Usage of multibody system in tractor hitch force effect analysis

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Abstract: The work is aimed on possibilities in usage of multibody systems in tractor hitch force effect analysis. Modern approach in tractor hitch force simulation is shown. First part of text describes the main principle of MBS. Then rear hitch of Zetor Fortera 140 HSX model creation is mentioned. Subsequently load is applied on computational model with usage of force load results obtained from previous measurement. Conclusion shows achieved results from hitch force effect analysis which were used as a source of force load on draft sensors.

Key-Words: MBS, tractor hitch, force load

Introduction

Three point hitch of the tractor consists of several links which are used as a coupling between tractors and implements. During field operations forces are generated in linkage. For force analysis, a measurement of the forces in each link is important. For monitoring of the forces, three point hitch dynamometer is required. Simply it's an ordinary tractor hitch fitted by strain gauges on each. From this kind of hitch forces output could be achieved for an analysis. Consequently, the force analysis could be realized with a usage of several methods. One of the most progressive and nowadays method is an application of a multibody system. This system is defined as a system consisting of a finite number of bodies and joints between them [1]. Analogous model contains the real mechanical system. Simulations are held under the real load conditions with the possibility of oscillations inclusion. For the mechanism creation, dimensions of real mechanism are necessary. Among the other necessary parameters force load belongs. Thus assembled model is ready for application. The analysis output gives a force and momentum load which in this case defines load resultant which acts directly on tractor.

Complete model of virtual three point hitch can be used for searching of proper adjustment of the hitch or for finding of tractor force load. Model described in this text serves as a computational model for force analysis of lower arms including draft sensors and adjustable spacer. Dimensions of three point hitch were obtained from Zetor Company. The outcome of this work is a force load located on to draft sensors for its calibration and sensor output examination.

Material and Methods

Three point hitch dynamometer

There are several designs of tractor hitch dynamometers. One of them is equipment which uses ordinary linkage mechanism called tractor hitch. Each link is fitted by calibrated load cells for a proper measurement of force during the field operations. There are at least five load cells on that kind of hitch. One is located on upper link, others ale placed on lower arms and rest of them on lift arms. This composition allows monitoring of draught forces and momentums generated from implement. Disadvantage of this approach is utilization only on one testing specimen of a tractor. There is a possibility of device reinstallation but only on tractors of the same brand and hitch category.

Another option is to develop central T-shaped box which can be telescopically adjusted and installed between tractor and implement. This approach brings the opportunity for universal solution. Still there is one major disadvantage. Geometric configuration of the rig is amended due to diameters of T-shaped box. Original connection is not respected [6].

Then there is an idea of usage of draft sensors as strain gauges for monitoring of draft force in lower arms. With a combination of upper link fitted with strain gauge and this kind of solution idea of universal tractor hitch dynamometer arises. There is necessity of draft sensors suitability investigation. Aim of this paper is draft sensor output examination with usage of multibody system application.

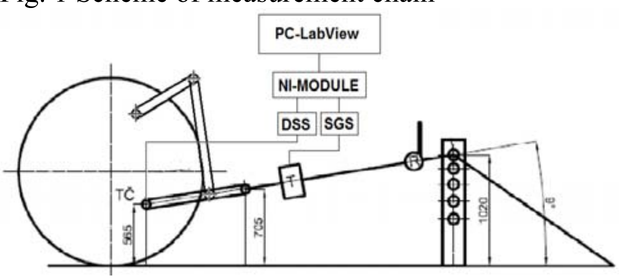
Draft sensor definition

Draft sensors takes the form of bearing pins located between tractor body and lower arms. Magneto elastic effect is used when the shear stresses occur at the bearings. Draft sensor operating principle consists of primary and secondary coil, primary and secondary pole face and steel sleeve. In case of non-load condition, a symmetrical magnetic field is formed between the poles by means of the primary coil. When the draft forces are introduced, there is a change in the originally isotropic magnetic properties. Subsequently, the magnetic field becomes asymmetrical. Magnetic potential difference occurs between the secondary poles. This causes a magnetic flux through the secondary circuit. Voltage is induced in the secondary coils. This voltage is proportional to the influencing force. Signal is amplified and rectified in an integrated evaluation circuit. [5]

Obtaining of force input

Measurement of force input was held on Zetor 140 HSX tractor which is equipped by three point hitch of III N category. Measurement chain composed of tractor itself, connection to the tractor hitch via adjustable spacer located between left and right lover arm, chain and ratchet mechanism with a strain gauge sensor for force generating and monitoring and National Instrument modular sensing control unit for monitoring of draft sensor signal and signal output from load cell. LabView evaluating program was used and proper program was designed. Measurement chain is plotted in figure 1. Ratchet mechanism was anchored to the top of fixed beam. Also supportive chain was connected to the same part of the beam and other end of the chain was anchored to the anchor embedded in the ground.

