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VALIDATION OF THE FEM-BASED STRESS ANALYSIS OF AN INNOVATIVE LOAD-BEARING STRUCTURE OF AIR-ASSISTED SEED DRILLS WITH ELECTRONIC SEEDING CONTROL

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Abstract: *The paper presents a validation of the FEM analyses based on the tensometric method. The model of the load-bearing frame used in the research has been described with detailed location of the tensometers. The analysis includes the development of the load characteristics based on the operating conditions data. The comparative analysis of the results has provided information related to the distribution of stresses in the frame and has confirmed the significance of the results of the simulation with an acceptable level of error. The authors specifically focused on the presentation of the implementation of loads for the case of field sowing.*

Keywords: Modeling, Load-bearing frame, FEM analysis, Tensometry.

1. Introduction

Reaching high efficiency of sowing as well as other farming activities is possible only through increasing of the cruising speed and the operating width of the machinery. Increasing the cruising speed is, however, limited by dynamic phenomena that deteriorate the quality of the machine operation, increase equipment loads and unit consumption of energy. Hence, in order to achieve high efficiency, machines of increasingly greater operating width are designed. With the operating width exceeding 3 meters, it is necessary to apply a folded frame system, widely used in large air-assisted seeding equipment (Rutkowski et al., 2005, Markowski et al., 2013).

The folded frames pose a variety of durability-related problems. In an experimental mechanical-pneumatic seed drill of the operating width of 4 m, developed by our team within the NR03-0021-06/2009 development project, a special frame of patented design was applied PL 395969 (2014). The drill coulter beam in this model is divided into two segments folded for transport in the horizontal plane on the side of the seeding drill (Kęska et al., 2012). Two beamed coulters are designed in such a manner that in each of them a pressure accumulator is located with a patented system of coulter pressure system PL 396735 (2013).

This type of design has not yet been applied in the seeding equipment, which is why before it was manufactured, its durability was precisely validated with the finite elements method. This method is currently the most widely applied and the most effective method of durability calculations of load-bearing machinery structures. It allows analyses of a variety of load-bearing structures of complex geometry subjected to loads in the form of concentrated forces, loads originating in reciprocal influence of components as well as the inertia forces and gravity (Chodurski et al., 2015, Szczepaniak, 2008, Łodygowski et al. 1994). When analyzing previous achievements related to the discussed design, the authors also dealt with the problem of principles of design and durability analysis of the equipment (Zienkiewicz & Taylor, 2005) using FEM and numerical analysis (Karayel et al., 2004, Kukiełka et al., 2014) with mathematical modeling and optimization (Keska et al., 2011, and Zastempowski et al., 2014).

Despite the fact the finite elements method is getting increasingly accurate, the results obtained from the simulation may include a significant level of error. The error may result from the adopted assumptions such as: loads or lack of accuracy in the development of the model etc. Therefore, there is a significant margin of uncertainty of the results of the calculations. This can be reduced by performing empirical

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research validating the calculations. When analyzing the works performed thus far, one may encounter a variety of methods validating the strength of the equipment: preliminary strength calculations already at the stage of conceptual design, simulation research utilizing mathematical modeling (Zastempowski et al., 2015) or tensometric measurements of physical objects.

The first stage fo the works were the FEM calcuations, for which e renowned I-DEAS software was utilized. Example stresses reduced according to the Huber von Mises hypothesis (Ellobody et al., 2014, Zienkiewicz et al., 2005) have been shown in Fig. 1.

