International Journal of Future Generation Communication and Networking
Vol. 13, No. 2, 2020 pp.1167-1174

Structural Analysis Of Composite Drive Shaft For Rear Wheel Drive Engine

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Abstract

This paper presents the structural analysis of the drive shaft of vehicle,although shafts are used in various transmission,but in this paper,the aim is to replace solid shaft in a specific vehicle case by a tapered hollow shaft,structural analysis of new shaft is in two parts firstly designing the shaft same structure dimensions limiting values.Secondly, compare it with original solid shaft,on some parameters such as weight,yield strength,,along with that analysis is performed on Solidworks stimulation for support result.The results show significant points about the feasibility of using hollow tapered shaft.

Keywords*—drive shaft,tapering,static torque,centre of mass,*

I. INTRODUCTION

Nowadays the use of shaft in transmission is quite familiar whether in industrial machines or automobiles,shaft in industries are designed specific,as per its use.but in case of automobiles and vehicle the use of shaft can be classified in categories ,as used in trucks,small loaders,four wheel drive vehicle, marine ships.Their are mainly two types of shaft that we all are familiar with, used in vehicle solid and hollow shaft,if both solid and hollow are of same weight, the hollow shaft is considered better then solid shaft on parameters such as polar moment of inertia torque produced and power to weight ratio, but still not used commercially in vehicles over solid shaft due to obvious reasons such as shaft body will be bigger,manufacturing cost of shaft will raise and few more aspects.The terminology propeller shaft is used for shaft in vehicles.Their are many reports presented on Desgin of propeller shaft and its material selection,which is mainly due to regular need of improvement.Through studies we find that the factors which mainly affect the performance of the shaft are Dimension of shaft,Structure of shaft,Weight,Critical speed,Strength,Stiffness.Their are other factors but they also somehow related to these factors mentioned.

II. DESIGNING OF HOLLOW TAPERED SHAFT

A. Significance

The torsional stiffness and resistance to bending of shaft increase directly in proportion to the cube of shafts diameter.This means that only a small increase in diameter will considerably stiffen the shaft, but the centre portion of the shaft contributes little to the torsional stiffness of the shaft.Since in hollow shaft the the absence of centre area from solid shaft does not affect much but the decline in weight of the shaft plays more effective role of improving efficiency of torque transmission,further lowering the weight of shaft considering minute degradation in other properties can be a good scenario to have.

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B. *Assumption*

Book formula for volume of frustum is accurate.The trigonometry relations holds good for small angles.Shaft is perfectly balanced considering centre of mass lies at the centre of the axis of rotation,under static as well as kinematic condition. The relation between mass and density for volume valid throughout the shaft crossection.The destination of the integration is true for number of elements elements tends to infinity under the limiting values.

C. *Specification*

In designing a new shaft a practical reference is the need to test the feasibility of Desgin in comparison to the original shaft within structure dimension limit and evaluating its parameters which it has to transmit the power.Selected a commonly used shaft with accurate specification provided from reliable source of information and data evaluate from precise experiments, get the data and find the tolerance under which the changes can be made considering factor of safety and application of the shaft used for the primary objective i.e, the transmission of power in vehicles.The structure of the selected solid shaft is shown in Fig.1 and the proposed model is shown in Fig. 2.Data for solid shaft is as follow

TABLE I. DIMENSION OF SOLID SHAFT

Length	**Diameter**
911.86219mm	58mm

TABLE II. SPECIFICATION OF SOLID SHAFT

Torque	**Max. RPM**	**Max. Power output**	**COM**
35.7Nm	2000rpm	11.3kW	457.6mm

Some properties parameter of the solid shaft from the source information are as follows.

$$S_S = 2.1\times10^{-6} G \, {}^{N}\!/_{m}$$

$$m_s = 26.4042\ell\partial$$

$$J_S = 1.1109\times10^{-6} m^4$$

$$T_S = 1.494\times10^{-3} p$$

Where COM stands for centre of mass,S_S stands for stiffness,m_S stands for mass of solid shaft,J_S stands for polar moment of inertia for solid shaft, Ts stands for strength of solid shaft

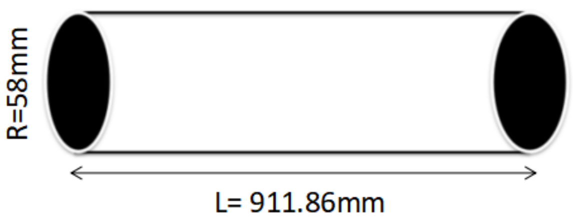

Fig.1

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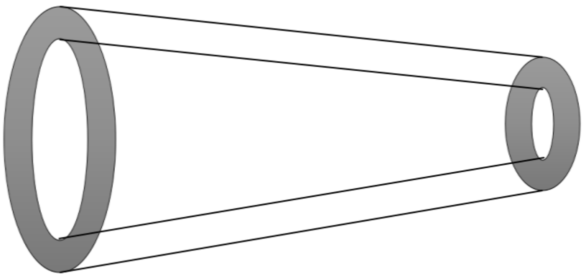

Fig.2

D. Calculation

- The permissible tapering allowance from original shaft is 0.251333^0 and we know the bigger outer radius of the shaft is 58mm $Sin\theta = \frac{p}{h}, Cos\theta = \frac{b}{h}, Tan\theta = \frac{p}{b}$ (1)

$b^2 + p^2 = h^2$ (2)

Where b,p,h are base ,height and perpendicular respectively of the triangle formed by the tapering angle.Using (1) and (2) we find the outer radius of the smaller end and the radius at the centre of mass. R1 is 25mm and R2 is 50mm.

