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ACCELERATED TESTING OF DEEP SOIL LOOSENING MACHINE RESISTANCE FRAME

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Abstract: *Conception, design and fabrication of agricultural machinery, in modern age, cannot be achieved in competitive conditions without including in these activities the one of experimental research through field and laboratory testing. Acceleration of tests is a way of hurrying up the information obtaining regarding products behavior in conditions of economic efficiency. By accelerated testing concept we understand time compression and acceleration of braking mechanisms in a reasonable amount of time so that the products reliability will be evaluated. This concept is also applied to agricultural machinery testing, especially of those high stressed in exploitation. The paper will present the stages which have to be passed for design validation of a resistance frame from a deep soil loosening machine by applying an accelerated testing program within a laboratory unit. For this, we will present the real solicitations spectrum at which the machine is subjected in exploitation and the synthesized accelerated test program obtained using a Rainflow counting algorithm. Then, the deep soil loosening machine will be mounted on a specialized stand and will be subjected to strains according to the obtained testing program, with the final purpose of its resistance frame design validation.*
Keywords: *accelerated testing, resistance frame, rainflow*

INTRODUCTION

As a general rule, an agricultural machine design is based on the physical operations it has to perform during work. The design may be new, innovative, but also inspired by a similar operation performed by an existing machine. The bearing structure, the frame or the chassis are designed and sized appropriately to a reserve which ensures the good running of the activity (maximum strains not affecting the work quality and maximum stress applied on structure, which cannot determine failures). This primary structure is subjected to a structural analysis process for a better or even optimal dimensioning. This structural analysis process comprises the stages: structural modeling, static analysis, analysis of own frequencies, dynamic simulation, fatigue test [4]. Following these stages, the structure theoretical dimensioning can be decided. The structure physical building is followed according to theoretical process data, by the physical testing stage. This test is of two types: testing in the field, under different working regimes, respectively bench testing.

The field tests first aim to determine the quality of the work performed, as well as to determine favorable (maybe optimal) working regimes, but also the general behavior of resistance structures (strains, components stress, vibrations, resonances, fatigue, etc.). At the same time, there are monitored the operations the machine has to perform, namely the machine mission profile [5]. Following this identification and based on field tests the machine shock response spectrum, is defined. Based on this spectrum, the mechanical laboratory tests to which the machine will be subjected, are established [1,6].

The main mechanical tests are thoroughly performed on testing stands, in simulated and accelerated regime. Observations and corrections made in these stages can bring back the product at the design stage for improvements, after which the testing stages continue and the cycle keeps going on till all the machine problems are satisfactorily solved. When the machine is appropriate to designers, potential beneficiaries, users and testers, it can reach the stages of model, prototype and respectively production.

MATERIAL AND METHODS

The stages necessary to achieve an accelerated testing program at which the machine resistance structure be subjected based on a real stress spectrum, are the following:

≡ achieving the structural model of machine resistance structure; then, real excitation and supporting points of structure will be chosen in order identify the structure critical points;
≡ applying sensors (strain gauges) in critical points for registering the real stress in the filed;
≡ performing tests in transport and in exploitation and estimating their share out of the machine total operating period;ț
≡ processing the signals obtained in the field using a counting algorithm of rainflow-type cycles [3] and a program synthesizing the test signal;
≡ preparing a test stand in laboratory which should reproduce the real operation conditions;
≡ performing laboratory tests, on testing stand;
≡ results conclusions.

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The structural model presented within the thesis for MAS-5 scarifier is probably the simplest structural simulator, made only of 1-dimensional finite elements. It was built starting from the MAS-65 machine experimental model, available for performing physical tests both in the field and laboratory. This way, the main components of machine resistance structure and their basic profiles, were identified and their dimensions were measured and after that, the structural model was built.

Figure 1. Machine MAS-65 in aggregate with New Holland TD80 tractor during the work in fallow laid field

In fig. 2 is given the map of stress state (Von Mises) equivalent in structural model of scarifier MAS – 65. Maximum value of equivalent stress is of 39.4 MPa and the bar which models the upper hydraulic cylinder and the bars connecting to tractor, are located.

