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# MODELING AND OPERATING VERIFICATION IN THE DESIGN PROCESS OF MOBILE WORKING MACHINES

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ABSTRACT: This contribution deals with methods of creation of 3D model in the construction process, verifying of technical parameters of the machine and life estimation of the selected modules. Life determination of mobile working machines, respectively their carrying modules comprises process of investigation and subsequent processing of results gained by service measurements. Machine life quoted by a producer is relative, because load of these machines depends not only on the way of work on that particular machine, state of material which is manipulated by machine, but in great extent on machinist, observance of security regulations, and prescribed working procedures.

KEYWORDS: load spectrum, lifetime, verification tests, loading spectrum, stress analysis

## ❖ INTRODUCTION

Use of modern, computer-aided modeling system allows a time reduction in complex design of mobile working machines. Design programs allow us to create a complete 3D model of the proposed machine or machine parts. It also performs stress analysis and optimization of the kinematic assemblies. Work efficiency in the design stage is increased by using of interactive programs also total costs for the development of machines are reduced. An important part of the development of new designs is a real verification of the proposed basic technical parameters which represent force influence to working tool, together with their limit state in the field of mobile working machines. In operational practice, the limiting factor of machine life is the fatigue damage of their carrying parts. It is therefore necessary to pay attention to the fatigue limit already in the process of design. We use various hypotheses of fatigue damage cumulation to estimate of service lifetime. Acquired results are subjected to careful analysis, because it can lead to wrong conclusions.

## ❖ CREATION OF 3D MODEL

3D computer aided design software reduce the design time but also make it easier to perform the repairs and provide a complex 3D model of the proposed machine or parts. Most commonly used systems in practice are: CATIA, SolidWorks, Solid Edge, Pro/ENGINEER, Autodesk Inventor and other. Rotary front loader of PPS Group's company in Detva with a type number HON 200 was also designed by using of 3D modeling system. Later it received into real production. A complete virtual model of loader was created by using of modeling software, including its working device (Fig. 1).

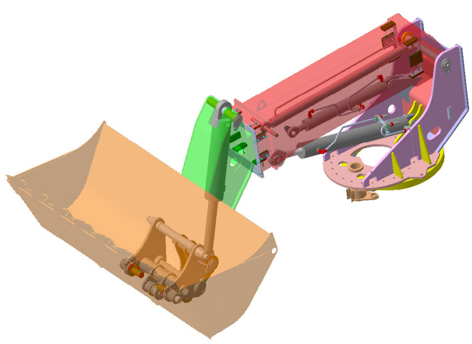

Figure 1: Telescopic boom of loader "HON 200t"

Created model served as input for stress analysis by using of the finite element method. Example of output to Fig. 2 represents the tensions in particular places of working device module. On the results of the analysis it can be performed strength verification of prototypes and obtained a complex overview of the structure tension, as well as the nodes with the highest concentration of stress. It can be performed optimization of selected components for kinematic analysis of assemblies. Referred software products make easier further decision steps in the design stage of prototypes. MSC.ADAMS. is the most widely used program for optimization tasks. In the design stage of loader HON 200 (in a program MSC.ADAMS) the parametric model of telescopic boom was created through optimization of variables coordinates of the main points of kinematics to meet the required criteria. For example, tearout force process of optimized loading equipment depending on the angle of the working tool is shown in Fig. 3, [1].

## ❖ VERIFYING OF TECHNICAL PARAMETERS OF THE MACHINE

Optimization results were verified by tests on the prototype. Verification of the proposed parameters is performed by ISO 14397-1 and ISO 14397-2, which is verification tearout, lifting forces and over-end load. The process of tearout force, depending on the boom position after optimization of kinematics of working device is shown in Fig. 3. The results of measured tearout forces are shown in Fig.4.

