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An Extensive Design and Analysis of a Tractor Implement System through Design and Development Technique

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ABSTRACT

Nowadays developments occur in mechanical as well as agricultural industry in our country for competing worldwide market. Automotive industry is the leading sector in India which can be utilized in directly or indirectly to the various country development fields. In this scenario technical developments are needed for the agricultural fields in India. All the leading manufacturers of automotive industry, needs technological improvement and implementation for their development and customer satisfaction for the survival in the global market. This project attempts to identify one of the failures which really affect the performance of the agricultural equipment industry. A detailed study of the failure is made, and analysis will carried out based on the design and development techniques. Corrective action and introducing new methodology or mechanism will be developed through the Techniques.

Keywords: Off road vehicle, product design, PTO shaft

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1. Introduction

A tractor is a vehicle specifically designed to deliver a high tractive effort (or torque) at slow speeds, for the purposes of hauling a trailer or machinery used in agriculture or construction. Commonly, the term is used to describe a farm vehicle that provides the power and traction to mechanize agricultural tasks, especially tillage but nowadays a great variety of tasks. Agricultural implements may be towed behind or mounted on the tractor, and the tractor may also provide a source of power if the implement is mechanized. Older farm tractors use a manual transmission for power transmission. They had several gear ratios, typically 3 to 6, sometimes multiplied into 2 or 3 ranges. This arrangement provides a set of discrete ratios that, combined with the varying of the throttle, allow final-drive speeds from less than one mile per hour up to about 25 miles per hour (40 km/h), with the lower speeds used for working the land and the highest speeds used on the road.

Care is needed to ensure that the physical space around the transmission allows for installation of the PTO. The PTO is engaged/disengaged using the main transmission clutch and a remote control mechanism which operates on the PTO itself. Typically an air valve is used to engage the PTO, but a mechanical linkage, electric or hydraulic mechanisms are also options.

1.1 Power take-off Systems and Hydraulics

In addition to towing an implement or supplying tractive power through the wheels, most tractors have a means to transfer power to another machine such as a baler, swather, or mower. Unless it functions solely by pulling it through or over the ground, a towed implement needs its own power source (such as a baler or combine with a separate engine) or else a means of transmitting power from the tractor to the mechanical operations of the equipment. Modern tractors use a power take-off (PTO) shaft to provide rotary power to machinery that may be stationary or pulled. The PTO shaft generally is at the rear of the tractor, and can be connected to an implement that is either towed by a drawbar or a three-point hitch. This eliminates the need for a separate implement-mounted power source, which is almost never seen in modern farm equipment.

1.2 Power Take Off

A power take-off (PTO) is a splined driveshaft, usually on a tractor or truck that can be used to provide power to an attachment or separate machine. It is designed to be easily connected and disconnected. The power take-off allows implements to draw energy from the tractor's engine. Semi-permanently mounted power take-offs can also be found on industrial and marine engines. These applications typically use a Cardan shaft and bolted joint to transmit power to a secondary implement or accessory. In the case of a marine application, such shafts may be used to power fire pumps. Truck transmissions have one or more locations which allow for a PTO to be mounted. The PTO must be purchased separately and care is required to match the physical interface of the transmission with a compatible PTO. PTO suppliers will usually require details of the make, model and even serial number of the transmission. Care is also needed to ensure that the physical space around the transmission allows for installation of the PTO. The PTO is engaged/disengaged using the main transmission clutch and a remote control mechanism which operates on the PTO itself. Typically an air valve is used to engage the PTO, but a mechanical linkage, electric or hydraulic mechanisms are also options. Agricultural PTOs are standardized in dimensions and speed. The ISO standard for PTOs is ISO 500, which as of the 2004 edition was split into three parts:

- ISO 500-1 General specifications, safety requirements, dimensions for master shield and clearance zone
- ISO 500-2 Narrow-track tractors, dimensions for master shield and clearance zone)
- ISO 500-3 Main PTO dimensions and spline dimensions, location of PTO.

1.3. System Analysis

The original type calls for operation at 540 revolutions per minute (rpm). A shaft that rotates at 540 rpm has 6 splines on it, and a diameter of 1⅜". Two newer types, supporting higher power applications, operate at 1000 rpm and differ in shaft size. The larger shaft has 20 splines (1¾" diameter), while the smaller has 21 (1⅜" diameter). All three types rotate counterclockwise when viewed from the tractor. A 10 spline type was used with some early equipment such as the 1948 Land Rover; a six spline adapter was usually supplied. It is customary for agricultural machines manufacturers to provide the nominal PTO power specification, an indication of the available instantaneous power at the shaft.

