

Stress Analysis of Crossbar of Moldboard Plough Pulled by Massey Ferguson 285 and 299 Tractors

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Abstract: Frequent failures of mechanical elements in machines and equipment due to exerted loads reveal the importance of researches and studies in this regard to optimize or redesign the parts. Practically, crossbar's pins in moldboard plough are frequently failed. So, stress analysis of that was conducted in this study by finite element method. After drawing the three-dimensional model in Solid Works Software and transfer it to ANSYS Software, the constraints, boundary conditions and loads were applied on the model. Then the static analyses were done for the model. To estimate the exerted forces on the crossbar, the draft forces of Massey Ferguson 285 and 299 tractors were considered. The results of static analysis showed that the maximum static stresses based on von Mises criteria occur at the junction between the left and right pins with crossbar. The stress values based on Massey Ferguson 285 Tractor were 126 and 83.7 MPa, respectively, and based on Massey Ferguson 299 Tractor were 136 and 90.6 MPa, respectively. The obtained safety factors for the left and right pins were obtained as 1.57 and 2.36, respectively, based on the maximum draft of Massey Ferguson 285 Tractor and 1.45 and 2.18, respectively, based on the maximum draft of Massey Ferguson 299 Tractor. These results show the higher probability of failure at the left pin junction.

Keywords: Moldboard Plough, Crossbar, Static Analysis, Safety Factor, Finite Element Method

1. Introduction

The used equipment for cutting and pulverizing the soil, such as: rotary tiller, moldboard plough and subsoiler, are of the main tillage machinery. On one hand, this equipment consumes the highest energy compare with other agricultural machinery, and on the other hand the manufacturing process and testing of this equipment are expensive. So, optimum design of these implements is one of the most important factors to reduce the production, evaluation and application costs [1].

In most countries, moldboard plough is considered as one of the main primary tillage implements [2]. Complex shape and working depth of these implements cause the breakage of their different parts during work. One of the critical parts of moldboard plough is crossbar which is under bending loads and breakage. Breakage of the crossbar wastes the time and also costs of tillage operation. Today, using computer aided design technique, design factors such as force, stress, deformation, optimization of machine parts and also the

performance of structures under loads can be simulated and analyzed more efficiently and faster [3].

Using finite element method to calculate the stress, strain and deformation of the piece is a relatively new technique. Compared with other methods, this method has many advantages, for example: the distribution of stress - strain obtained in all the pieces can be obtained which makes it possible to identify all the critical and non-critical points in a reliable manner. Strength improvement can be conducted quickly, easily and effectively by changing properties such as the used material, the surface conditions and so on. Using this method leads to the analysis in a virtual environment without using physical models [4].

Some researches were conducted to analyses agricultural machinery by finite element method. Bahrami *et al.* analyzed a subsoiler with curved stem. The results of their research showed that the maximum stress happened around the small hole in the bottom of the lower stem and joint point of the stem with chassis [5]. Mouazen and Nemenyi studied the stress applied on subsoiler blade in a non-homogenous sandy-loam soil using finite element method. The results of

their study were compared with the results of the subsoiler in soil and they concluded that the finite element method is suitable for modeling and analysis of tools in soil [6]. Bayrakceken researched on the bevel pinion shaft of bus. He resulted that high stress concentration in some parts of the shaft was the main reason for cracking [7]. Analysis of mechanical stress and soil deformation by power harrow blade showed that the highest stress and deformation occur on the tip of the harrow blades [8]. Kamali *et al.* analyzed a two-wheel cultivator using finite element method. The results showed that the maximum stress is obtained in joint point of tool with the cultivator chassis [9]. Jafari *et al.* analyzed front axle of JD 955 combine harvester under static loading. The results of their research showed that the calculated value of safety factor was too low. They stated the front axle wasn't strong enough to be installed on the harvester [10]. Hassan *et al.* researched on fatigue analysis of gear type hydraulic pump of JD 955 combine harvester by finite element method. They stated by considering fully reverse loading, the life gear can be estimated and critical crack growth points can be found [11]. Tarighi *et al.* analyzed the static and dynamic behavior of front axle housing of a tractor using finite element

method. They obtained the maximum stress and safety factor according to Von-Mises criteria [12]. Aduloju *et al.* studied the effect of tilting of tractor front axle support. They reported that based on von Mises criteria, the safety factor of the designed component was low [13].