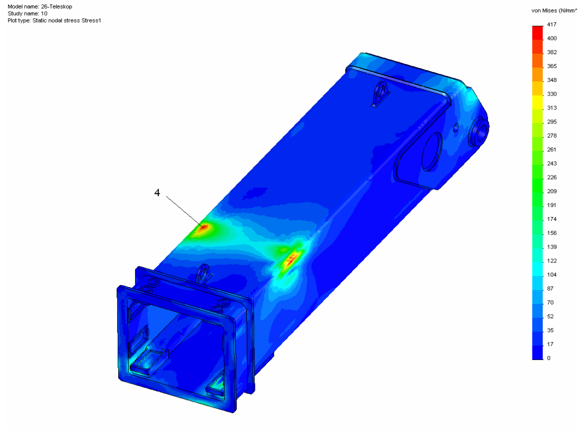

Figure 2: Stress analysis of the selected working machine

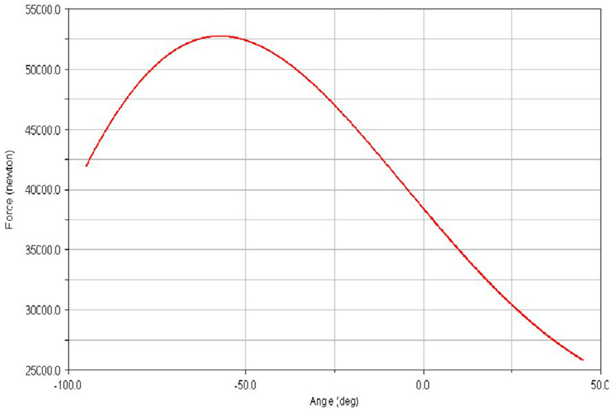


Figure 3: The result of optimalization – process of tearout strength

Values obtained by measuring for the same parameters as were used in optimization are not significantly different. (An analysis - 42kN, 46kN - measured values). We can say that results of computer modeling (applies for a well-developed model, loaded by adequate force effects) and operational measurements do not significantly different from each other and can be considered trustworthy, [2].

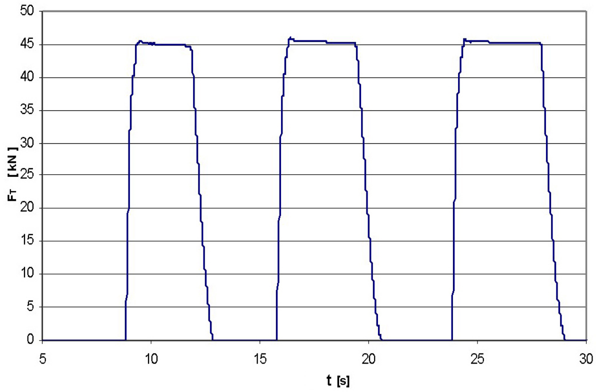


Figure 4: The process of tearout force measured during the tests

## ❖ LIFE ESTIMATION OF THE SELECTED MODULE

Service tests performed under the abovementioned standards have the character of static tests. It is necessary to perform the operational tests to get an overview of loads occurring in the construction of the machine during the operation. Measurements are made during the real operating of machine. Time responses of force of performed work technology to critical points of the machine are monitored. Typically these measurements are made at a standard (Fig. 5) working load. During machine operation, however, it cannot be excluded the presence of non-standard loading, which may have a particular nature. States of this nature may be induced and their influence to load of the structure also may be determined. Non-standard load can be caused by deliberate overload of the machine or carelessness of operator.

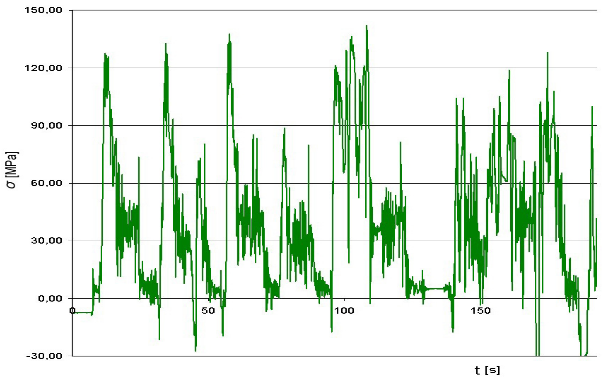


Figure 5: Process of loading during the manipulation with soil

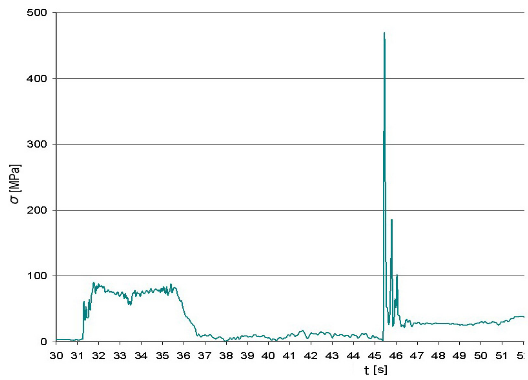


Figure 6: process of loading by an impact

Operational measurements serve as major source of information for estimation of service life of critical parts on the working machine. Acquired processes of loads have generally random character. Number of some parameters of the loading process (maximum amplitude, relative amplitude, mean, crossing levels etc.) are determined through various methods of analysis the measured record, [4]. Rain-flow method is the one of the most frequently used methods.