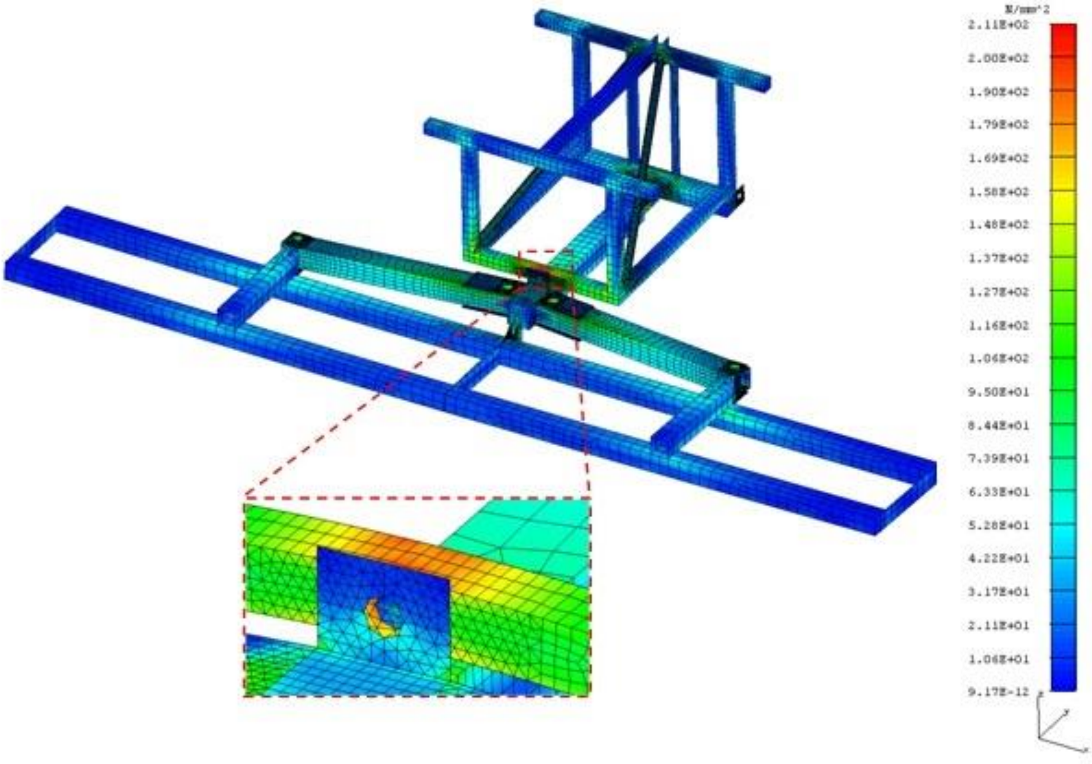

Fig. 1: Stresses reduced according to the Huber von Mises hypothesis.

In the field tests of the seeding equipment no visible damage or plastic deformations of the frame were observed.

In order to increase the level of confidence regarding the theoretical calculations, an empirical validation of the FEM calculations was carried out by measuring the actual frame deformations at selected points with the tensometric equipment.

2. Methods

The experimental research was carried out in the laboratory at Poznan University of Technology and under field conditions. The test seeding was performed in the spring of 2013 on a farm in Gowarzewo near Poznan on a sandy soil prepared for seeding of oat and wheat. Fig. 2 presents the seeding equipment a) on the test stand and b) under field tests.

Fig. 2: Tensometric measurements of the load-bearing frame: a) laboratory; b) field.

The tensometers were placed on the outer walls of the load-bearing frame profiles at six points most exposed to the load. A diagram of the location of the tensometers has been shown in Fig. 3. The points were selected based on previously performed FEM simulations on the original version of the frame (Gierz et al., 2011).

The measurements were carried out with an 8 channel Spider 8 by HBM connected with a portable computer via an RS232 cable. The measurement equipment was fitted on the seeder and powered from the power generator located in the front of the tractor serving the purpose of providing power to the seeder blower and all of its electronic components. For the operation of the tensometric bridges, proprietary software was used that supported HBM systems. The software was developed by Institute of Machines and Motor Vehicles of Poznan University of Technology.

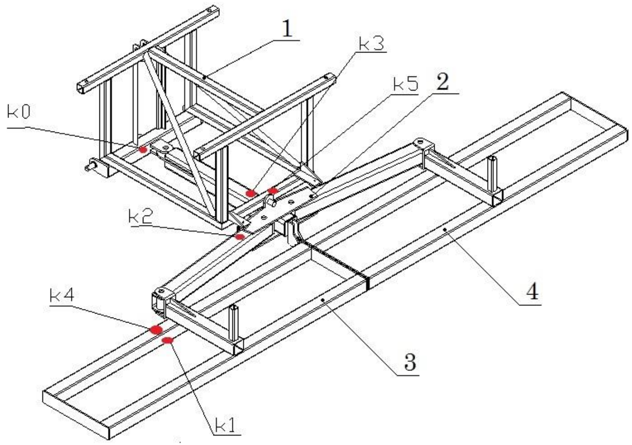

Fig. 3: The model support frame and the diagram of the arrangement of the strain gauges: 1 - backbone, 2 - main frame, 3 - right coulter frame, 4 - left coulter frame, k0 - k5 – another set of strain gauges.