Fig. 1 Scheme of measurement chain

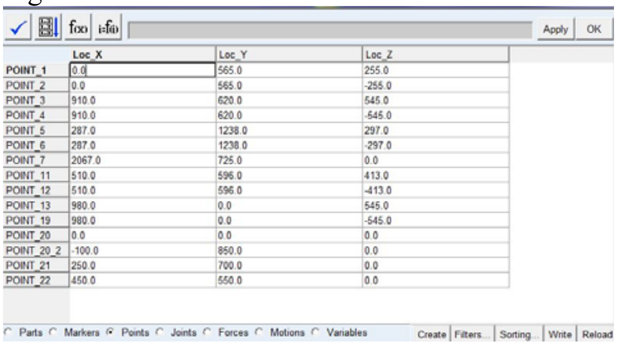


This measurement successfully provided input data for multibody system model. As can be seen from figure 1, specific geometric configuration was achieved. This was reflected in formation of the computational model.

MBS hitch preparation

Formation of a computational model was based on diameters and dimensions obtained from Zetor Company. Firstly points in space were defined. Point table was used for brief and fast definition and it's plotted in figure 2. This approach provided the possibility of geometric configuration change. Spatial points system was obtained and it was prepared for placement of bodies.

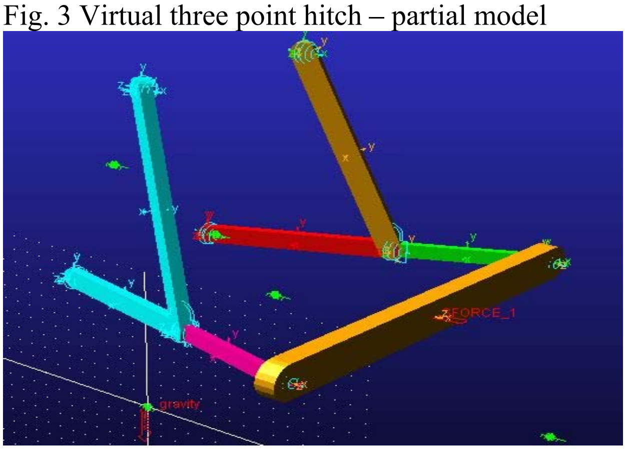
Fig. 2 Point table of tractor hitch



	Loc_X	Loc_Y	Loc_Z
POINT_1	0.0	565.0	255.0
POINT_2	0.0	565.0	-255.0
POINT_3	910.0	620.0	545.0
POINT_4	910.0	620.0	-545.0
POINT_5	287.0	1238.0	297.0
POINT_6	287.0	1238.0	-297.0
POINT_7	2067.0	725.0	0.0
POINT_11	510.0	596.0	413.0
POINT_12	510.0	596.0	-413.0
POINT_13	980.0	0.0	545.0
POINT_19	980.0	0.0	-545.0
POINT_20	0.0	0.0	0.0
POINT_20_2	-100.0	850.0	0.0
POINT_21	250.0	700.0	0.0
POINT_22	450.0	550.0	0.0

Each point represents beginning and ending position of link of tractor hitch. Subsequently connection between each point is defined. Body consists of a mass properties and type of used material. In this case construction steel defined by density, Young´s modulus and Poisson´s Ratio was specified. Next step in design of virtual three point hitch was clarification of constraints between each of the bodies. In connection between lower arms fixed and spherical joint was used. Lift arms are connected via spherical joints in the middle of lower arms. Subsequently adjustable spacer is connected via spherical joints at the end of each lower arm. Lower arms are fixed to the ground. Adjustable spacer is connected to the ends of lower arms via spherical joints. Due to spherical joint several degrees of freedom are available. Figure 3 represents the virtual three point hitch (partial model) in MB system.

Fig. 3 Virtual three point hitch – partial model



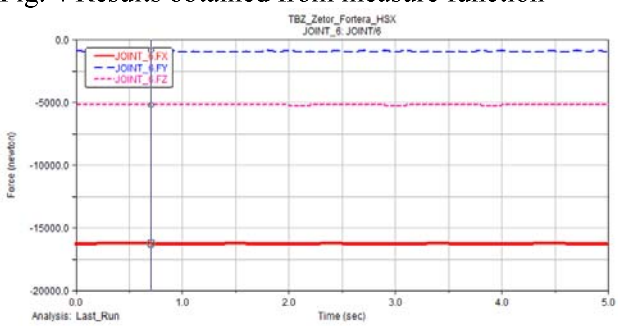
Another part of the virtual three point hitch completion was definition of force load. As can be seen from figure 3 force was applied in the middle of adjustable spacer and direction was specified by points which correspond with measurement chain from laboratory measurement plotted on figure 1. Ending point for a force direction was located on the top of fixed beam. This definition determined the direction of the force. As a source of force load previous draft measurement was used. From the output of strain gauge equivalent force was obtained. Correct value was placed into the computational model. Last part of preparation of the model was to define measure function. This function is a basic feature of mutlibody system software and the purpose of this is to clarify the examined variable. Measure function was located in left pin of lower arm where draft sensor is located. After this step force analysis could be successfully realized.

