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Design, Fabrication, and Testing of a Hay Bale Trailer

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Abstract: The purpose of this study was to design and construct a specific pilot trailer to be attached to a baler so that the packs in the packing process can be thrown on the trailer instead of ground. It will be resulted to saving time and cost. To design the device, using some engineering modeling softwares, the model of the intended trailer was designed and then with aid of some analysis softwares, the loads and boundary conditions on the model were inserted. Frame as the most important and sensitive part of trailer was analyzed in the ANSYS software and the maximum value of tensions were obtained to be about 110 MPa. Regarding the obtained results, the safety factor was between 2 to 4 in the sensitive parts and the trailing force of the trailer at the critical condition of load and ground was also obtained to be 4000N. In the intended model, the highest tensions were in the places where the frame trailer is connected to the body and in bent parts of the frame and carrier of the wheels as well. The reinforcement of these sections at the time of manufacturing will result in the required safety. Following the phase of model analysis of the trailer and being assured of safety, the device was fabricated in compliance with the dimensions proportional to those of the model analysis phase.

Key words: Agricultural machinery, draft force, mechanical analysis, transportation

INTRODUCTION

In the world today, hay is produced in every country. Millions of tons of hay are harvested each year. Alfalfa is the most common hay crop. In order to reduce labor requirements and save time, a simple machine for hauling hay bales from the field to storage bins is needed. In usual it takes about 90 $min.ha^{-1}$. and need at least 4 trailers, each trailer has 80 bales capacity and 3 labors are needed, for loading and unloading at the storage site, without attaching a trailer to a baler. The simplest method is to add an extension chute to the bale chamber of baler and pull a wagon behind the baler. A labor then stacks the bales on the wagon bed. This vehicle has drag-chain deck for unloading to carry bales from the deck to ground. It has a hydraulic ram in order to decline the deck.

Literature review: A method for complete vehicle analysis based on Finite Element (FE) technique was presented. This method was used for analysis of complete vehicle features such as vehicle dynamics and durability (Johansson and Gustafson, 2002). Stress analysis of a truck chassis with riveted joints was performed by using FEM. Determination of the stresses of a truck chassis before manufacturing is important due to the design improvement (Karaoglu and Lay, 2001). A newly developed adhesively bonded hub/shaft joint, that allows curing the adhesive at defined high hydrostatic pressure, is presented. Shear strengths of the adhesive are determined after curing by quasi- statical tension and torsion of the joints as well as by fatigue tests for two different types of adhesives and two combinations of adherent materials (Mengel *et al*., 2007). The employment of the FE-method in conceptual and detail design of a secondary deck platform for trailer bodies was presented. The main objective of the project is to design a versatile, light and cheap secondary deck. The FE-method was used in order to gain fair structural analysis data (Hogberg, 2001). Effects of trailer speed on existed aerodynamic forces were studied. By aerodynamic pressure distribution, coefficients of draft and torque function of wind speed were determined (Haloy, 2003). Effects of trailer vibration on packages in the trailer and its damages were studied (Johnston and Singh, 2005). One model for tractor with trailer stability was presented. In this study, effects of tractor travel speed and tractor with trailer size on stability were studied (Hales and Crolla, 2003). Effect of pattern type on bale stability was studied by Sweatman and Christopher (2003). According to their results, Alternative pattern was more stable than simple pattern.

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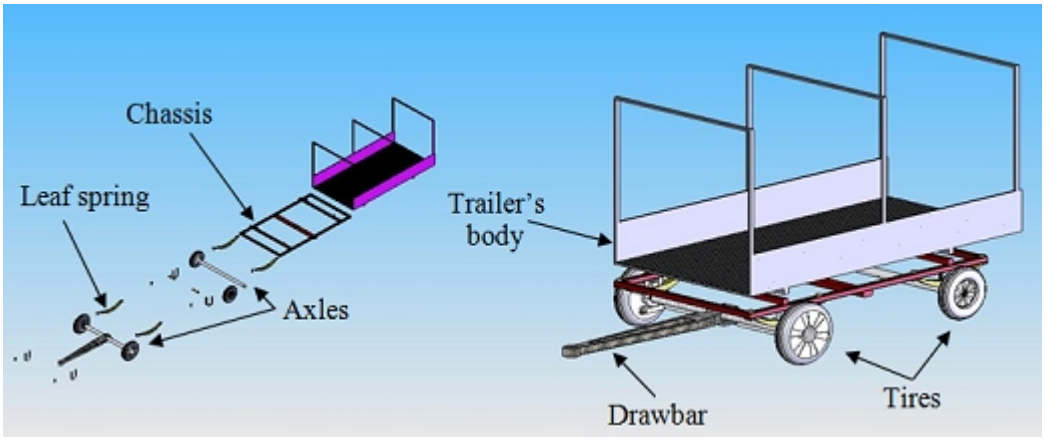

Fig. 1: Trailer model with components

Objectives: Gathering, lifting and transporting the hay bales from the farm to the agricultural storage bins is a time consuming and an expensive task. A hay trailer can solve this problem. Hence, this study focused on the design, analysis and fabrication of a hay trailer.