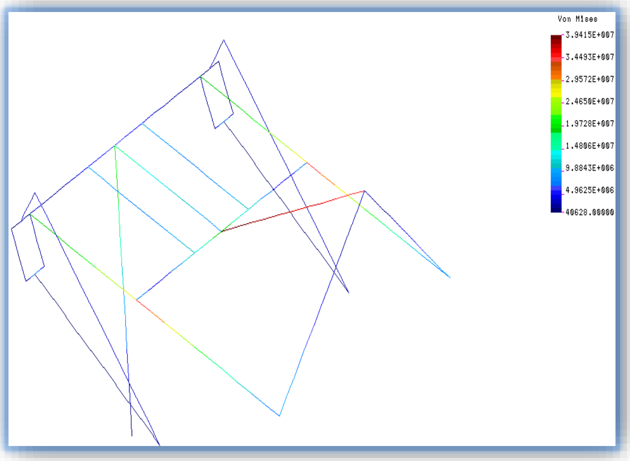

Figure 2. Map of equivalent stress in structural model of scarifier MAS-65 [N/m^2]

The main excitation source of resistance structure of soil deep loosening machine was identified as its working part which is the interface between resistance structure and soil. Therefore, in structural model, the excitation forces were directly applied on the beam simulating the machine's working part.

At the same time, 14 interest points situated on MAS-65 machine resistance structure were identified, in which strain gauges measuring the specific deformations registered during tests, were placed. A part of measuring points was empirically identified, being situated next to the welded joints between the resistance structure components. As it was used a structural model with unidimensional elements, the strain gauges measuring direction were along the components symmetry axis and where it was possible, an additional strain gauge perpendicular on this direction, was installed. In order to perform the tests in laboratory and in the field, a number of 14 LY11-6/350 strain gauges, manufactured by Hottinger company were applied, having the base of 6mm and resistance of 350 Ohmi, factor k=2.03 ±1.0%, transversal sensibility -0.1%. The amplifying modulus used for measuring the specific strains was of QuantumX 1615 type, with 16 amplifying channels. Results of measurements have been registered within ASCII-type files , representing by columns the time information and value of specific strain registered for each point.

In order to obtain the real stress spectrum of MAS-65 soil deep loosening machine, there were identified the machine usual operating conditions.

Thus, for taking the field samples, the following extreme working parameters were established:

- ≡ *Working depth 50 cm;*
- ≡ *Displacement speed 2 km/h;*
- ≡ *Working width 1.5 m*
- ≡ *Rotative speed at tractor's PTO: 540 rot/min*

After analyzing the seasonal operating conditions, an average productity of 150 ha/season, has been identified with an approx. transport distance of the machine of 10 km/day.

Experiments with MAS-65 machine were performed in INMA testing fields, using a 80 H.P. tractor.

RESULTS OF RESEARCH AND DISCUSSIONS

Strain gauges have registered the specific deformation on beams(bars) surface of machine resistance structure. As the structure permanently worked in elastic domain (resistance structure is made of OLT 45, with fatigue stress of 210 MPa), the specific strains turned to tensions according to Hooke law [2].

After processing the data recorded, the table 1 was obtained, where the values measured during work are statistically shown insurance of the air-seeds mixture homogenization.

The geometrical place of structure excitation points have been chosen being its working part and having mounted at its base the M5 gauge, so the signal registered by it is being used for buiding the packages of test signals in laboratory controlled regime. After applying the algorithm of counting the cycles of rainflow type and establishing the relevant characteristics, the data shown in table 2 and figure 3 were obtained. For the counting algorithm, the maximum domain of stress amplitude was divided in 12 intervals, for which the solicitation cycles were counted. Amplitudes shown in table 2 are related to average stress value of -57.392 MPa.

