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STRAIN GAUGE VERIFICATION OF NUMERICAL ANALYSIS OF FORAGE TRAILER SUPPORTING STRUCTURE

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Abstract

The paper presents experimental verification of forage trailer supporting structure. Conditions for performance of strain gauge measurements of stresses at selected frame points were presented. Results of strain gage measurements were compared with results of calculations by method of complete elements. Dozen percentage compliance of results of numerical calculations and experimental measurements was obtained. Maximum stresses were specified with accuracy of ca.2%. During measurements asymmetrical distribution of load in the frame was stated.

Keywords: *agricultural machinery, forage trailers, strain gauge measurements, numerical analyses*

1. Introduction

At the stage of constructional works numerical analyses are conducted in order to evaluate structure. Such tests are mostly performed with the finite elements method FEM. Results, obtained during analysis, refer to boundary conditions specified for FEM and in particular they assume that tested objects did not indicate any process defects and material they are made of met continuum criterion continuum and criterion of isotropy of mechanical properties [3]. Thus, distribution of stresses in real constructional elements can differ from values set numerically. In order to estimate the scale of such differences, experimental tests are performed on stress state in constructional elements. One of most widely used measurement methods in this respect is resistance strain gauge measurement. [2].

The paper undertakes verification tests of numerical analyses of the structure of modified supporting frame of forage trailer. For the frame a discrete model of geometric shape was prepared and bonduary conditions were proposed. [1]. As a result of solving FEM issue, distributions of deflections and stresses were set. Based upon distributions of stresses specified in the paper [1] characteristic points of supporting frame were specified at which strain gauge measurements were performed.

2. Object of tests

The object of tests was supporting frame of a low forage trailer EVO Fig. 1. Geometric form of tested trailer was described in detail in the paper [1]. Main supporting beams are made of closed profiles x160. The frame is made of S235JR steel. On two rear holders and one front holder. (Fig. 1) basket filled with feed is installed. Moreover a screw for infeed mixing is installed in the

basket. Frame load results from the mass of the very basket and its filling. The frame is supported on two supports located in rear part at height of head of supporting beam. Rear supports are used for mounting of axis with wheels. Trailing hook acts as the front support.

