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CHOOSING THE PROPER MATERIAL TO OPTIMIZE THE FRONT AXLE OF THE TRACTOR MF285 USING FINITE ELEMENT

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اختيار المواد المناسبة لتحسين جبهة المحور من الجرارة MF285 استخدام عنصر محدود

ملخص

يجب أن يكون لمحور جرار القوّة الميكانيكية الكافية بسبب قوتها الديناميكية والثابتة أثناء التشغيل. قبل التصنيع ، يمكن التحقق من القوة الميكانيكية عن طريق اختيار مواد مختلفة من خلال برامج هندسية لاختيار المواد الأكثر ملاءمة .في هذه الورقة ، تم اقتراح ثلاثة أنواع من المواد ، وهي St37، Cm45 و St52 من أجل تحسين المحور الأمامي للجرار MF285. تم التحقق من القوة الميكانيكية لكل مادة بواسطة برنامج هندسي. تم استخدام برنامج Solid Work لتحليل النماذج ثلاثية الأبعاد للمحور وتم استخدام برنامج ANSYS لتحليل العناصر المحدودة. في الحد الأقصى للتحميل الساكن على المحور الأمامي للجرار ، كان عامل الأمان لـ St37 و Cm45 و 3.61 St52 و ٧.١٧ و ٥.٤٥ على التوالي. وأظهرت النتائج أن Cm45 و St52 لديها قوة ميكانيكية كافية لتحمل الحمل المطبق على المحور بسبب تكلفة التصنيع. وأخيرًا ، ووفقًا لحالة الجرار في الحقل وإمكانية تركيب الحفار الميكانيكي أمام الجرار ، تم اقتراح Cm45 لتحسين المحور الأمامي لجرار MF285 الذي تم إنتاجه في شركة تصنيع الجرارات الإيرانية.

Abstract

The tractor axle must have sufficient mechanical strength due to its dynamic and static forces during operation. Before fabrication, mechanical strength can be checked by selecting different materials through engineering software to select the most suitable material. In this paper, three types of material, namely St37, Cm45 and St52 were proposed in order to optimize the front axle of tractor MF285. The mechanical strength of each material was investigated by engineering software. Solid Work software was used for the analysis of 3D modeling of the axle and ANSYS software was used for finite element analysis. In the maximum static loading on the front axle of the tractor, the factor of safety for St37, Cm45 and St52 were 3.61, 7.17, and 5.45 respectively. The results showed that Cm45 and St52 have sufficient mechanical strength to withstand the load applied to the axle due to the cost of fabrication. Finally, according to the condition of the tractor in the field and the possibility of mounting of mechanical digger in front of the tractor, the Cm45 was proposed to optimize the front axle of MF285 tractor produced in Iran Tractor Manufacturing Co.

1. INTRODUCTION

Agricultural tractors require optimal design and choice of suitable material and alloy for fabricating of parts due to their uneven field conditions and under heavy dynamic loads. Any excess load on the tractor parts can lead to excess stress on it and cause permanent deformation, failure or cracks in the part. The parts used in the tractor must have an acceptable factor of safety, because most agricultural tractors work out of the city, and in the event of a problem during work, the farmer will pay any expenses incurred. Component manufacturers are looking to reduce production costs as well as reduce the production time of a part, in order to optimize and develop a piece at the lowest cost (Bickert, 1996; Kojima, 2002). Therefore, the tractor manufacturers are trying to not only reduce the weight of the parts by choosing the best materials, but also have optimal design for each part. This is only possible using high-tech engineering and processing software in the shortest time and at the lowest cost, which even accelerates the production processes (Lee, 1999). Front axle, in addition to bearing the weight of the front of the tractor, has several other tasks, such as the safe system, steering, maintaining the front axle angle, absorbing shocks caused by road, as well as the suspension of the tractor. Therefore, the damage to this part can be very dangerous and a life-threatening. Available statistics indicates that most tractors of Iran's farms belong to tractor MF285 and their axle has the worst failure and return to the after-sales service of the company. Iran's tractor manufacturing Co. has made several revisions in casting and forging operations to prevent the failure of the axle, but it is nevertheless necessary to analyze the axle under loading in order to be evaluated the tolerance of axle using application of different materials. The goal of this paper is to model and analyze of front axle of the tractor MF285 made in Iran Tractor manufacturing Co, for choosing the best material using the finite element method.

