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TESTING THE RESISTANCE STRUCTURES OF TRACTORS AND AGRICULTURAL MACHINERY UNDER SIMULATED AND ACCELERATED REGIME

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ABSTRACT

The need for an increased quality of products, the reduction of the production entry time and the restrictions imposed by the service period of products are the essential reasons which impose the necessity of using the simulated and accelerated regime tests. An accelerated test is necessary to produce the same content of wear deterioration as that one supported by the product (machine, gear, subsystem or component) on its lifetime in normal functioning conditions. Although a test in accelerated regime doesn't have to produce big loads, unrealistic, which could alter the defecting mechanism? The paper presents the principal methods of test acceleration and exemplifies the test in accelerated and simulated regime by a test of endurance effectuated on the structure of a two plough body, on the Hydropulse stand inside of Testing Department from INMA Bucharest. Also, the paper present photos that were taken during the years from tests in simulated and accelerated regime, on the Hydropulse stand, of different machines and agricultural gears.

INTRODUCTION

The importance of testing machinery, equipment or components results from the fact that different types of tests, as part of the process of research, development, design, manufacturing, operation and repair of products, contributes significantly to their continuous improvement, in all phases.

Mechanical testing aims:

- to verify if the main design parameters, technical and economic indices, quality of work, performance, operational safety and wear resistance of components, subassemblies or products are in accordance with the technical documentation of the construction company;
- to undertake a continuous quality control of manufacture (repair), to verify and improve the prototypes or new processes and materials, etc., at the manufacturing and repair companies;
- in operation, to determine which is the type of component, subassembly or product most suitable for specific work conditions, and also to establish the best working regimes;
- to obtain comparative technical data for new works of design or for technical manufacturing processes;
- to provide data for determining the service life of the component, subassembly or product.

By their destination, mechanical testing classify into: durability tests and tests for determination of various parameters. Durability tests are classified into long term tests and simulated and accelerated tests.

Long term tests are performed in order to determine the service period under real operating conditions, characterized by normal testing regimes, corresponding to those in the actual operation.

Simulated and accelerated tests are characterized by overload of the machines, equipment or components in forced regimes, operating for reduced periods under laboratory conditions or on special tracks that provide such regimes.

The requirements for a successful resistance test are the following:

- The test should be adequate for what it must be tested, whether this is a component, a subassembly or a complete product.
- The test should reproduce the same failure mechanisms observed in the real loading environment.
- The test must be representative for the real loading environment, within the known the statistical margins.
- The test should be accelerated, where is possible, in order to improve the development programs and to reduce costs; however, it mustn't produce high unrealistic loads that could alter the failure mechanism.
- An accelerated test should produce the same content of fatigue damage as that supported by the machinery, equipment or component throughout their lifetime.

MATERIAL AND METHOD

Tests under simulated and accelerated regime are performed because is aimed:

- Increased quality of products: one of the most acute trends encountered on a large scale of consumer, industrial and military markets, is the need for high quality products. In *consumer markets*, a high rate of product failures can lead to *loss of manufacturer credibility* with the consequence of *dramatic drop in sales*, and the recovery would take many years. In *industrial markets*, a high rate of failures can lead to *significant growth in service costs*. In *military markets*, product damages could result in *loss of human life*.
- Reduction of time for entry into production: most machines, equipment or components must pass certain tests of sustainability certification before going into production, in order to ensure an effective transition from design technology to production technology. This leads to cost efficiency and places the company in a favorable position in the struggle for winning marketplaces.
- Restrictions imposed by the time of service: there are special situations, such as the testing of agricultural machinery and equipment, when the testing period is limited by the length of service in a year (usually one season) - a harvester combine for cereals is in service for a short time, about two months of a calendar year. Hence, the need to test, in accelerated regime, various components or subassemblies in order to ensure the necessary time for any changes until the beginning of the service time of the combine; there are products with continuous operation and / or very high lifetime (years) - in this case, in order to determine the lifetime of the product, is absolutely necessary its testing under simulated and accelerated regime, acting both in order to reduce the time, taking under consideration only the events that cause significant damage, and also to amplify the load.

An accelerated test should produce the same level of fatigue damage as the one resulting from working in real conditions, throughout the lifetime of the assembly / component subjected to testing.

Accelerated testing takes into consideration certain data / measurements determined during operation with the machinery (or its components), which will provide a basis for imposed test parameters with the requirements of standard / directive (when there is a regulation for the respective component or machinery). For each event are measured the amplitude – time signals, estimating how often the product could meet these events during the service time. The variation of signals in time contains information about the amplitude, frequency, phase and sequence. All these factors can influence the lifetime at fatigue life.