One of the main problems of moldboard plough is breakage of crossbar pin during work. This fracture increases the cost of maintaining and repairmen of the plough. So, mechanical analysis of crossbar under the critical working condition in order to optimize and increase the mechanical strength of the bar is necessary. Therefore, the aim of this study is to analyze the crossbar of moldboard plow by finite element method.

2. Materials and Methods

In the present study, a crossbar of one-way moldboard plough was considered to be evaluated by finite element method. Firstly, the cross bar was simulated in SolidWorks 2013 Software with its true dimensions. The isometric view of the model has been showed in Figure 1.

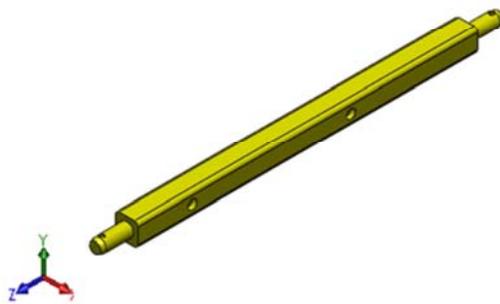


Figure 1. The isometric view of simulated model.

Then the model was imported into ANSYS 15 Software. The characters of steel (ST37) was used for modeling the crossbar of moldboard plough in the software. The details of ST37 were presented in Table 1.

Table 1. The specification of ST37 [14].

Specification	Emblem	Quantity	Unit
Ultimate stress strength	σ_{ut}	235	MPa
stress yield limit	σ_y	198	MPa
Poisson's ratio	ϵ	0.3	-
Elasticity	E	200	GPa
Density	ρ	7860	kg/m ³

In order to static analysis of the model by ANSYS Software, firstly Solid Brick 10 node 187 element was selected. This element type is a three dimensional one that has 8 nodes with three degrees of freedom for each node. The

model was meshed so that 51866 nodes were created (Figure 2).

After meshing, the boundary conditions of the model were applied in all respects. To consider the crossbar loading force, the maximum draft force of two types of commonly used tractors in Iran, Massey Ferguson 285 and 299, with the specifications contained in Table 2 were used.

The pins on both ends of cross bar are attached to the lower connection arms of tractor. The forces are applied on the pins when pulling the moldboard plough by the tractor. As different pins on both ends are not at the same distance from the tractor connection arms, the amount of forces acting on the crossbar pins are not equal. So, the acting force on each pin was calculated. The force direction was considered same as the tractor motion (X direction). Considering back view of the tractor, the distance between right support and right pin is less than that of left support and pin (Figure 3).

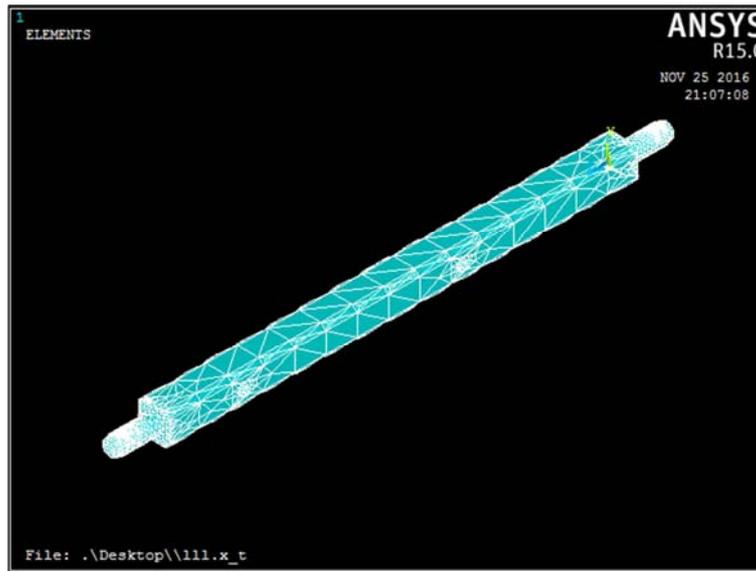


Figure 2. The meshed model.

Table 2. Technical specifications of used tractors.