Table 1. The values measured during work

Gauge	Minimum value, MPa	Maximum, MPa	Average value, MPa	Mean square deviation, MPa	Kurt, MPa	Number of cycles/45 sec
M1	26.229	41.905	33.227	3.211	-0.727	1464
M2	-37.564	-8.543	-22.053	5.608	-0.483	1033
M3	-28.663	-11.514	-19.891	3.704	-1.058	1316
M4	-11.439	-1.466	-5.294	1.758	0.433	860
M5	-93.283	-36.913	-57.392	10.734	-0.244	907
M6	-6.758	-1.459	-3.584	1.073	-0.584	1178
M7	3.007	13.759	7.168	2.045	-0.618	1478
M8	10.188	28.61	16.355	3.424	0.283	758
M9	2.709	3.449	3.09	0.116	-0.043	1500
M10	3.351	8.38	6.408	0.707	1.829	1107
M11	-113.039	-44.772	-73.057	12.269	-0.479	1173
M12	5.574	14.094	9.782	1.831	-1.074	1213
M13	-14.154	-4.195	-7.783	1.524	0.838	733
M14	-44.806	-20.198	-28.572	4.718	-0.12	1298

Table 2. The relevant characteristics

In work, in fallow laid field, with vibration		
Number of cycles	Amplitudes	Frequences
133	2.349	1.333
151	4.698	1.511
107	7.046	1.067
127	9.395	1.267
109	11.744	1.089
131	14.093	1.311
69	16.441	0.689
51	18.79	0.511
20	21.139	0.2
7	23.488	0.067
2	25.836	0.022
0	28.185	0

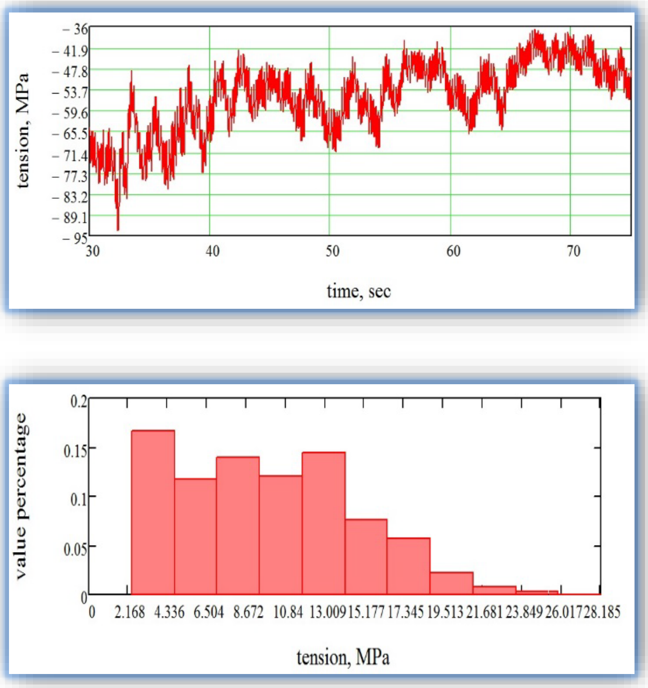

Figure 3. Time evolution of strain measured at machine working part and cycles distribution

Based on data obtained above testing signals packages have been built, which are shown in figure 4, as a sinusoidal sequence of different amplitudes and frequences, easy to reproduced in laboratory.

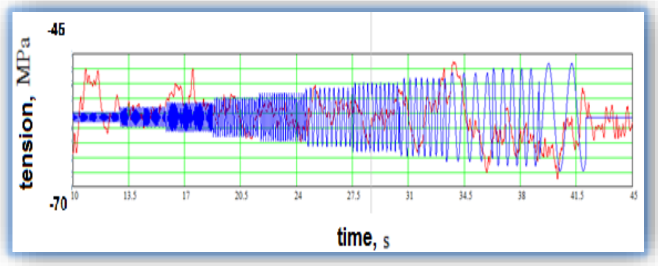

Figure 4 . Package of signals tested by hyropulse (with red -the original signal, with blue-the synthesized signal)

Signals for the command of hydraulic cylinder used for operating the resistance structure of the machine presented in figure 4 were introduced in a programme generated in programming graphical medium LabView , for physically generating as continous current levels, which served as referrence signal for hydraulic actuator used.