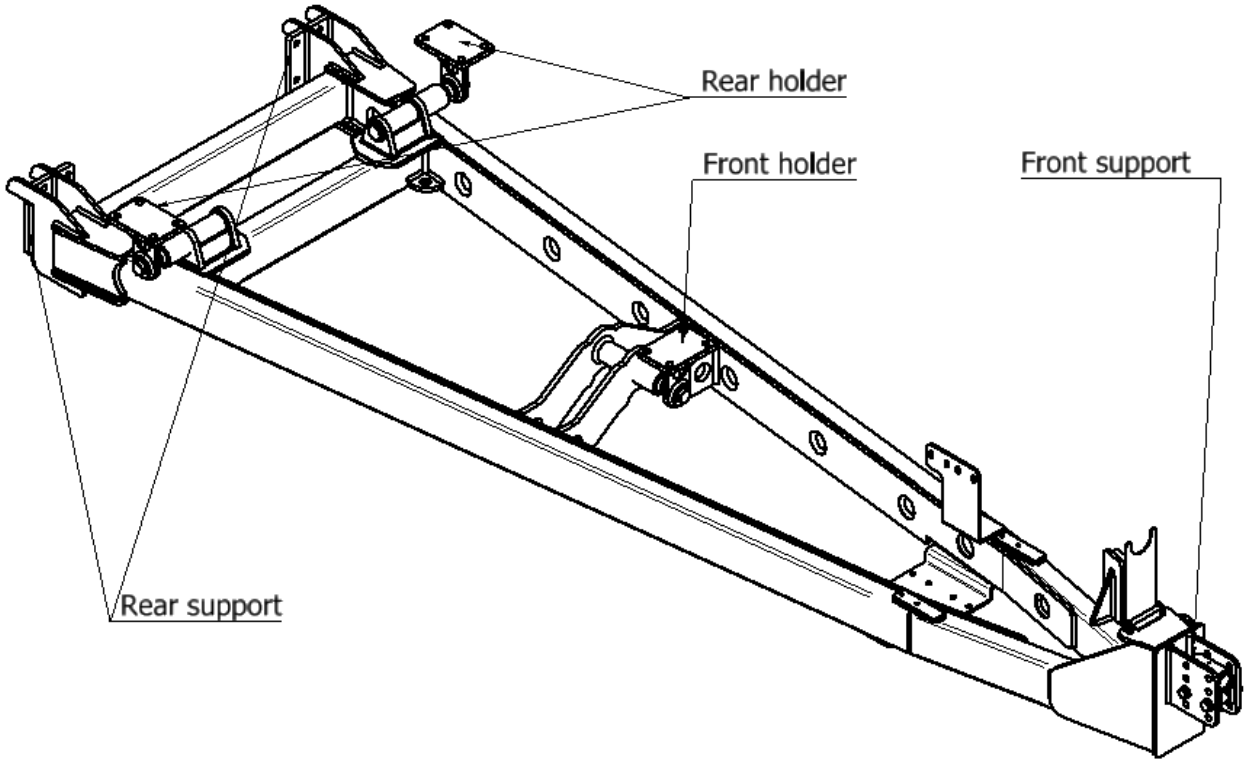

Fig. 1. Object of tests

3. Conditions for performance of tests

Based upon results of numerical analyses, characteristic points on the surface of supporting beam were indicated and strain gauge measurements were performed at these points. The scheme of numbering of strain gauges is presented at Fig. 2.

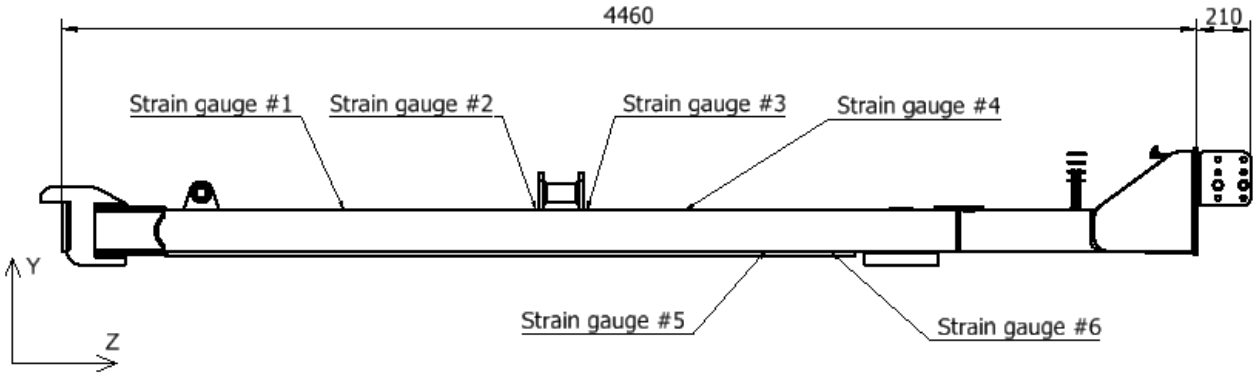

Fig. 2. Scheme of numbering of strain gauges

On upper shelf of right beam there are strain gauges located at locations no 1 to 4. on lower shelf of right beam there are strain gauges located at locations no 5and 6. In addition, on left beam there are strain gauges located at locations no 3 and 4. The system located on right beam was specified as strain gauge no 3 and on left beam as no 3L. Similar convention was adopted for labelling of strain gauges no 4. Location of strain gauges no 1 to 4 in relation to component elements of frame is presented at Fig. 3.

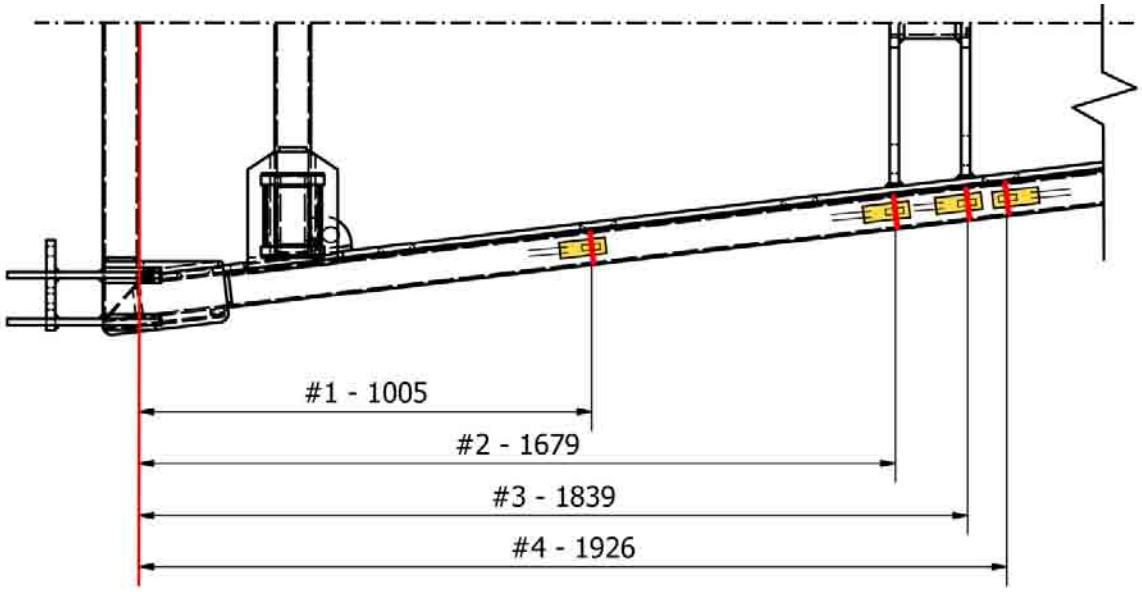

Fig. 3. Scheme of location of strain gauges 1 to 4

Location of strain gauges no 5 and 6 in relation to component elements of frame is presented at Fig. 4.