Tractor type	Manufacturer	Engine model	Number of cylinders	Weight (kg)	Power (hp)	Maximum draft force (kN)
MF 285	Iran Tractor Manufacturing Co.	A4-248	4	3441	75	32.2
MF 299	Iran Tractor Manufacturing Co.	A4-244	4	4164	82	34.8

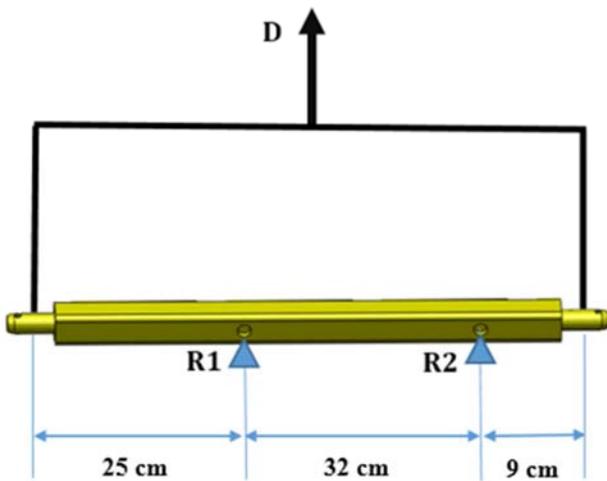


Figure 3. The supports and their distances on the crossbar of moldboard plough. R1 and R2 are the support reaction of left and right pins, respectively, and D is the maximum draft force.

The magnitude of the support reaction of left pin (R₁) was calculated using Eq. 1:

$$\sum M_{R_2} = 0 \quad D \times 24 - R_1 \times 32 = 0 \quad (1)$$

The support reaction of the right pin (R₂) was calculated by Eq. 2:

$$\sum F_x = 0 \quad R_1 + R_2 = D = 32200 \text{ N (MF285)}, 34800 \text{ N (MF299)}$$

$$R_2 = D - R_1 \quad (2)$$

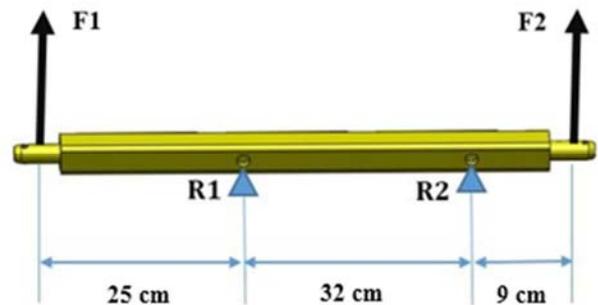


Figure 4. The exerted forces on the pins. F1 and F2 are the portions of tractor draft exerted on the left and right pins, respectively.

The magnitude of the portions of tractor draft exerted on the left and right pins were calculated using Eq. 3 and 4:

$$\sum F_x = 0 \quad F_1 + F_2 = R_1 + R_2 = D \quad F_1 = D - F_2 \quad (3)$$

$$\sum M_{R_2} = 0 \quad F_1 \times 57 - R_1 \times 32 - F_2 \times 9 = 0 \quad (4)$$

The force on the anchor pin and the forces of reaction have been reported in Table 3.

For static analysis of the crossbar, the loads were exerted on the real nodes of the pins. After analysis in ANSYS Software, the amount of stresses was recorded based on the theory of von Mises criteria. Then, safety factor of cross bar in static loading was calculated using Eq. 5. [15].

$$FS = \frac{\sigma_y}{\sigma_{all}} \quad (5)$$

Where FS is safety factor in the static loading, σ_y is the yield point and σ_{all} is the maximum stress exerted on the model. In the design of a machine part, to achieve least

safety, the maximum amount of applied stress must be lower than the yield point of materials.

Table 3. The exerted forces (N) on the anchor pin and calculated reaction forces.

Variable	Tractor Type	
	MF 285	MF 299
Left anchor reaction force (R ₁)	24150	26100
Right anchor reaction force (R ₂)	8050	8700
Force on the left pin (F ₁)	16100	17400
Force on the right pin (F ₂)	16100	17400

3. Results and Discussion

The occurred deformation of crossbar of moldboard plough due to the exerted forces has been shown in Figure 5 and Figure 6. The maximum deformation value in the crossbar was equal to 0.121×10^{-3} and 0.131×10^{-3} mm based on the maximum draft of MF 285 Tractor and MF 299 Tractor, respectively. This deformation has been occurred in the left support.