Trighi et al. (2010) analyzed the Mitsubishi MT250 tractor under the static and dynamic loading using finite element method. Considering that most agricultural tractors are multifunctional, as well as placing an additional weight on the tractor can cause fracture in the parts, they need to analyze the stress in front axle of the tractor in order to mount the mechanical shovel in front of the tractor. The results showed that the front axle housing does not have the static and dynamic strength required to withstand the overload caused by mounting the mechanical shovel in front of the tractor. Leon et al. (2000) used experimental and numerical method to analyze the stress of the front axle of the truck. Mahanty et al. (2001) also used numerical and experimental methods for analyzing the stress of front axle. They used a new model for the front axle of the tractor that was simpler and lighter than the previous model. Their proposed model reduced the amount of materials used to fabricate the axle. Jafari et al. (2006) analyzed the stress of the JD955 combine under static conditions. They reported that the reliability coefficient obtained on the basis of the von Misses theory is 1.3, which is very low for a vehicle axle, especially an agricultural machine, which works under heavy conditions than other machines. They also argued that, in field conditions where dynamic loads are also driven axially, the coefficient of reliability of the calculated value may be lower. Therefore, in order to overcome this problem, they suggested an optimal design be made on the front axle of the combine JD955. Wang et al. (2004) obtained static and dynamic strength in five load conditions in order to investigate the possibility of retrofitting and increasing the reliability of the rear axle of the truck. The focal points of the axle were identified and optimal design was proposed in the points mentioned in order to strengthen the axle at the points and increase the reliability coefficient in those points. Tampaxi et al. (2008) studied on stress distribution and reliability coefficients of a gear box of a rotary tiller using Cosmos Works software, in which stress distribution between gears was calculated. Ruhollahi (1998) performed the static and dynamic analysis of the frame of articulated-truck using the finite element method with the ANSYS software. Sarfallah (1999) conducted a failure analysis of the gearbox using finite element method using ANSYS software. Ribbon & Suvagneson (2016) studied on optimization of the front axle of trucks. They analyzed the design parameters such as wheel roll, pin-king center, weight and axle load. They also measured the useful life and stress, and concluded that their design was sufficiently reliable. Oyaravlou et al. (2012) analyzed the existing design of the front axle of the tractor. The geometry of the front axle was modified and a new design was proposed. The front axle life was predicted under dynamic load with using the fatigue design module of the ANSYS software. Rezaei et al. (2015) designed an electronic system, mounted on the middle of the rear axle of the combine to measure the load on the rear axle of the combine JD 955. Then, various tests were carried out in static conditions at the laboratory as well as field conditions with different forward speeds and loads in several replications. With maximum static load, stress of more than 19.88 MPa was created in the middle of axle.

2. MATERIAL AND METHOD

In order to create the 3D model of front axle of 2WD tractor MF285, the axle was disassembled and measured using a 3D scan device with a precision of 0.002 mm and a coliseum with a precision of 0.02 mm. A 3D model was created using the Solid Work software (Figure 1). After the axle modeling, it was exported to the ANSYS software for finite element analysis and applying the loading conditions and boundary conditions. Next, the mechanical properties of the materials were introduced into the software to select the appropriate materials. Table 1 illustrated the characteristics of the three proposed materials for optimizing the front axle of tractor MF285.