One method to characterize the service load is by the loading spectrum, which is function of the relative number of occurrences ni/Σni versus the relative stress amplitudes, $\sigma_a/\sigma_{ai\ max}$, [3]. Fig. 7 shows the loading spectrum of the operation in standard conditions (Fig. 5 Working with soil) and Fig. 8 shows the loading spectrum with consideration of unexpected overload. The effect of overload (such as in the form of impact (Fig. 6)) is significantly reflected in the load spectrum. The figure shows that the influence of impact resizes the area under the curve from 21% to 7.4%. The result is a significant decrease of lifetime estimated by hypothesis. Load spectra arranged on bases of loading process of loader manipulating different materials have a log-normal distribution.

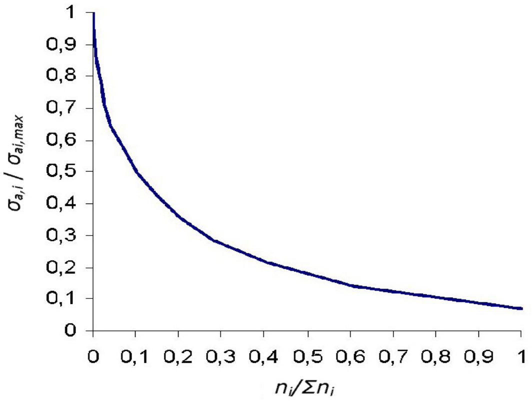


Figure 7: Unified loading spectrum ("standard mode ")

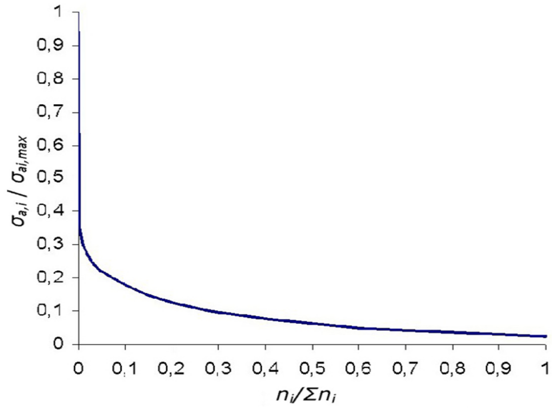


Figure 8: Unified loading spectrum ("non-standard loading - impact ")

Different hypotheses can be used to estimate the fatigue lifetime. Tab. 1 shows us the results of the lifetime estimation by most popular hypotheses as Palmgren-Miner, Serensen-Kogajev, Corten-Dolan, Haibach.

Table 1: Overview of fatigue life estimated by particular hypotheses

| Hypotheses | Relation for calculating of lifetime | Estimated lifetime |
|---|---|---|
| Palmgren-Miner | $\frac{n_1}{N_1}+\frac{n_2}{N_2}+...............=\sum\frac{n_j}{N_j}=1$ | 5488 [h] |
| Serensen-Kogajev | $\sum_{i=1}\frac{n_j}{N_j}=a \quad a=\frac{\sigma_{a\max}\xi-K\sigma_c}{\sigma_{a\max}-K\sigma_c}$ | 1100 [h] |
| Corten-Dolan | $\sum\left(\frac{\sigma_{ai}}{\sigma_{a\max}}\right)^d\frac{n_i}{N_{f\max}}=1$ | 11560 [h] |
| Haibach | $D_c = D_1 + D_2$ <br> $D_1=\frac{\left(\sum_i n_i.\sigma_{ai}^k\right)}{\left(N_c\sigma_c^k\right)} \quad D_2=\frac{\left(\sum_i n_i.\sigma_c^{(2k-1)}\right)}{\left(N_c.\sigma_c^{(2k-1)}\right)}$ | 10655 [h] |

The results obtained by various hypotheses show a considerable dispersion. Therefore, for guess of operational life is important to select suitable hypotheses. Selection and results as well are influenced by the nature of the loading. Nonetheless suitability of the selected hypotheses and information obtained by laboratory testing confirms the real service of working machine.

## ❖ CONCLUSIONS

An important stage of the development of a new design is to ensure reliability during the planned technical life. One of the criteria of reliability is an endurance of critical point/ts of structure, influencing life the whole structure. Hypotheses of fatigue damage taking into account the nature of the operational loads are applied to estimate of the service lifetime. The load spectra are generally determined on the basis of measurements on prototypes, or similar structures operating in the expected operating conditions. Reliability of the results of the estimate depends on the load spectrum representing the operating load and also choice of suitable hypothesis of fatigue damage cumulation. Hypothetical estimate is needed to verify by experiment. The best verification of parameters of new mechanical construction is the real operation.

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