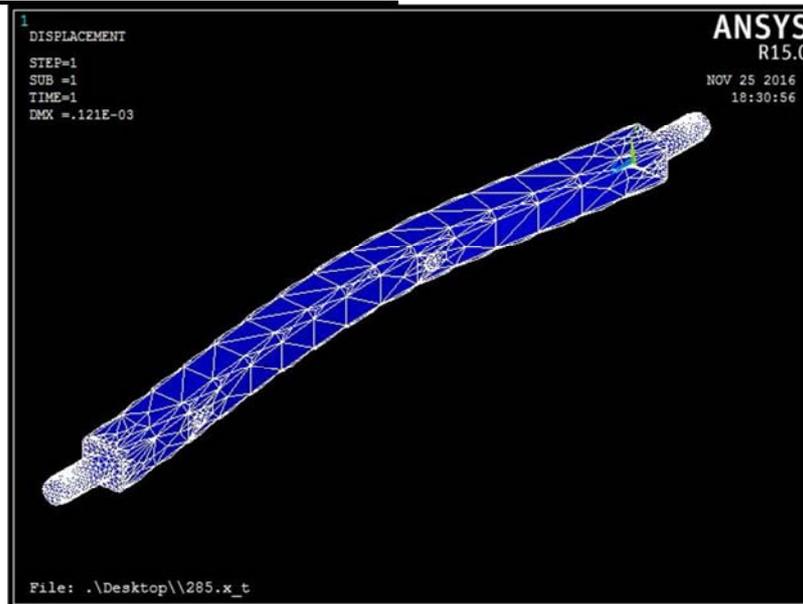


Figure 5. The deformation of the crossbar when connect to MF 285 Tractor.

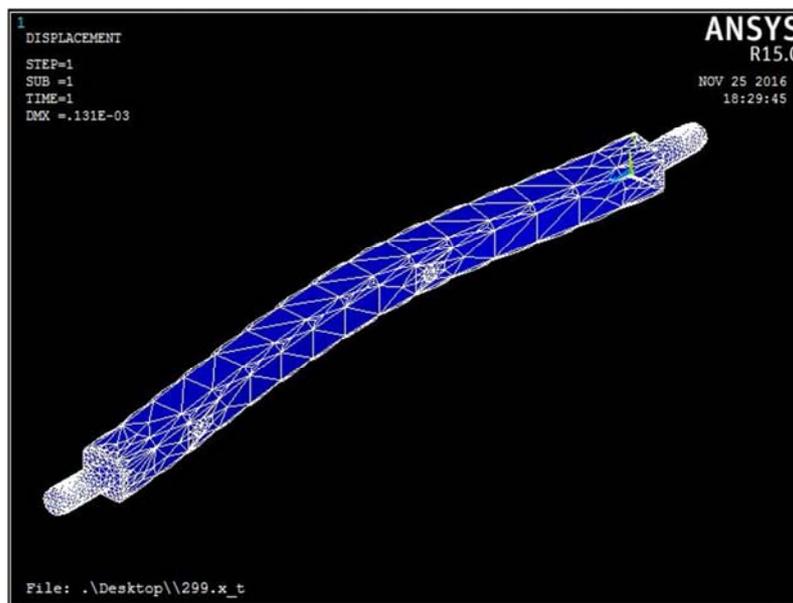


Figure 6. The deformation of the crossbar when connect to MF 299 Tractor.

Stress distribution based on von-Mises criteria in the crossbar has been shown in Figure 7, 8, 9 and 10. As can be seen in these figures, the highest amount of stress has been obtained in the pin junctions. In Figure 7 the maximum stress was shown on the right pin which is equal to 83.7 MPa and has occurred in node number 916 and 2554 based on the maximum draft of MF 285 Tractor. The highest stress value was seen in left pin (Figure 8) that is equal to 126 MPa and on node number 1284 and.