3. Results

The result of the empirical research was the determination of the longitudinal deformations and stresses at 6 selected points of the load-bearing seeder frame. The loads exerted on the load-bearing seeder frame during the field test originated from the resistance of the coulters and their pneumatic force as well as the loads coming from the seed accumulators. As can be seen in Fig. 4, the loads coming from the weight of the components hung on the frame are very small and do not exceed 10 MPa for all 6 tensometers (transport). Significant loads, however, reaching 220 MPa for the most exposed fragment of the frame, occur during seeding. Significant stress of the frame was observed at point k2 and at point k4 of the beam where the clamping stresses reach 125 MPa. The stresses at the other points are low and are not hazardous for the equipment.

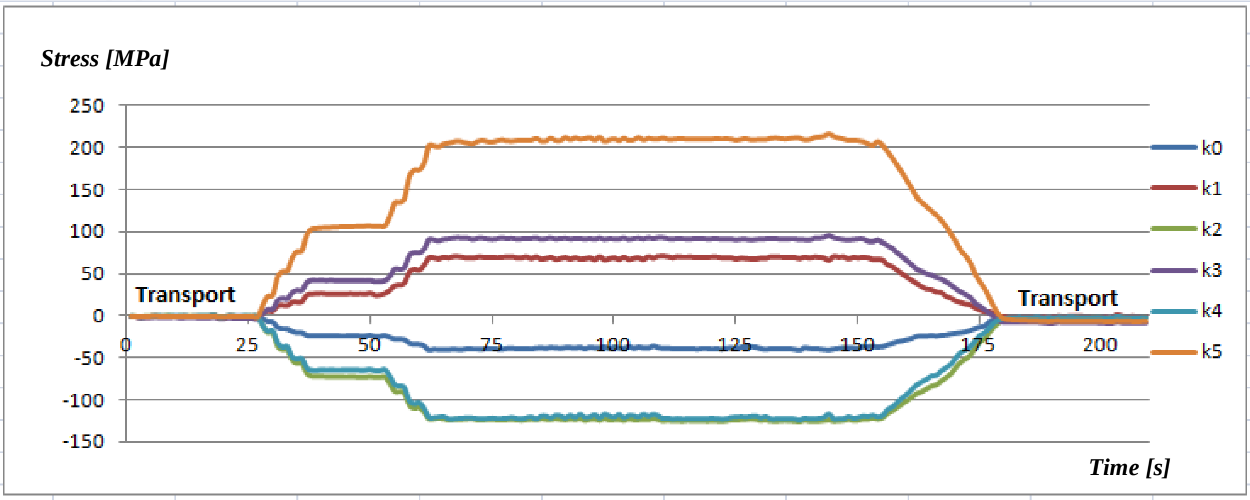

Fig. 4: Curves of the stresses for the load-bearing frame of a mechanical-pneumatic seeder in the operating and transport modes.

4. Conclusions

The presented results of stress measurements obtained with the tensometric method are very close to the analogical results obtained in the FEM simulations, which renders the presented mathematical model of the equipment and the loads exerted on the frame sufficiently adequate. The greatest difference between the results of the FEM calculations and the tensometric measurements remains in the range of 14 %. The analyses and measurements performed within this work have confirmed that the tested object has sufficient durability and has a significant stress reserve at many points, which enables its further optimization. The field tests have also confirmed the above. As the results indicate, none of the 6 measurement points recorded an excess of admissible stress in both the material and the welded joints. The results of the measurements will be of particular use in the optimization of the design of the seeder frame, and generally, for further improvement of seeders

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