Functionality Validation of New Three-point Hitch Dynamometer with Close Six Measuring Rods to Measure the Draft Requirement of Mounted Implements

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Abstract: This paper is focused on a new and special method used in agriculture, for observation of emerging forces between tractor and attachment connected through three-point hitch. These emerging forces are hard to capture by ordinary measuring device, so a special frame was designed for this measurement. This special frame consists of two triangular frames and these frames are connected together with six measuring rods. Connection of frames with rods is designed as fixed, so no motion is allowed between them. All measuring rods are made from steel with circular cross section and all rods are equipped with strain gauges to capture the tension and compression. These values are than recalculated and acting forces between tractor and attachment are obtained. FEM analysis of this frame was made additionally to find out adequate cross section of rods and for comparison if data from measurement correlate with data from analysis.

Keywords: dynamometer; three-point hitch; frame; tractor; rod; force, FEM analysis.

1 Introduction

Agriculture is one of the most important industry in the world. In agriculture and forestry, work machines integrated into the energy means are used by means of a three-point hitch. Knowledge of detailed force and moment effects acting on the machine or energy device during work is necessary for the creation of analyzes, knowledge know-how, verification of work or design of innovative new generation machines. Research and development in the field of agriculture and forestry focuses on the development of machines with higher working widths, the grouping of operations into one, variable tillage or new tillage technologies. The proposed measuring equipment should meet the above requirements for the development and verification of the work of new machines and technologies.

Main goal of this special measurement is to validate acting forces in rods during testing, compare these results with FEM analysis results and calculate calibration constant . In future, this dynamometer can help to optimize selection of tractor or the attachment for farmers. This could help them to enhance fuel consumption and also enhance a distribution of pressure from wheels acting on a ground. These forces acting between tractor and attachment are measured by a special frame which is designed only for this purpose. Tensile and compressive forces are measured by strain gauges placed on rods which connect two triangular frames.

2 Instrumentation

For this experiment is designed a special frame (see Fig. 1) which can be connected to a tractor with 200 horsepower and work machines by three-point hitch. This special frame is more complex than so far designed frames [1–3]. This frame consists of one welded front frame which connects to a tractor (see Fig. 1–1), one welded rear frame which connects to work machines (see Fig. 1–2) and six measuring rods (see Fig. 1–3). These frames are coupled together with measuring rods with spherical hinge at the end to limit bending