MATERIALS AND METHODS

This study was conducted in the Razi University of Kermanshah, Iran, during September 2007 to June 2009. The following steps were carried out under this study.

Modeling: The machine and its elements were modeled by computer. By considering the recommended sizes, elements were modeled in PART area of SOLID WORKS 2005 software. Then in ASSEMBLY area the parts were assembled by SUBASSEMBLY, and two-dimensional drawings were made in DRAWING area. Main parts of trailer were chassis, trailer's body, drawbar, leaf springs, hydraulic ram, axles, and tires (Fig. 1).

In order to design and construct the trailer, some parameters were needed as follows:

Specifications of bale: Experimental bales were alfalfa with 15-20% d.b. moisture content. Mean weight was 24 kg with 95*45*35 cm dimensions (bale chamber size). There are 16 bales in bed of the wagon with six rows in height. This wagon carries bales up to 24 kg apiece. So, total weight is about 22602 N. Approximately with a labor, total weight has considered as 24 KN. Dimension of the bed of wagon is 4*2 m therefore distributed load is 3000 Pa.

Measuring of some physical attributes of bale (material was alfalfa): Density and mass of 10 bales were determined as bale's physical attributes. Mean value of this attributes were 18.86 kg and 115.4 kg/m^3 for mass and density, respectively.

Table 1: Physical and mechanical properties of steel AISI 1018

Specification	Values
Modulus of elasticity	200 GPa
Poisson's ratio	0.3
Density	7850 Kg/m^3
Yield strength	250 MPa
Compressive strength	250 MPa
Tensile strength	460 Mpa

Analysis of stress and strain: After modeling of components in SOLID WORKS, mechanical analysis of these components was carried out using ANSYS software. Force (weight of bales and wagon parts) was inserted on components by considering boundary conditions and physical and mechanical properties of construction material (Table 1). Weight of components was computed by the software, depends on density and geometrical model.

Fabrication: After mechanical analysis of components by ANSYS, primary trailer was fabricated, as shown in Fig. 2.

Determining draft between trailer and baler: Draft and its variations in various loadings and different conditions of farm9land were determined by load cell BOUNGSHING model and it's data acquisition unit (Fig. 3 and 4).

Different conditions of trailer load were as follows:

- No load trailer
- Medium load trailer (loaded by chaff)
- Maximum load trailer (loaded by alfalfa)

Fig. 2: Fabrication the trailer

Fig. 3: Data acquisition system used in the draft test

Different conditions of farmland were as follows:

- Trailer on even farmland
- Trailer on uneven farmland

Method of the draft test is shown in Fig. 4, which in that the load cell was located between tractor and trailer.

RESULTS AND DISCUSSION

Chassis analysis: Results of chassis mechanical analysis are shown in Table 2 and Fig. 5. Accepted safety factor was applied as to be three that was appropriated for designing. In order to construct the trailer, a 90 mm section profile was selected.

Fig. 4: Method of draft test

Table 2: Comparison of 4 samples of profiles for analyzing and construction

No. of sample	Profile section, mm	Max.stress (Von Mises), Mpa	Factor of safety
1	70	217.9	1.613
2	80	131.5	2.674
3	90	110.2	3.190
4	100	103.3	3.403

Mean stress safety: Safety factor was obtained; based on mean stress in model, yield strength, and construction material. This shows that the model is suit and safe. It is better to design the model with fatigue loads. These loads were chosen by Godman, Gerber and Souderberg criterions (Shigley and Mischke , 1989) (Fig. 6).

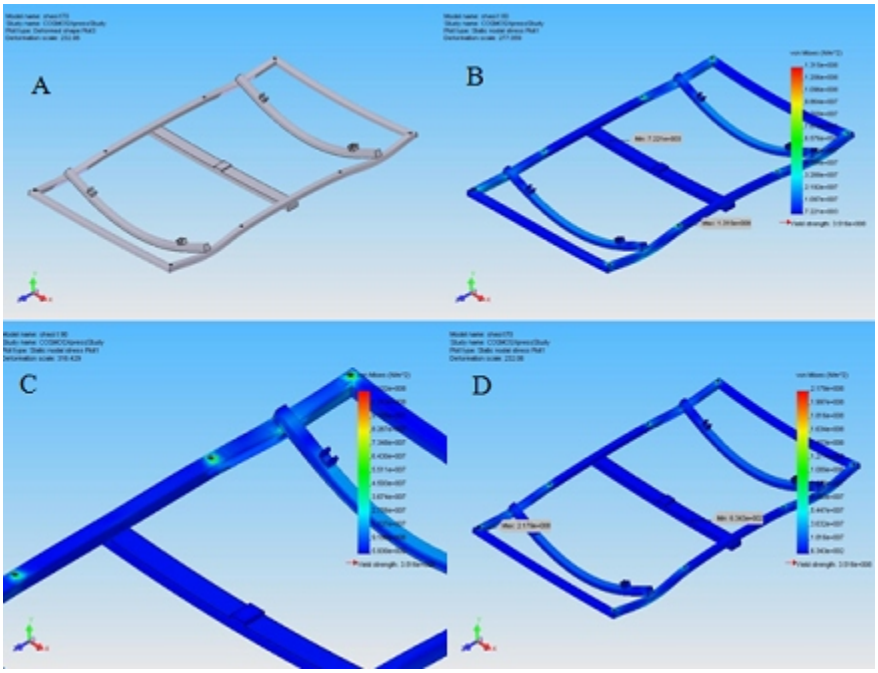

Fig. 5: Stress in 4 samples profile; A: sample 1, B: sample 2, C: sample 3, D: sample 4