Results and Discussion

Force analysis of three point hitch

After the model creation and measure function placement on draft sensor location force analysis was realized. Results are shown in graph in figure 4. As can be seen force resultant is divided to X,Y and Z axis. Major draft force is located in X axis direction of measure function. Coordinate system of measure function is orientated with it X axis longitudinally with tractor axis with direction pointing forward from the tractor. Resultant force magnitude reached mean value of -16235 N. Force analysis is shown with maximum force obtained from strain gauge. Various load steps were implemented and results were evaluated for all load cases.

Fig. 4 Results obtained from measure function

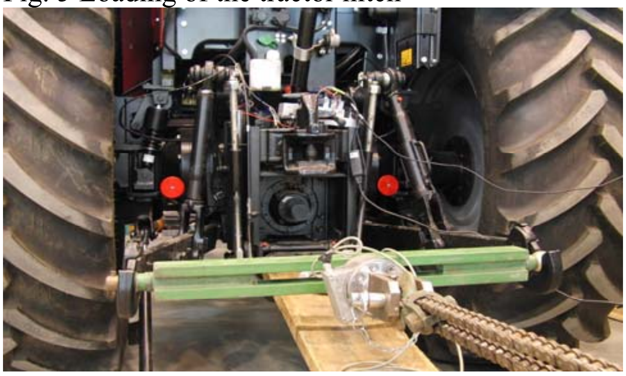


Determination of the resultant force is possible in any location of the virtual hitch. This can be used in case of largest load searching or in optimization of upper link connecting position to the lower arms in design of tractor hitch. In this case the resultant force was used for definition of load for draft sensor.

Force resultant on draft sensor

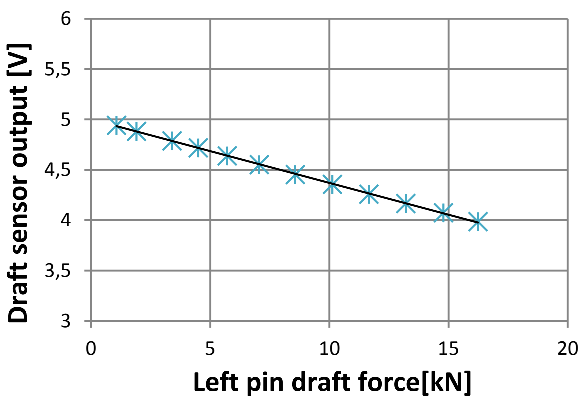
Force load generated by ratchet mechanism was gradually increased from 0 to 32,587 kN. Main goal of the measurement was to observe the output from draft sensor. Due to load character, force load analysis was necessary to run. With the maintaining of symmetry initial assumption was to divide the main force obtained from strain gauge in half. With respect of lift arms connection, force analysis was realized with usage of MB system approach. Figure 5 shows the principle of tractor hitch force loading. Chain is connected to strain gauge which represents load force. Adjustable spacer is located between connecting points of lower arms. As can be seen lift arms are connected to the lower arms. This approach has been taken into account during the computational model design.

Fig. 5 Loading of the tractor hitch



From measured values of draft sensor voltage output and draft force computed with usage of force analysis in multibody system computational model dependency was obtained and it is plotted in figure 6. Dependency between left pin draft force and draft sensor output shows linearity.

Fig. 6 Dependency between force and voltage output of draft sensor



This brief review shows possibility of usage of modern approach in force resultant analysis.

Conclusion

The work is aimed on possibility of multibody system usage in force resultant analysis. With force input obtained from previous measurement the force load on draft sensor was calculated. This allowed finding out dependency between voltage output and force load of draft sensor. These results will be used in design of three point hitch dynamometer.

This is one of the possibilities in usage of multibody system. Another option is to search for largest load in this kind of linkage mechanism or in optimization of upper link connecting position to the lower arms in design of tractor hitch. Also complete model of virtual three point hitch have got lot of opportunities like searching for path generation of hitch points [4]. During the measurement modern opportunities were interconnected. This approach indicates brief and fast solution for solving problems of a similar type.

Acknowledgement

This study was supported and financed by the internal grant agency of the Mendel University in Brno – Faculty of Agronomy, No. IP 15/2014.

The research has been supported by the project TP 4/2014; Analysis of degradation processes of modern materials used in agricultural technology; financed by IGA AF MENDELU.

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