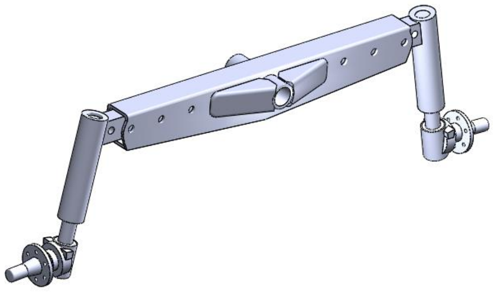

Figure1. The 3D model of front axle of tractor MF285

Table1. Characteristics of proposed materials for optimizing the front axle of the MF285tractor

Proposed Materials	Young's Modulus (MPa)	Density (kg mm^-3)	Yield Strength (MPa)	Tensile Yield Strength (MPa)	Poisson's Ratio
Cm45	2.e+005	7.85e-006	385	470	0.3
St52	2.e+005	7.85e-006	275	355	0.28
St37	2.e+005	7.85e-006	237	237	0.28

The forces on the tractor axle can be static, dynamic and even impact force. In this study, the stresses were only investigated on the axle under static conditions, because if static loads were not tolerated, axle would certainly not have sufficient mechanical strength against dynamic loads.

The integrated axle 3D model was transferred to the ANSYS software in order to analyze the stress. For meshing the model, a quadratic quadrilateral element was used which the number of 85345 nodes and 67566 elements were generated that the size of each element was 2 mm. Figure 2 shows the mesh-shaped model of the axle and how to loads on it.

3. RESULTS AND DISCUSSION

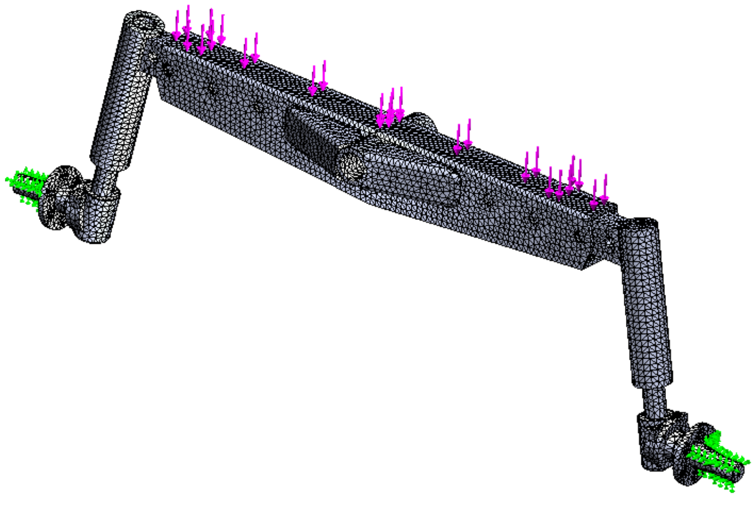

Figure2. Finite element model of the housing

The next step was the application of boundary conditions. In this study, the axle was considered as a two-headed beam with fixed supports and the load direction was applied to the axle according to Figure 2. After applying the boundary conditions, the mechanical characteristics of the suggested materials were entered into the ANSYS software for optimization and the finite element analysis was performed for each of the proposed materials namely Cm45, St52 and St37. The maximum load on the axle was statically applied to the tractor with a static weight distribution of 11180 N. The maximum amount of the stress was 65.54 for all three types of proposed material. Figure 3 shows the *stress distribution* on the axle.

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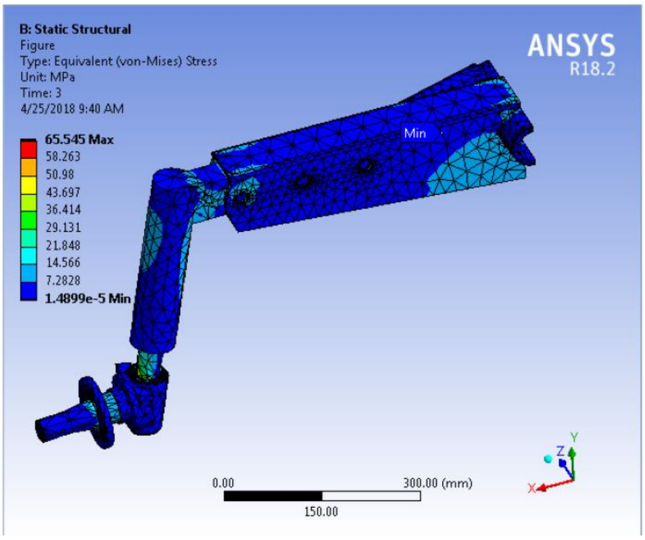