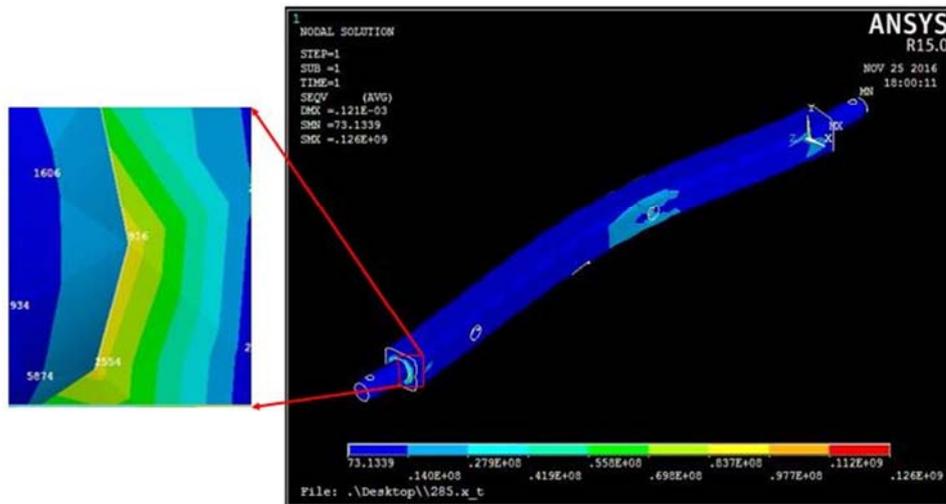


Figure 7. Stress distribution on the right pin of the crossbar when connected to MF 285 Tractor.

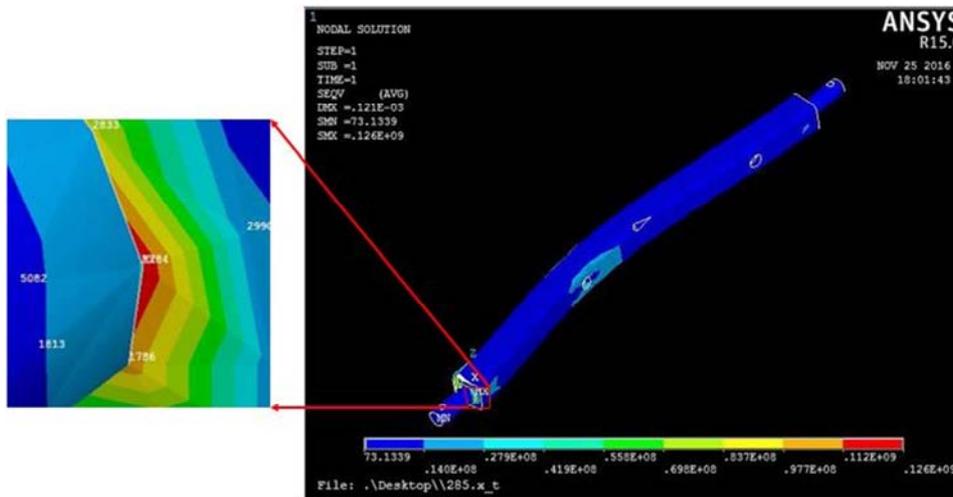


Figure 8. Stress distribution on the left pin of the crossbar when connected to MF 285 Tractor.

Based on the maximum draft of MF 299 Tractor, the maximum stress was seen on the right pin which is equal to 90.6 MPa and has occurred in node number 916 and 2554 (Figure 9). In Figure 10, the highest stress value was seen in left that is equal to 136 MPa and on node number 1284.