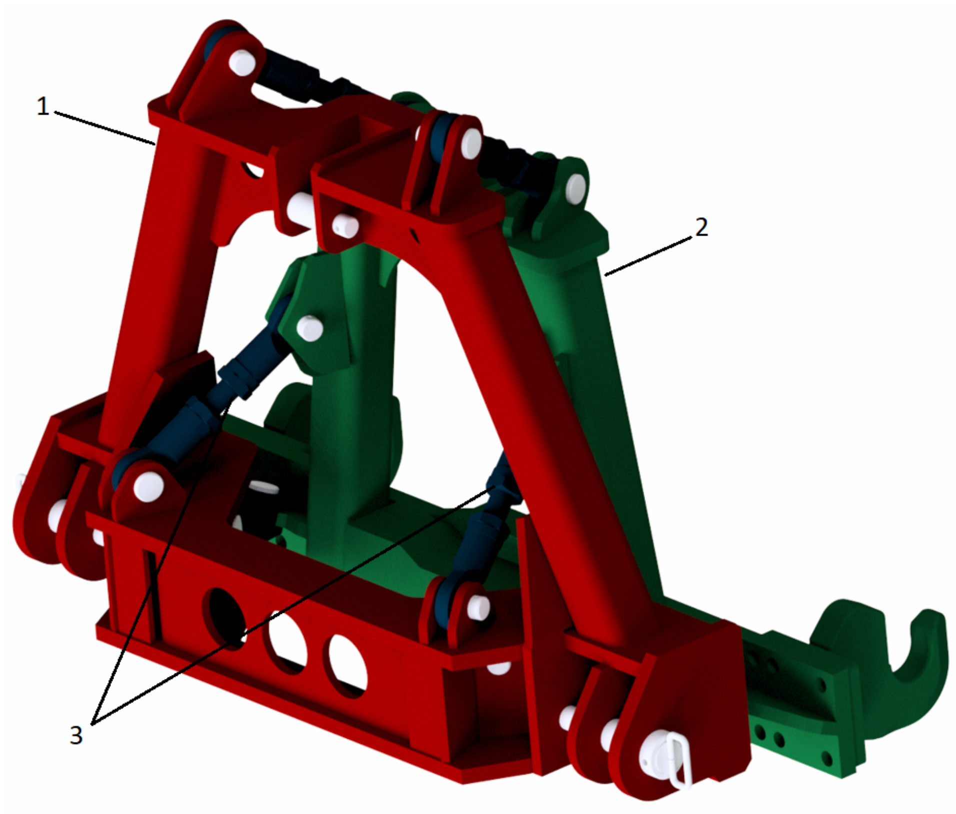

Fig. 1: Measuring frame (1 front frame, 2 rear frame, 3 measuring rods (6 pcs)).

moment. These measuring rods are similar as are used in tram [4]. Due to the rods, frames are fully fix with each other.

Measuring rod is an assembly which connects two welded frames. These rods consist of a rod with circular cross section, two spherical hinges, two hexagonal nuts, two strain gauges and a cover. For this measurement are used strain gauges with one measuring grid [5]. Two strain gauges are installed on a smooth surface of a rod with circular cross section with a diameter of 36 millimeters. Thanks to the strain gauges, the deformation of rod is measured and data are recalculated to forces. Because the dynamometer is designed as space rod system which can capture forces acting in more direction, it is made a FEM analysis to find out acting forces in rods to choose adequate diameter of the rod. Thanks to this is elected suitable strain gauges which are connected in quarter bridge and cables transfer data to measuring device. To protect these strain gauges from dust, protective cover is applied on them.

Fig. 2: Measuring rod.

3 Calibration of measuring rods

Fig. 3: Calibration of rods.

Before the measurement started, the frame is disassembled because it is necessary to calibrate all the measuring rods. This step is done to enhance accuracy of data obtained from the measurement. All rods are calibrated separately.

Firstly, one spherical hinge is connected to a forklift truck by rope to fix a rod in one position. On the second spherical hinge, a weight of 802 kilograms is attached to cause a deformation of a rod. Thanks to this deformation, the resistance of strain gauges differs from catalog data of strain gauges. All data are captured by measuring device.

All data are saved and then postprocessed to find out actual value of tension acting in a rod in comparison with real value from the weight. During the comparison is found out calibration constants which is used in next measurements to make measurement more accurate.

4 Validation of welded frame by FEM analysis

When calibration of measuring rods is done, the complementation of dynamometer starts. Thanks to the 3D model is determined an exact position of both frames with each other. To fix frames in one position with each other, measuring rods are used and are jointed by pins to both frames. First test of this special frame took place in laboratory of Research Institute of Agricultural Engineering, p.r.i.. The frame is fully fixed to a forklift truck and to simulate acting force on this frame in z axis, the weights are fastened to the middle part of the frame(see Fig. 4). Acting force is caused by weight of 160 and 450 kilograms. To make sure that this weight is correct, HBM measuring device force transducer U10M is attached between weight and measuring frame (see Fig. 4) [6]. In case that the force transducer U10M is connected between frame and weight, the connection differs from the situation without a force transducer U10M (see Fig. 4). Due to this weight acting in z axis are captured data of tension or compression forces in measuring rods. To validate, if these forces are appropriate or if the frame is welded and connected precisely, FEM analysis of the frame is made again. FEM analysis is made in RFEM software [7].

To validate forces emerging in rods, virtual model for FEM analysis is made (see Fig. 5). Model is supported on one side of a frame which is connected to tractor by three-point hitch and load is placed in same position as the weight of 160 and 450 kilograms is placed. Thanks to this model, acting forces in measuring rods are obtained.

Tab. 1: Validation of dynamometer.

