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HYDRAULIC FRONTAL LOADER MECHANISM ATTACHED TO AN AGRICULTURAL TRACTOR

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ABSTRACT

Many mounting possibilities have been developed in time for a wide range of auxiliary equipment to the basic agricultural tractor that has become in this way a universal agricultural machine. Thereby, using a single basic machine, multiple activities are accomplished related to soil tillage but also other farm agricultural activities. This paper performs a functional description for a piece of hydraulic frontal loader equipment that can be attached to an agricultural tractor model, by means of which various loading activities of grain, construction aggregates or other material types can be accomplished using the agricultural tractor. A three-dimensional assembly model has been developed for the frontal loader equipment which was structurally analyzed in order to emphasize the deformations arising from the enforcement efforts that can occur during loading operations.

KEYWORDS: hydraulic actuation, frontal loader, auxiliary equipment, agricultural tractor, structural analysis

1. INTRODUCTION

The agricultural machines are considered as part of mechanical equipment category capable to perform the mechanized works in farmlands**.**

The continuous evolution of agricultural equipment mainly aims at the development of specific technological processes, constantly increasing the operation speed and also increasing engine power.

The agricultural tractor is the most important basic machine used in agriculture, for the planning and preparing the field for crop establishment.

The agricultural tractor performs soil preparation, fertilizers distribution on the ground, planting seeds and conducting plant protection treatments through multiple devices that can be attached to the base machine.

One of the auxiliary equipment that can be attached to the agricultural tractor is represented by a frontal loader assembly through which different works can be performed regarding grain, granular materials, or construction aggregates loading, depending on the specific needs arising within the farm.

This equipment can be easily mounted on the tractor, when necessary, without the need for endowment with a specialized frontal loading machine to achieve these work operations.

The auxiliary equipment presents a relatively simple construction, being hydraulically operated and the working body type can be: simple bucket, pallet fork, or snow blade.

2. AGRICULTURAL TRACTOR WITH FRONTAL LOADER EQUIPMENT

An agricultural tractor represents the basic machine used in a farm, being equipped with an internal combustion engine of considerable power. The power reserve provided by engine is intended for performing the specific operations related to field or road displacement, or task performing when various pieces of auxiliary equipment are attached for carrying out different agricultural work.

The frontal loader auxiliary equipment can be mounted at the front of the agricultural tractor by means of a special mechanism that achieves equipment fixation on the basic machine.

A schematic representation for the agricultural tractor with some auxiliary frontal loader equipment mounted is shown in Fig. 1

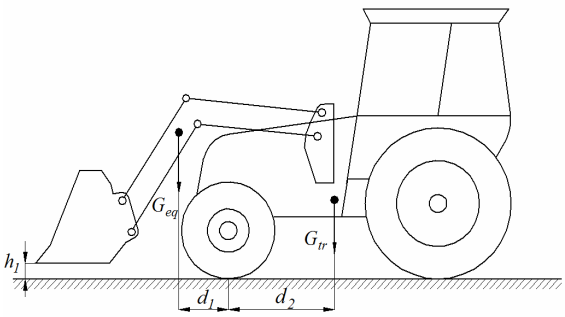


Fig. 1. The schematic representation of the agricultural tractor with the mounted frontal loader equipment

3. THEORETICAL APROACHES REGARDING THE OPERATION OF THE FRONTAL LOADER EQUIPMENT

The loader equipment represents an optimal solution, to be attached to an agricultural tractor, thus increasing the number of working tasks that can be done by the tractor, apart from the basic work for which it was conceived related to the soil preparatory work for crops establishment within the farm.

The tasks carried out using the attached equipment are related to the loading of grain or construction aggregates, depending on the farm requirements.

Moreover, apart from the active body type bucket loader, other working bodies may be attached such as fork for pallets and hay or bales storage at a specific height, snow blade, etc.

Depending on the tractor engine power, the traction force may be determined for the case when the tractor is operating with frontal loader equipment attached, carrying out the loading operation with the bucket. In this case, the bucket penetrates the loaded material with a velocity of up to 5 km / h.

The traction force (F_t) can be calculated with the formula:

$$F_t = \frac{360 \cdot P_n}{V_i} \eta_t \qquad (1)$$

where:

F_t - the traction force;

P_n - driving motor power;

V_i - cup charging velocity;

η_t - total yield.