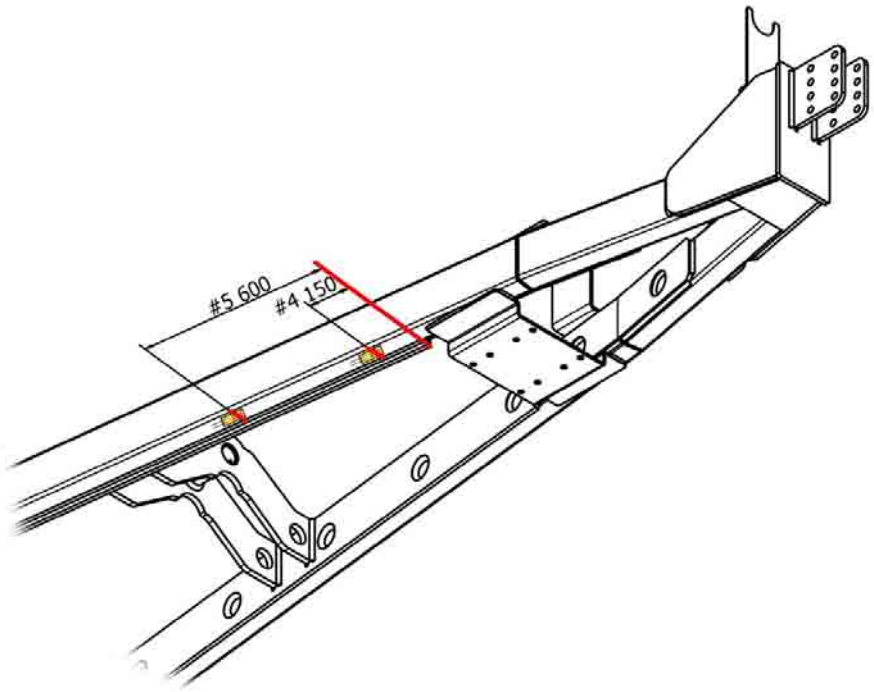

Fig. 4. Scheme of location of strain gauges 5 and 6

Measurements were performed on a complete forage trailer (Fig. 5). Load was applied to forage basket and measured with a scale included in the trailer equipment. Strain gauge tests were performed with 8 channel universal strain gauge bridge made by National Instruments – NI SCXI-1520 and USB module for data acquisition with 13bits resolution and sampling frequency of 200 kS/s – NI SCXI-1600. Strain gauges made by HBM – 1-LY11-6/120-3-3m were used, with measurement base of 6 mm and fast drying glue 1-Z70. Data was recorded with NI LabVIEW SignalExpress software.

Fig. 5. Conditions for performance of strain gauge measurements

4. Results of strain gauge measurements

Results of strain gauge measurements and their corresponding values of stresses set numerically for load of 2 000kg are presented in table 3, for load of 3 350kg in table 4 and for load of 2 000kg in table 5. Percentage error of measurements is specified from dependencies (1).

$$\delta = \left|\frac{\sigma_{FEM}-\sigma_{gauge}}{\sigma_{FEM}}\right| * 100\% \quad (1)$$

Table. 3. Stresses set strain gauge and numerically for load of 2000kg

Strain gauge	Set no 1			Set no 2		
	FEM [MPa]	Measuremen [MPa]	δ [%]	FEM [MPa]	Measuremen [MPa]	δ [%]
1	-26.89	-21.0	21.9	-26.89	-22.5	16.3
2	-33.37	-26.0	22.1	-33.37	-27.0	19.1
3	-34.60	-30.0	13.3	-34.60	-30.0	13.3
3L	-34.60	-32.5	6.1	-34.60	-32.5	6.1
4	-33.37	-35.0	4.9	-33.37	-34.0	1.9
4L	-33.37	-35.0	4.9	-33.37	-36.0	7.9
5	28.24	27.5	2.6	28.24	27.5	2.6
6	23.64	22.5	4.8	23.64	22.5	4.8

