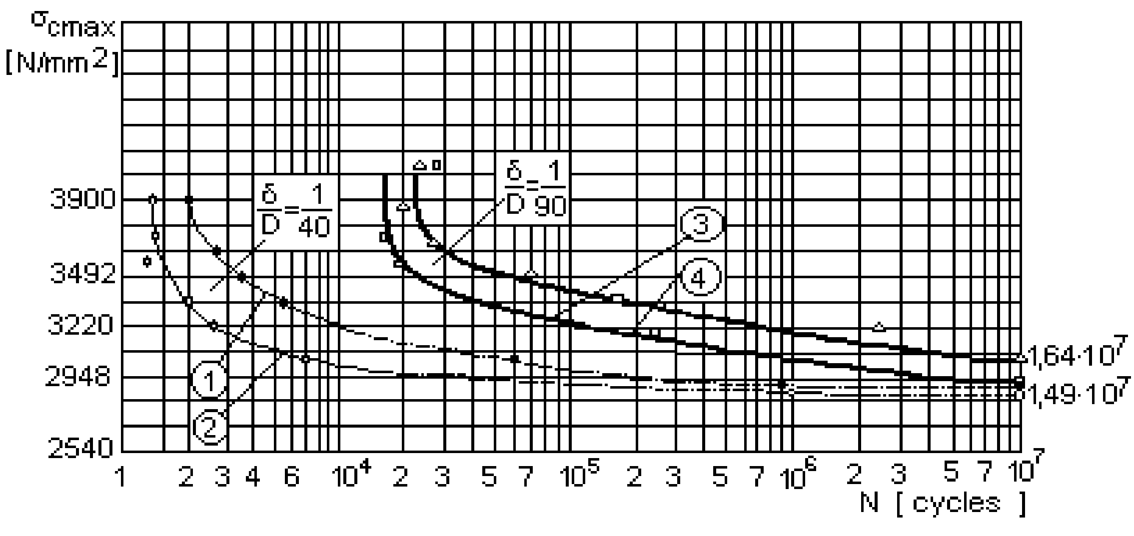

Fig.2 *The lifetime variation for the tested wires on the [NB] testing machine, in function of the contact compression stress*

3. Results and conclusions

The present calculus connects the stresses in wires, caused by the compression contact, with the lifetime of the traction wire ropes subjected to particular variable loading which have a specific nature for the working on of wire ropes.

After the software running on, the cumulative deterioration coefficients for every loading steps and the total cumulative deterioration coefficient have been obtained. The value of the total cumulative deterioration coefficient was of 6,75. A similar procedure has to be used in order to estimate the cumulative deterioration coefficient for any real loading cycle.

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