An important parameter in the loading operation using the attached equipment to the agricultural tractor is represented by the weight of adhesion (G_a) defined as the ratio between the maximum traction force and the ground adhesion coefficient (φ_a), which is chosen for the toughest working conditions.

$$G_a = \frac{F_t}{\varphi_a} \qquad (2)$$

The machine total weight (G_{tot}) is represented by the tractor weight (G_{tr}) supplemented with the attached equipment weight (G_{eq}).

$$G_{tot} = G_{tr} + G_{eq} \qquad (3)$$

The lifting capacity (Q_l) with the filled bucket to the maximum height is ensured through the machine stability condition during loading operations as follows:

$$Q_l = C_s \left(G_{tr} + G_{eq} \right) \qquad (4)$$

where:

C_s - safety coefficient ranged at 0.25-0.3.

The nominal bucket volume is determined as follows:

$$V_n = \frac{Q_l}{\gamma_m k_n} \qquad (5)$$

Because the frontal loader equipment is endowed with a hydraulic drive, there are a number of hydraulic cylinders working for the movement of arms and bucket necessary to conduct specific loading operations.

The dimensioning of hydraulic cylinders can be accomplished considering the maximum amount of effort into the cylinder.

The working pressure into the hydraulic cylinder can be calculated as:

$$p_c = \frac{S_c}{\frac{\pi D_p^2}{4}\eta_{hc}} \quad (6)$$

where:

p_c - fluid pressure inside the hydraulic cylinder;

S_c - maximum effort within the cylinder;

For the auxiliary frontal loader equipment that can be attached to the agricultural tractor, a hydraulic diagram of the components was performed represented by the actuating pump, hydraulic distributors which direct the working fluid, linear hydraulic motors actuating the loading arms and the bucket as the working body. The hydraulic diagram is shown in Figure 2.

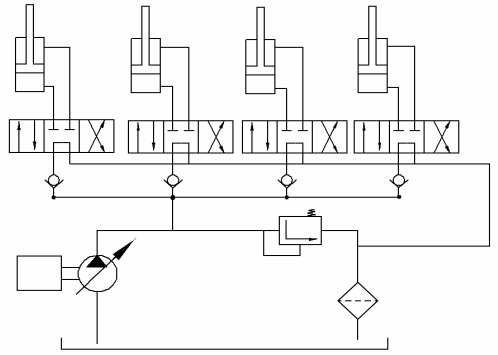


Fig. 2. Hydraulic components diagram for the frontal loader equipment

4. STRUCTURAL ANALISYS FOR THE FRONTAL LOADER WORKING EQUIPMENT

A three-dimensional assembly model for the frontal loader equipment was performed using Solid Edge V20 program.

The assembly comprises the fastening elements to the basic machine, the operating arms and the bucket representing the working body. On each of the two arms, two hydraulic cylinders are mounted necessary for performing the rotational movement of the arms and the bucket during operation.

For the frontal loader assembly model, a structural analysis was carried out using ANSYS Static Structural software in order to highlight the major efforts and structural deformations that occur within the elements while performing the loading operation.

Two cases with different values of loads were taken into consideration.

For case 1, have been declared the forces within the cylinders (400 daN for the bucket cylinders and 450 daN for arm cylinders), the rotational velocity of the bucket of 2 rad/s and the earth gravity (figure 3).

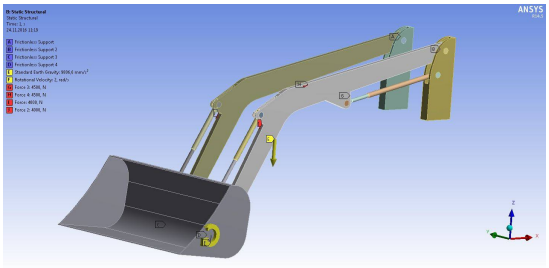
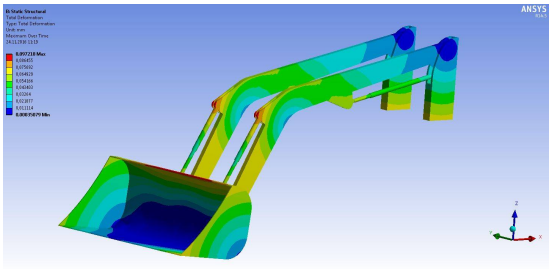
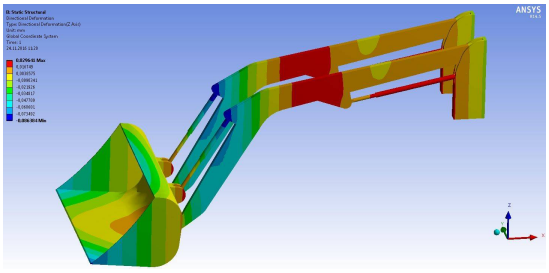