2. Objective

Various failures identified in the tractor implementation system was tabulated with the help of customer complaints and the feedback received from the direct farmers. The table 1 shows that the majority of the failures occurred in the PTO shaft when compared with the other failures. The main problem in shafts is they break down before the warranty period that is given by the manufacturer usually 3 years. It is due to the unequal power distribution from the power transmission shaft. For replacing the damaged shafts the manufacturer is spending about thirty thousand rupees. The breaking of shafts is due to improper power sharing. The number of splines present in the shaft

Sl.no	Problems	Part Damaged	No of complaints
1	Transmission Failure	Transmission System	5
2	Drive Failure	Hydro pump	3
3	Rear PTO /Case Failure	PTO shaft	50
4	Clutch Failure	Attachment Engagement	25
5	PTO Bearing failure	PTO Bearing	10
6	PTO housing Failure	Rear PTO housing	15

Table :1 Feedback & customer complaints

also plays a major role in the factor. The problem rectification method is being studied and found some methods for it. The problem can be solved by the following steps

- Reducing the number of splines on the shaft.
- Varying the material specification.
- Revising the arrangement of positioning of shaft.
- Providing pin projections on the face of shaft.

After finding the proper method of increasing the life of the shaft, the author can provide an accurate result for farmers as well as manufacturers so that they can make use of it in mere future

2.1 Methodology

Detailed study about the tractor & Implements

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Problem identification

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Collect the feedback used to prove the problem

↓

To find out original dimensions of the shaft

↓

Design process

↓

Analyzing the design

↓

Calculations

↓

Results and discussions

Figure: 1 Methodology

Figure: 1 shows the steps followed to analyze the existing system through product design and development technique. In the above methodology the original dimensions obtained by the physical measurement instruments.

2.2 Shaft Details

- PTO Speeds: Tractor PTOs are designed to rotate at 540 rpm or 1000 rpm. Shift able, dual-speed PTOs may reach a maximum power.
- PTO Splines: By counting the number of splines, or teeth on a PTO stub shaft, the beginning operator can identify the speed of the PTO shaft in RPMS. A 540 rpm PTO shaft will have 6 splines or teeth. A 1000 rpm PTO shaft may have 20 or 21 splines or teeth.

- PTO Sizes: PTO stub shaft diameter for a 540 rpm shaft is 1 3/8 inch. The 1000 rpm stub shaft with 21 splines or teeth is 1 3/8 inch. The 1000 rpm stub shaft with 20 splines or teeth has a diameter of 1 3/4 inch.

2.3 Modeling Of PTO Shaft

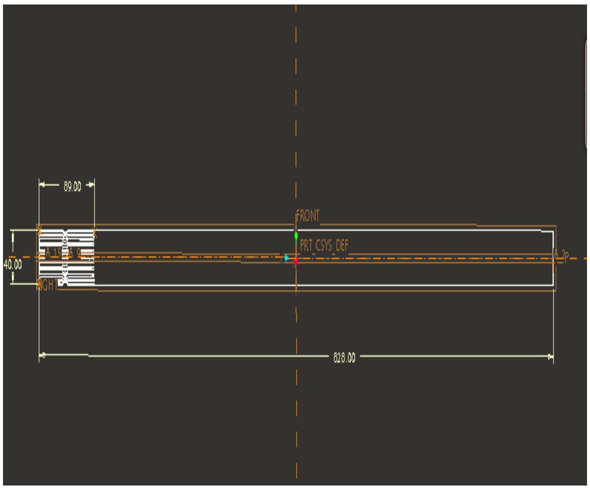


Figure 2.Power Take Off Drive-2D

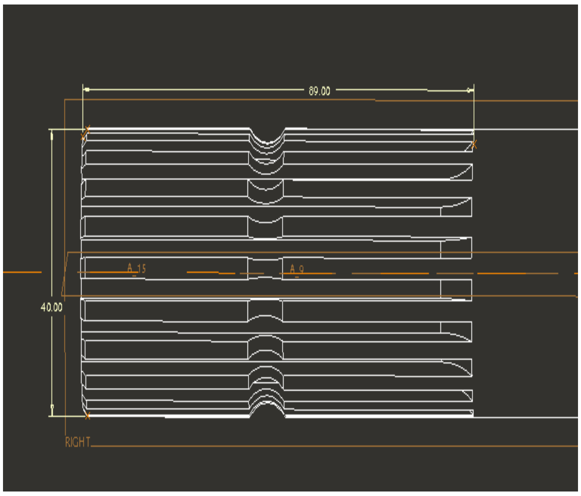


Figure 3.Power Take Off Drive-2D (Splines)

Modeling of the PTO shaft made by the use of Pro E wildfire software because it was identified that very much suitable for solid modeling. Figure 2 and Figure 3 shows the two dimensional details of the PTO shaft with specific view of the splines.