In figures 5 and 6 is presented the testing stand of MAS 65 machine resistance structure in simulated regime. It is made of device which simulates the three-points connecting to tractor, two props on which the supporting wheels and a hydraulic cylinder of 100kN, with 200 mm course, lean.

Figure 5 .Testing stand of deep soil loosening machine MAS 65, general view

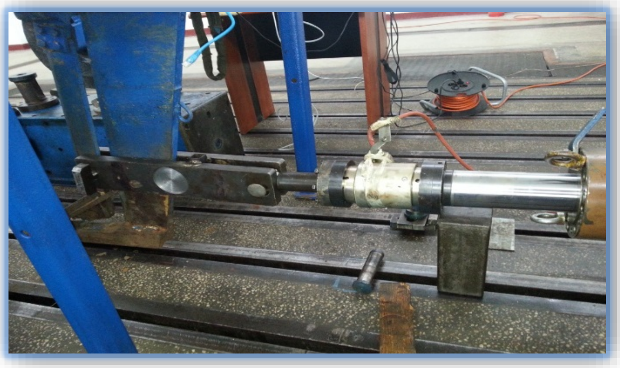

Figure 6 . Testing stand of deep soil loosening machine MAS 65, coupling detail of force cylinder to machine working part

The testing program package obtained for experimental measurements performed in fallow laid field was applied for evaluating the structure response to it. In order to cover the whole span of life of the machine, the synthetized testing program should be repeated 18000 times, which represents the field work of 150 ha.

Results obtained for M5 are shown in figure 7 where can be noticed 4 repetititions of testing program.

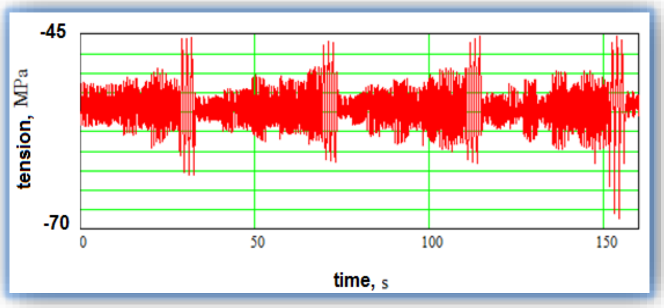

Figure 7. Voltage-time diagram obtained for M5 gauge, after applying the testing program

CONCLUSIONS

≡ *After analyzing the experimental data, it can be noticed that the strains appearing in measured points represent approximately half of the fatigue limit of material which the machine is made of, thus the material fatigue is very small. Though, the laboratory test should be done for validating a minimum span of life and verifying the quality of joints used.*

≡ *In order to obtain an optimal acceleration of tests, the testing packages simplified by eliminating the unsignificant cycles out of registered signals, in terms of material fatigue, should be achieved. This can be done by two methods: changing the characteristics of cycles counting algorithm or by directly removing them from testing programs by introducing certain passing thresholds.*

≡ *Continuing the researches, it will attempt to assess the share of field quality comparing to value of stress amplitudes registered, and if the case is, a combination of working packages will be achieved;*

≡ *The acceleration test will be chosen related to manufacturer requirements.*

≡ *The probable span of life of structure subjected to final testing packages will be checked by calculation;*

≡ *The time repartition of testing stages will be estimated;*

≡ *For achieving the tests in simulated and accelerated regime of a resistance structure, clear operating stages have to be respected: structural modeling, field tests and laboratory tests. When the structure stress spectrum is known,then the field test stage may be omitted. The engineer has to identify the leaning, fixing and excitation points of the structure so that the test does not determine abnormal behaviors of tested equipment. When these phenomena appear, then measures for diminishing them will be taken.*

≡ *Laboratory tests will not totally describe the field situation, because of constraints related to testing stand, testing equipment limitations, as well as the lack of certain factors (soil) or appropriate operating conditions (e.g.,speed, acceleration, elements in rotation movement). Though, they represent a valuable instrument for engineers due to precious information given in a short period of time on equipment structural integrity, its reliability, etc.*

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