Table. 4. Stresses set strain gauge and numerically for load of 3350kg

Strain gauge	Set no 3			Set no 4		
	FEM [MPa]	Measuremen [MPa]	δ [%]	FEM [MPa]	Measuremen [MPa]	δ [%]
1	-45.04	-36.0	20.1	-45.04	-36.0	20.1
2	-55.90	-41.5	25.8	-55.90	-42.0	24.9
3	-57.96	-46.0	20.6	-57.96	-47.0	18.9
3L	-57.96	-52.0	10.3	-57.96	-52.0	10.3
4	-55.90	-55.0	1.6	-55.90	-55.0	1.6
4L	-55.90	-57.0	2.0	-55.90	-57.0	2.0
5	47.30	46.0	2.8	47.30	46.0	2.8
6	39.59	35.0	11.6	39.59	35.0	11.6

Table. 5. Stresses set strain gauge and numerically for load of 2000kg

Strain gauge	Set no 5			Set no 6		
	FEM [MPa]	Measuremen [MPa]	δ [%]	FEM [MPa]	Measuremen [MPa]	δ [%]
1	-26.89	-22.5	16.3	-26.89	-22.5	16.3
2	-33.37	-26.0	22.1	-33.37	-26.0	22.1
3	-34.60	-29.0	16.2	-34.60	-29.5	14.7
3L	-34.60	-32.0	7.5	-34.60	-32.0	7.5
4	-33.37	-34.0	1.9	-33.37	-34.0	1.9
4L	-33.37	-35.0	4.9	-33.37	-36.0	7.9
5	28.24	28.0	0.9	28.24	28.0	0.9
6	23.64	22.5	4.8	23.64	22.5	4.8

For each tested levels of load two series of measurements were performed. Averaged values of percentage error at load level for individual strain gauges are presented in the form of a graph at Fig. 6.

Comparison of measurement error for strain gauges no 3 and 4 indicates asymmetrical distribution of load on the frame. Stresses set at selected points located on right frame side (Fig 4) reach higher values than analogical stresses at left frame side. This can be due to inaccuracy in structure engineering of the welded frame. Maximum stresses each time were measured in strain gauges no 4 and 4L. values read on these strain gauges at maximum load of 3350kg are characterised with low value of error, ca. 2%. Maximum error for the whole analysis does not exceed dozen of percentage. Higher error values occur at the side of overestimation and lower at

the side of underestimation of numerically set stresses. Along with the load increase, underestimation error of stresses decreases.

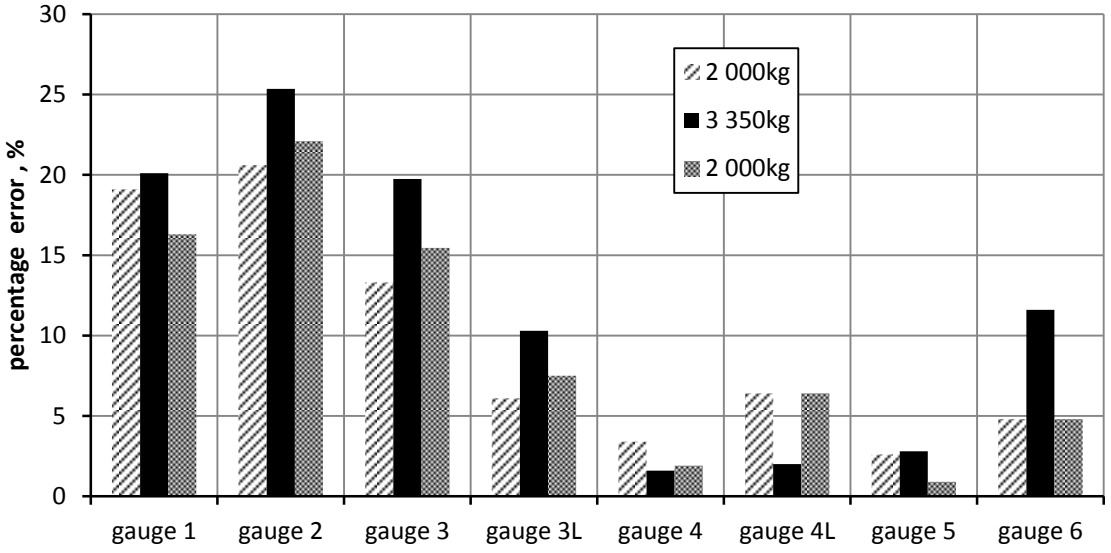

Fig. 6. A set off errors in strain gauge measurements

5. Summary

The paper presents conditions for performance and results of strain gauge tests of forage trailer supporting structure. Measurement results were compared with results of numerical calculations FEM. Good compliance of experimentally set stresses with the ones obtained from FEM calculations was achieved. FEM analyses error does not exceed dozen of percentage in the whole measurement range. For maximum measured stress values FEM analyses error does not exceed several of percentage. During measurements asymmetrical distribution of load in supporting structure was observed.

References

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