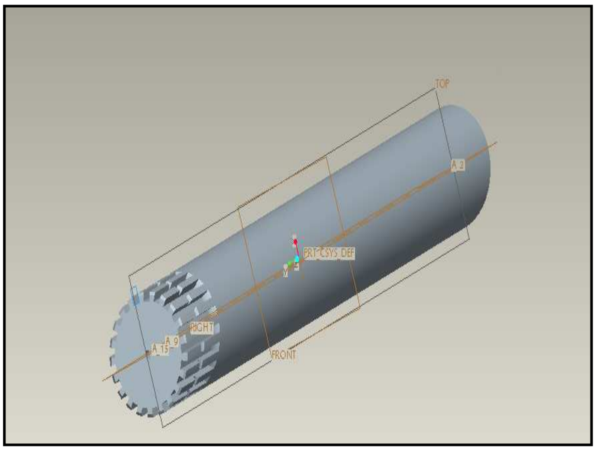


Figure 4.Power Take Off Drive-2D

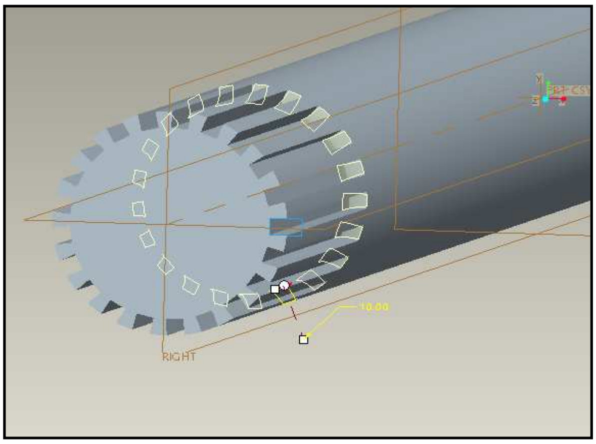
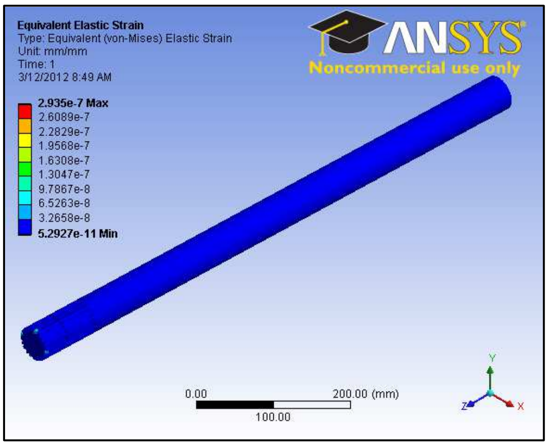


Figure 5.Power Take Off Drive-2D (Splines)

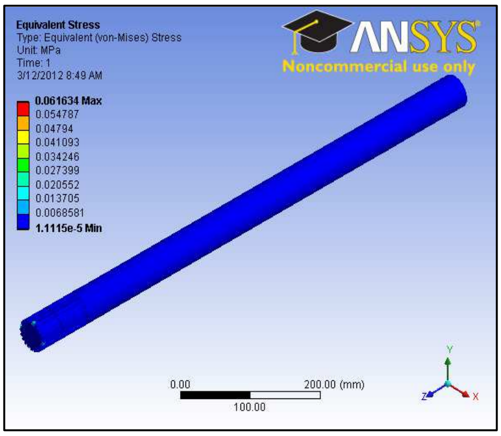
Figure 4 and 5 shows the three dimensional details of the existing PTO shaft for the analysis.