	Rod	1	2	3	4	5	6
Load 160 [kg]	Real force [N]	855	436	-871	224	227	-1 293
	RFEM force [N]	726	726	-758	47	47	-758
Load 450 [kg]	Real force [N]	811	3 759	-2 771	-128	-47	-1 522
	RFEM force [N]	3 142	3 142	-2 900	-188	-188	-2 908

Values in Tab. 1 represent values in rods obtained during the first test where the frame is loaded by weight of 160 or 450 kilograms and values obtained by FEM analysis. As it can be seen, for both results, the tension and compression forces are in same rods, but values differ. FEM analysis shows that forces are symmetric in

(a) 160 kg

(b) 450 kg

Fig. 4: Testing of frame.

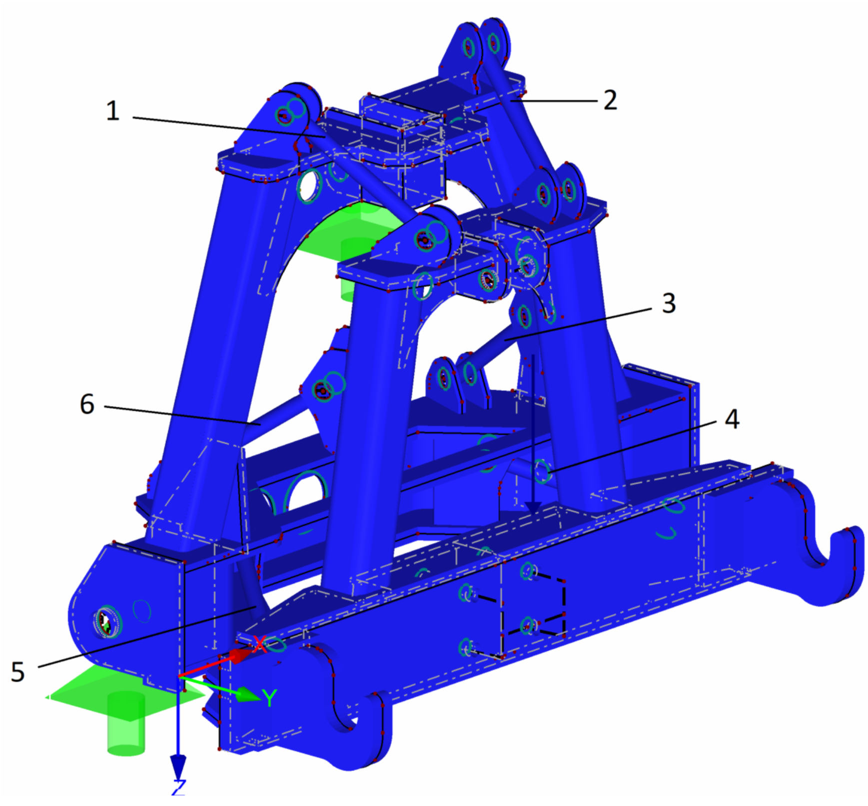

Fig. 5: Model in RFEM.

YZ plane. On the other hand, forces emerging in measuring rods are not symmetric. These results represent that there are some imperfections in the frame.

5 Conclusion

Thanks to this special frame connected between a tractor and agriculture attachment, acting forces in axis x, y and z to a tractor can be determined. This special frame consists of two welded frames which are connected by six measuring rods. These rods measure deformation of a rod by strain gauges and all data are recalculated by equations to a tension or compression force acting in a rod. Rods were firstly calibrated by weight to ensure that other measurement will be more accurate. After first measurement, the results were compared with FEM analysis to find out if this special dynamometer measure precisely. As the comparison was made, it was found out that results obtained from the measurement don't correlate with data from virtual model and it was impossible to determine calibration constant between real value and RFEM values. Thanks to this was made a conclusion that there is some imperfection on the frame. First imperfection can be caused by wrong positioning of two welded frames that are connected with the rods. Second imperfection can be caused by wrong welding of the frames themselves. Although there were found some differences between testing and FEM analysis, it can be said that this device can be tested in fields connected to a tractor after small inspection because dynamometer acts as it was expected.

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