Fig. 3. The declared efforts on the equipment assembly model (case 1)

The results obtained for case 1 are presented in figure 4.



a) assembly total deformation results



b) assembly directional deformation

Fig. 4. The results obtained from the frontal loader assembly model structural analysis (case 1)

For case 2, have been declared the normal force acting on the bucket with a value of 800

daN, the rotational velocity of the two arms of 2 rad/s, the bucket vertical displacement and the earth gravity (figure 5).

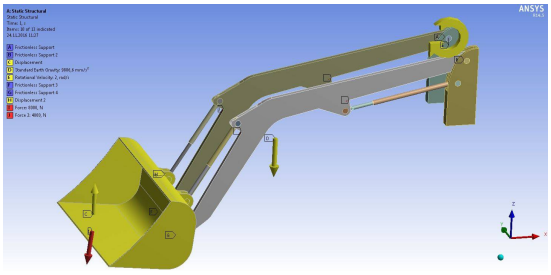
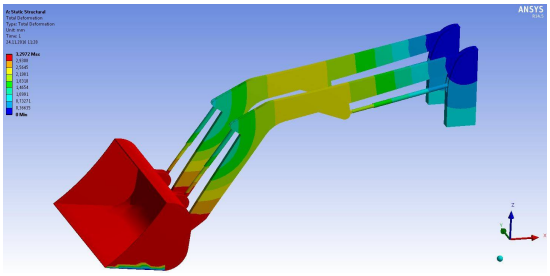
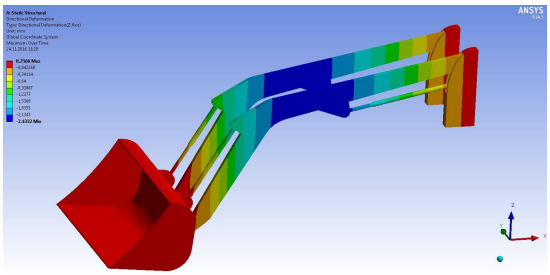


Fig. 5. The declared efforts on the equipment assembly model (case 2)

The results of the performed analysis are presented in terms of total and directional deformation at the assembly components level, as shown in Figure 6.



a) assembly total deformation results



b) assembly directional deformation

Fig. 6. The results obtained from the frontal loader assembly model structural analysis (case 2)

The results show the recorded values for total and directional deformations at the assembly components level, due to the application of the declared efforts.

It can be seen that there are higher deformation values at the bucket level for the two examined cases, especially in the case 2 where was considered a direct loading of the bucket. Based on the results, tensions and deformations occurring on equipment components can be analyzed and, further in this regard, their proper dimensioning can be achieved.

5.CONCLUSIONS

The agricultural tractor represents a basic machine that belongs to farms, by means of which most of the soil work is carried out. There are many possibilities to expand the range of performed work by attaching special equipment through which other specific work may be executed.

Such auxiliary equipment is represented by a frontal loader that can be attached to the tractor in order to perform various working activities related to loading of grain or various construction aggregates.

A three-dimensional model for the frontal loader equipment assembly was built using Solid Edge software.

For this virtual model, a structural analysis using ANSYS software V14.5 was performed in order to highlight the deformations values occurring when are considered the main efforts acting on the assembly components, corresponding to equipment operation.

The obtained results show the total deformation and directional deformation on a main direction of the components assembly when applying the specific forces defining the working operation of loading, bucket rotation and arms lifting.

In addition to the loading bucket, other various working bodies can be attached to this equipment such as pallets and bales fork, blade for snow removal and others.

The use of some auxiliary equipment that can be attached to the agricultural tractor within a farm represents a more economical and highly useful alternative option than the purchase of an item of specialized equipment to perform such working operations.

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