3. Results and Discussions

3.1 No of splines modifications:



(a)



(b)

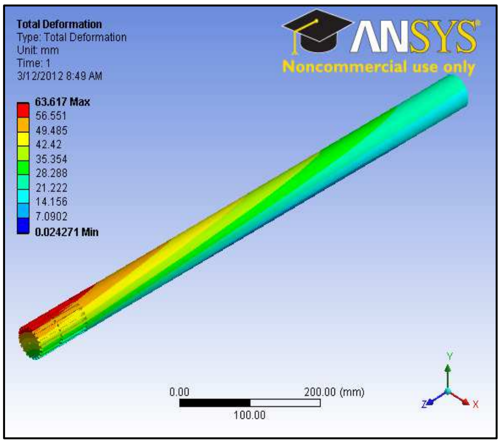


Figure:6 (c)

In the problem rectification method first step proposed is changing the no of splines in the existing system to analyze the stress level on the shaft. Figure 6 a, b, c shows the total deformation, von mises strain and von mises stresses clearly. The stress level will be higher on the spline surface, so that the damage on the splines occurred.

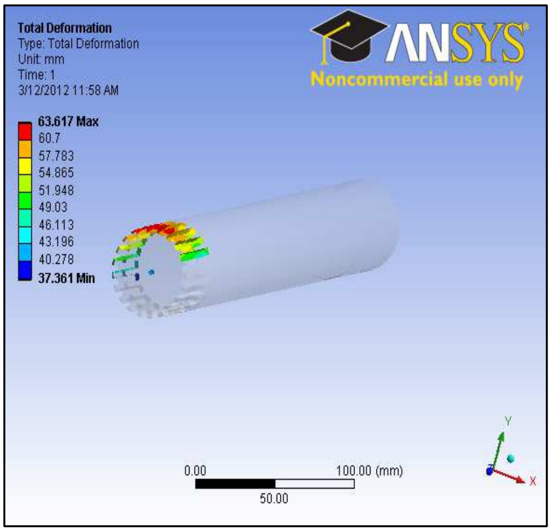
S.No	No of splines	Total deformation(mm)		Von mises stress(MPa)		Von mises strain(mm/mm)	
		Max	Min	Max	Min	Max	Min
1	21(Existing)	63.617	0.0242	0.0616	1.1115e-5	2.9350e-7	5.2927e-11
2	22	65.153	0.0646	0.0650	1.7150e-5	3.0966e-7	8.1171e-11
3	20	63.109	0.0264	0.0273	1.1006e-5	1.3037e-7	5.2411e-11
4	19	61.724	0.5103	0.0360	1.6608e-5	1.7513e-7	7.9084e-11
5	18	57.662	0.1147	0.0356	7.2464e-6	1.6953e-7	3.4507e-11
6	17	57.546	0.1109	0.0614	4.1509e-6	2.9257e-7	1.9766e-11

7	16	57.250	0.0686	0.0963	8.8477e-6	4.5892e-7	4.2132e-11
8	15	56.825	0.0585	0.0856	5.3652e-6	3.4659e-7	2.6265e-11
9	14	55.850	0.0407	0.0614	1.5323e-6	2.9284e-7	7.9266e-11
10	13	55.375	0.0161	0.0414	1.3619e-5	1.9750e-7	6.4852e-11
11	12	54.635	0.0230	0.0145	9.6686e-6	6.9219e-7	4.6041e-11
12	11	53.717	0.1518	0.0236	8.1080e-6	1.253e-7	3.8181e-11
13	10	53.307	0.0191	0.0299	7.7535e-6	1.4278e-7	3.6922e-11
14	9	53.558	0.0752	0.0918	8.4902e-6	4.3759e-7	4.0429e-11
15	8	53.577	0.0023	0.0849	1.5475e-5	4.0474e-7	7.3692e-11
16	7	55.769	0.0853	0.0584	1.6902e-5	6.5369e-7	8.5689e-11
17	6(Existing)	57.765	0.1279	0.0282	1.8801e-5	8.9531e-7	8.9531e-11

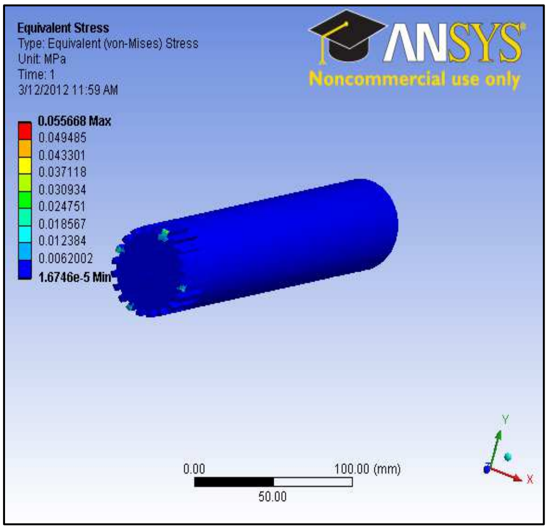
Table 2 Consolidated Results For Change In Splines

Table 2 shows the consolidated results by changing the splines on the circumference of shaft. Results shows that the reduction in no of splines will increase the capacity to withstand the produced stress.