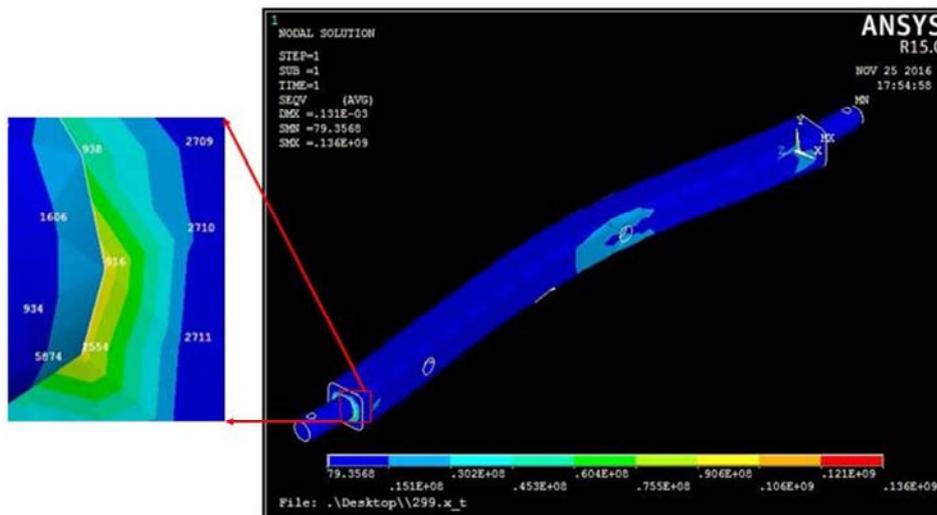


Figure 9. Stress distribution on the right pin of the crossbar when connected to MF 299 Tractor.

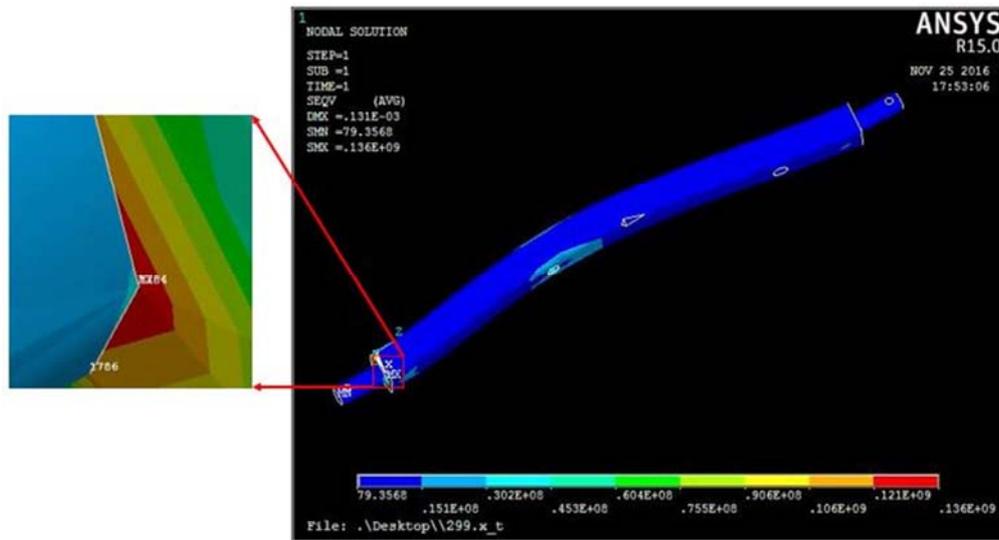


Figure 10. Stress distribution on the left pin of the crossbar when connected to MF 299 Tractor.

According to Figure 7, 8, 9 and 10, the highest stress in EM model of the moldboard plough crossbar based on von-Mises criteria occurred at the junction points of the left pin. So, this analysis gave higher probability for fracture of left pin junction. This result is due to more distance between the left pin and support and therefore more force applied on that compare with right pin. Also the cross-section area of the pins is smaller than other points in cross bar. In addition, the connection angle between pin and cross bar is 90° with high stress concentration factor that increase the fracture possibility.

Using Eq. 5 and maximum stresses in the right and left pins, the safety factor was achieved based on the maximum draft forces of MF 285 Tractor as 2.36 and 1.57, respectively and when connected to MF 299 Tractor 2.18 and 1.45, respectively. This result indicates higher risk in left pin for failure compare with that of right pin. In practice, the left pin is fractured and then welded by machinery owners (Figure 11). So static analysis result of the present research is in agree with which practically is happened for crossbar of moldboard plough.



Figure 11. The left pin of crossbar, a) healthy pin and b) broken and welded pin.

4. Conclusions

Finite element method is widely used in engineering problems such as static and dynamic structure. By examining the static force exerted on the crossbar of moldboard plough, the maximum stress based on von-Mises criteria was obtained for left pin. The exerted force in the left pin was more than that of right pin, because left anchor had more distance to the pin. The safety factor derived from static analysis for right pin connecting point was more than that of the left one. With this result, the fracture possibility of left pin was lower than other points due to lower safety factor. Although safety factor in the left pin is more than unit, but

practically, unbalanced and/or sudden loads lead to failure of left pin of crossbar.

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