Based on measured data is created a command signal which will be used on the test bench, the signal must contain at least the same amount of fatigue damage as the one in real conditions.

There are two main methods of accelerating the test: testing in compressed time and load amplification. Tests in compressed time remove the cycles that don't produce damage, whereas load amplification methods exploits the exponential relationship between stress amplitude and fatigue damage in order to exaggerate the damaging effect of the load. A combination of the two methods is often used for test optimizing.

- *The method of load amplification*: it scales the input signal through a suitable size in order to shorten the time of test. Load scaling will reduce exponentially the time of test. In this case it must be ensured that the loads are not excessively scaled, by inducing local cracks or modifying the path of load applying. Since the method maintains the frequency, phase and sequence, is suitable for dynamic and quasi-static components with multiaxial or uniaxial loading. Often, it is used in conjunction with one of the time compression methods.
- *The method of extracting extreme local values (maximum and minimum)*: if the response of component is quasi-static, then the frequency is no longer important and it can be removed from the signal. This is done by removing any point which is not a turning point (local maximum or minimum). A further reduction can be made by dividing smaller cycles which are below the endurance limit of the material. A common practice is to remove any cycle with an domain smaller than 10% of the maximum domain. Maximum-minimum loading sequence contains information about the amplitude and sequence, without taking into account the frequency or phase between different channels. Therefore, it is only recommended only for firm states, uniaxial loading of quasi-static components and is applicable only in the case of controlled displacement tests. This method can be further accelerated using the load amplification technique. However, the engineer must be aware of the special precautions necessary to avoid overloading.
- *The method of loading sequence*: effects of sequence are usually of secondary importance in fatigue and the test can be simplified considerably by only extracting the fatigue cycles. This is done using the Rainflow algorithm of cycles counting. The load profile obtained will have the same damage content as the full signal in time, but it is considerably shorter and easier to apply to a testing stand. Further reduction can be achieved by dividing smaller cycles with amplitude below the endurance limit. Since this method doesn't take into account the frequency, it is only suitable for controlled displacement tests.
- *The method of statistical surplus*: statistical surplus is similar to the method of loading sequence, except that instead of the Rainflow algorithm of counting, is used the algorithm of "passing through the level." It results a graph of load domain - number of cycles. This type of representation is used especially in aerospace industry, where the domain is usually expressed in terms of acceleration in g.

The method of constant amplitude loading: this is the simplest form of resistance test, where a sinusoidal input load is applied to a component in a specified period of time. This test is destined for simple components.

The method of maximum-minimum local multiaxial extraction: many components receive simultaneously inputs from several axes. These can take the form of acceleration loading in one point on three orthogonal axes (x, y, z), or loads in multiple input points as vertical load input from the four wheels of a car. Usually, this leads to a complicated test, requiring an expensive multichannel test stand. Maximum-minimum multiaxial extraction is similar to that previously presented for a single channel, specifying that is applied to all channels simultaneously.

The method of loading frequency increase: by increasing the frequency of loading for a test, the time of test will be reduced, aiming that the increase of frequency does't causes dynamic amplification. Therefore, the test is usually accelerated so that the maximum frequency should not exceed 1/3 of the lowest natural frequency of the component. It is therefore necessary to make a preliminary analysis on the behavior of the component.

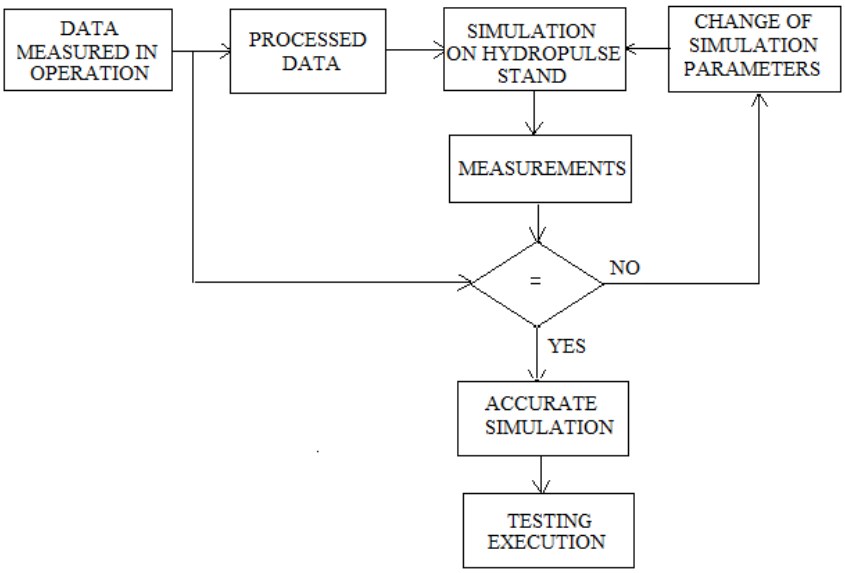
RESULTS AND DISCUSSIONS

- ***Testing under simulated and accelerated regime:*** physical tests are performed using a variety of testing stands, of which the most common type is the hydraulic vibrator (Hydropulse). These tests are usually performed by using as input data the acceleration and by vibrating the respective component.