3.2 Changes in the material specification:



(a)



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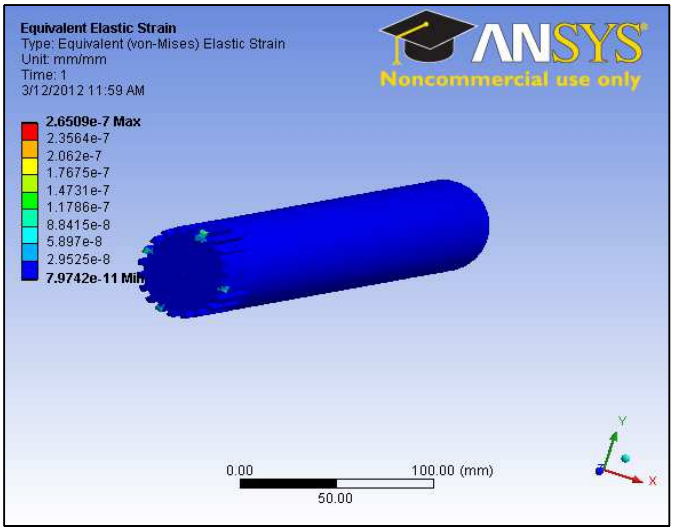

Figure: 7 (c)

In the problem rectification method second step proposed is changing the material specification in the existing system to analyze the stress level on the shaft. Figure 7 a, b, c shows the total deformation, von mises strain and von mises stresses clearly. The stress level will be higher on the spline surface, so that the damage on the splines occurred. The materials chosen for the analysis were C45, C55, ASTMA36, ASTMA242,ASTMA441, ASTMA572,Titanic steel and Al2014T6 with the help of material data book..Table 3 had the consolidated numerical result which consists of total deformation, von mises stress and strain.. From the table it was seen that change in material can cause the stress and strain values changed hence resulting in slight increase in life of shaft. Specifically ASTM A242 having some deviation when compared to the other standard materials.

S.No	Material	Total deformation (mm)		Von mises stress (MPa)		Von mises strain (mm/mm)	
		Max	Min	Max	Min	Max	Min
1	C45(Existing)	63.617	0.0242	0.0616	1.1115e-5	2.9350e-7	5.2927e-11
1	C55	63.617	37.361	0.05566	1.6746e-5	2.6509e-7	7.9742e-11
1	ASTM A36	66.798	1.0869	0.0556	1.6747e-5	2.7830e-7	8.3700e-11
2	ASTM A242	66.798	1.0869	0.0556	7.0120e-6	2.7840e-7	3.5060e-11
3	ASTM A441	66.798	0.0250	0.0616	1.2463e-5	3.0825e-7	6.2314e-11
4	ASTM A572	66.798	0.0250	0.0616	1.2463e-5	3.0825e-7	6.2314e-11
5	Titanic steel	66.798	0.0250	0.0616	1.2463e-5	3.0825e-7	6.2314e-11
6	Al 2014 T6	188.16	0.0720	0.0606	1.1890e-5	8.5455e-7	1.6750e-10

Table 3 Consolidated Results For Change in Material Specification

4. Conclusions and Scope for the Future

A detailed literature survey was completed to study about the Tractor, Implements and the Power Take Off system. Analyzing was been carried out using ANSYS software by applying load on the shaft and the power distribution among the shaft with different load conditions. From the first method by changing the no of splines, results shows that the reduction in no of splines will increase the capacity to withstand the produced stress. And second method result from the table it was seen that change in material can cause the stress and strain values changed, hence resulting in slight increase in life of the PTO shaft. Further improvement can be brought by changing the dimensions of the shaft with respect to ultimate shear stress, wear and tear.

Future work can be carried out in this concern by

1. Changing the dimensions of the shaft
2. Changing proper material
3. Strengthening the shaft by using like treatment.
4. The tilt angle of the shaft can be taken for different companies.

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