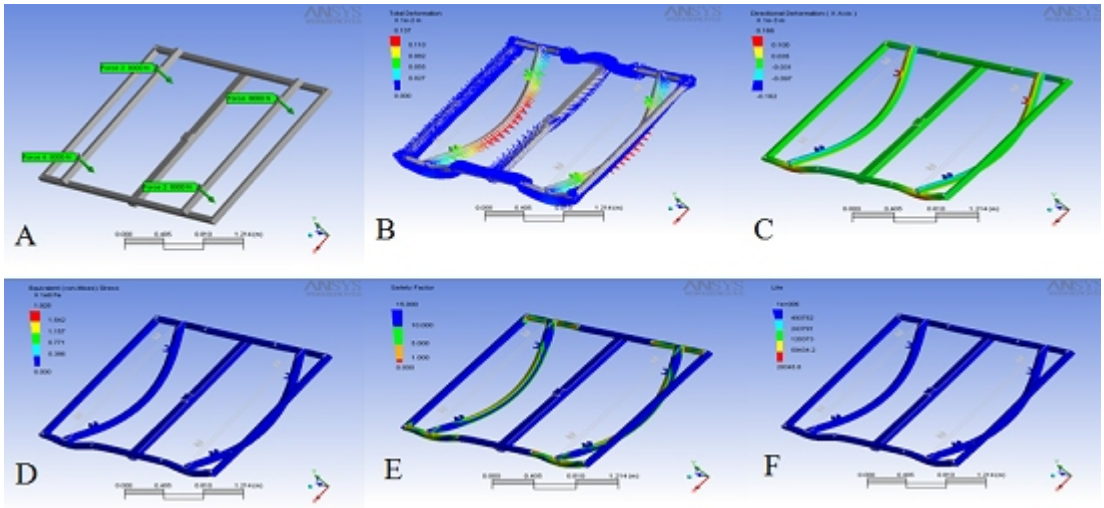

Fig. 6: A. model with exerted forces, B. total deformation, C. directional deformation contours, D. equivalent stress, E. safety factor, F. life

These results show that maximum stress is happened in places of frame having welding. Thus, in order to reinforce this welding in fatigue loading, grinding of welding is necessary. Maximum deformation of frame was occurred in the two minor bar, and to avoid from deform of frame, using an axial bar in the middle of frame must be favorable.

Draft force: Variation of draft forces at different conditions of even farm land and uneven farm land was significant. Draft force is going to increase, by loading on trailer. But, at even farmland conditions, variation of load on trailer was not significant (Fig. 7-9).

CONCLUSION

In this research in order to construct a hay trailer, modeling and analysis of machine's components were carried out at first. Analysis showed that maximum stressand maximum deformation obtained in the chassis

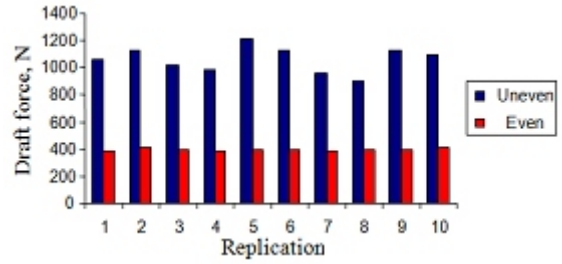

Fig. 7: The relationship between draft forces at no load

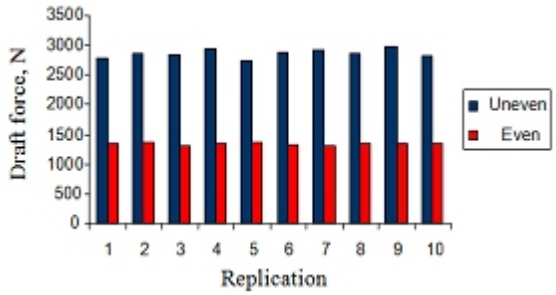

Fig. 8: The relationship between draft forces at medium load

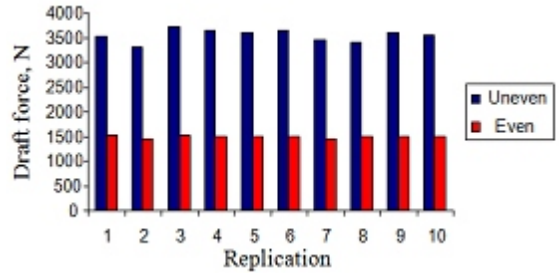

Fig. 9: The relationship between draft forces at maximum load

of trailer. Then the optimal model for chassis was selected. After fabrication of trailer, some tests were carried out on the trailer. Results showed that maximum draft force happened when trailer is working in the uneven land with maximum loading.

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