In order to reach the simulation results in accordance with the real phenomenon, real input data are required for initiating the simulation, which must come from measurements made in operating the product (machinery, equipment or component) or on some previously made products. Other data recorded during operation of the product will be later used to determine the degree of accuracy (the conformity with reality).

So, the measurements (strain, force, acceleration of vibrations, etc.) cannot be separated from the simulation process, as they are rather necessary primarily in the initiation phase of the simulation, and afterwards to ensure that the results are in accordance with the real phenomenon.

These are outlined in the following flowchart:



In order to achieve the physical tests is necessary to proceed sequentially through several stages:

- establishing the main stresses and measuring points: this is done taking into account the working mode of the tested machine, the interaction of working bodies and soil and also between the constructive elements of the machine, the operation regime or other requirements of the beneficiaries. Measurement points where the transducers must be placed are set either by analytical methods or by using modeling with finite element method.
- recording of stress in the field: by measuring in real operating conditions the parameters considered essential for establishing the lifetime of the machine.
- processing of recorded signals and establishing of the testing program. Processing of the signals collected in the field include operations of filtering, statistical analysis, frequency analysis, etc. Based on the analysis of results, are selected portions of

records considered significant in terms of applications, thus resulting the stress signal to be applied to the testing facility type Hydropulse.

- performing the test: the machine to be tested is fixed by means of devices in order to simulate both its catching with the other elements of the machine and to be in accordance with the real operating parameters. The file containing the control signal is loaded into the computer system, the test forces generated by hydraulic cylinders and applied to the tested machine being very close as form and amount with the established loading program (ideally identical);
- analysis and interpretation of results: in case of the structures for which was not required the placement of transducers for recording of strains or other measures, both during testing and at the end of the test is made a visual inspection or by using measuring devices, in order to establish the occurrence of cracks, tears, or strains of the structure. For structures on which have been placed transducers based on the information provided by them, optimal decisions can be taken to improve the product.

Among the tests under simulated and accelerated regime, on a Hydropulse installation, made for various types of agricultural machinery and equipment, respectively for assemblies and subassemblies, in accordance with national and international standards or based on own methodology, the following can be mentioned:

- *testing of coupling devices for various types of vehicles* (fig. 1)



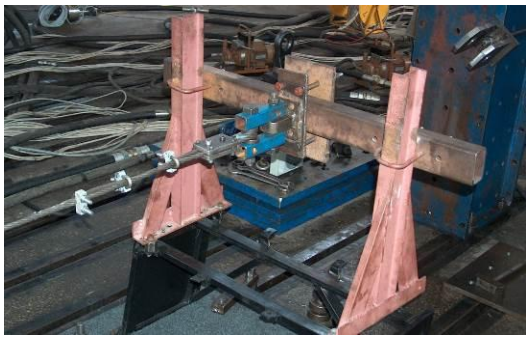

- *resistance testing of ploughs* (fig. 2):

- *testing of chassis of monoaxial or biaxial trailers and testing of suspensions* (fig. 3):


- *testing of safety devices in case of tractor rollover* (fig. 4):


- *resistance testing of seats* (fig. 5):


- *resistance testing of seat belt anchorage points* (fig. 6):

CONCLUSIONS

As input quantities of the tested system (displacements and forces) can be controlled very precisely and as laboratory measurement conditions are far superior to field conditions (accuracy, repeatability, etc.) the results obtained during the tests will be more eloquent. Thus, in addition to the possibility to determine more easily the moment of occurrence of the first crack in a structure, is also possible to study its behavior in time.

Because tests are performed in laboratory, different mechanical parameters sizes can be measured: mechanical force, displacement, torque, acceleration, strains, etc. so that information about the tested structure are more complete and can meet the additional requirements of the beneficiary.

Another major advantage is the drastic reduction of time required for the test (e.g. for ploughs, intended for operation about 10 years, testing is performed within two months).

Generally speaking, one of the real benefits of testing in simulated and accelerated regime is the ability to achieve time compression of the interrelations within a system, making it possible to observe the results of the interactions, which normally we would escape because they are not closely related in time and space.

Simulation, along with modeling, can provide a way of understanding the dynamic complexity of mechanical structures.

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