Figure3. Stress distribution of front axle of the tractor MF285

a. Calculating of Factor of Safety

In designing parts to resist failure, it is assumed that the internal stresses do not exceed the strength of the material. If the material to be used is brittle, then it is the yield strength that designer is usually interested in, because a little deformation would constitute failure. The distortion-energy theory is also called the Von-Misses theory, which is the most appropriate theory in the field of material selection (Shigley & Mischke, 1989). The von Misses theory was used to calculate the factor of safety. According to the theory of von Misses, the amount of stress on material is obtained from the following relationship:

$$(\sigma) = \left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2}{2}\right]^{1/2} \quad (1)$$

In which σ_1, σ_2 and σ_3, are the main stresses in three directions of coordinate axes. In order to ensure the performance of mechanical materials and to prevent the failure of material, the stress must be less than yield stress. According to this principle, the factor of safety can be calculated according to (2):

$$F.S = \frac{\sigma_y}{\sigma_{max}}$$

The minimum factor of safety with respect to the above theory was 7.17, 5.41 and 3.61 for Cm45, St52 and St37 respectively. Table 2 shows the values of stresses and factor of safety in the first three seconds of loading.

Table2. Analysis of the finite element of the proposed materials for the axle of tractor MF285

Material	**Factor of Safety**			**Equivalent Stress (MPa)**		
	Time(s)	Min	Max	Time(s)	Min	Max
	0.2			0.2		
	0.4			0.4	0	0
	0.7	15		0.7		
	1			1		
Cm45	1.2		15	1.2	2.9799e-006	13.109
	1.4			1.4	5.9597e-006	26.218
	1.7	10.24		1.7	1.0429e-005	45.882
	2			2		
	2.2	**7.17**		2.2	1.4899e-005	**65.545**
	2.4			2.4		

Material	Time(s)	Factor of Safety Min	Factor of Safety Max	Time(s)	Equivalent Stress (MPa) Min	Equivalent Stress (MPa) Max
	2.7			2.7		
	3			3		
	0.2			0.2		
	0.4			0.4		
	0.7	15		0.7	0	0
	1			1		
	1.2			1.2	2.9799e-006	13.109
St52	1.4	13.54	15	1.4	5.9597e-006	26.218
	1.7	7.7373		1.7	1.0429e-005	45.882
	2			2		
	2.2			2.2		
	2.4	**5.41**		2.4	1.4899e-005	**65.545**
	2.7			2.7		
	3			3		
	0.2			0.2		
	0.4			0.4		
	0.7	15		0.7	0	0
	1			1		
	1.2			1.2	2.9799e-006	13.109
St37	1.4	9.0395	15	1.4	5.9597e-006	26.218
	1.7	5.1655		1.7	1.0429e-005	45.882
	2			2		
	2.2			2.2		
	2.4	**3.61**		2.4	1.4899e-005	**65.545**
	2.7			2.7		
	3			3		

Table 2 shows the results of stress analysis in the first three seconds, and the mean of thirds second was considered as the least amount of factor of safety for proposed materials. The results of finite element analysis for proposed materials and the values obtained for factor of safety showed that the most strength material for the front axle of tractor MF285 is Cm45 and St52.

4. CONCLUSION

The following conclusions can be made from this study:

1) The maximum stress (65.545MPa) and minimum factor of safety was observed for St37 and maximum factor of safety was observed for Cm45.

2) In the axle made from Cm45 steel, the minimum F.S. increased to 7.17 with the same maximum stress of 65.545 MPa.

3) Results from finite element analysis showed that the Cm45 steel can be used to fabricate the front axle of MF285 tractor; but appropriate heat treatment of the part seems to be necessary.

4) Result showed that the St37 steel is not suitable material to fabricate the front axle, because of the low strength of this steel.

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