- For a balanced shaft,the centre of mass of the shaft should lie at the centre of the line of axis of rotation as its is in solid shaft. In that case the the plane perpendicular to the axis of rotation and passes through the centre of mass will divide the the shaft in two equal halves say A and B as in Fig. 3

We can tell that volume of portion A is equal to the volume of portion B.The volume of the regions $V = \frac{\Pi}{3} h(R^2 + r^2 + Rr)$ (3) where V is volume of respective region,h is depth of the respective portion, R is bigger side radius respective portion , r is smaller side radius of respective portion.Where h is half of the length of the shaft.We know that both A and B portion are hollow the inner inner portion of A has r_1 and A as the smaller and bigger radius of hollow part respectively. While r_1 and B are the smaller and bigger radius of the hollow part of portion B in Fig.4 and Fig. 5.Using and volume of solid portion A equals to volume of solid portion of B,using (3) gives us a relation

$3.24 = (B - A)(A + B + r_1)$ (4)

Under a limiting condition,due to outer radius i.e,

$A < 2.5; B < 2.9; 2.5 < r1 < 2.9$

For the solution of the equation (4) with three variables,can't be solved by any of the method's, therefor using PYTHON COMPILER for solving the question up to 3 decimals,provides us six results out of which only one set of values holds good with other dimensions. Gives the result A=1.5,B=2.1,r_1=1.8,which are the inner radius of the hollow shaft drawn in Fig. 6

Using the evaluated dimension of the shaft whee find the inner tapering angle is 0.376990 ,as shown in Fig.7

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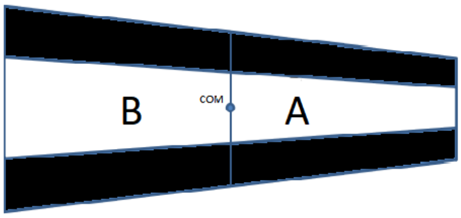

Fig.3

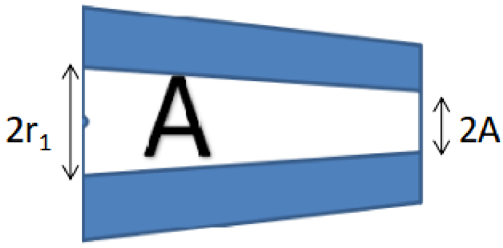

Fig. 4

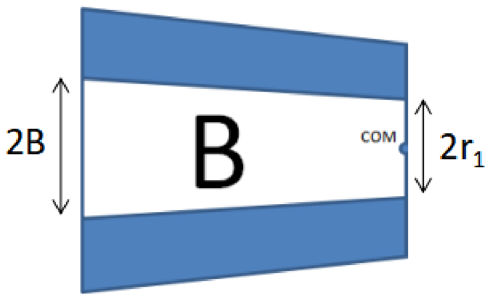

Fig. 5

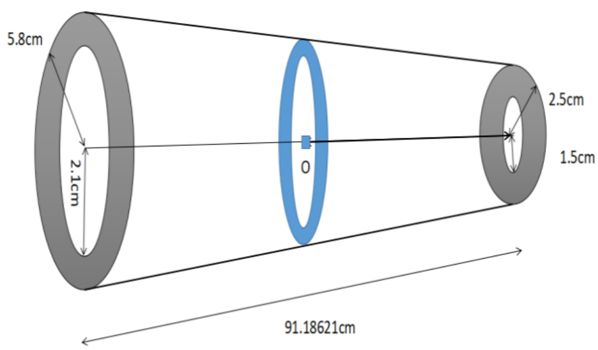

Fig.6

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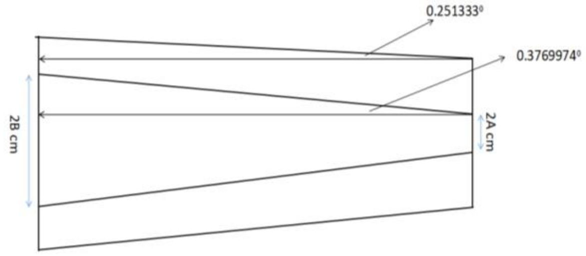

Fig.7

The weight of the shaft can be articulated using

$$\rho = \frac{m}{v} \tag{5}$$

Where v is volume of new shaft can be calculated using (3)
Volume of outer solid portion -Volume of inner hollow portion = Volume of new shaft gives,

$$m_n = 14.084\ell\partial$$

Other parameter to be evaluate are polar moment of inertia ,stiffness,strength,but as the cross section of shaft is not uniform throughout, the methodology used to find the polar moment of inertia is to disintegrate a shaft into tends to infinite parts,now each element is a hollow shaft with very small length,evaluation the polar moment of inertia of these elements whose limit tends to infinite,from their using PYTHON COMPILER helps to find the polar moment of inertia of the hollow tapered shaft using double integration.

$$J_{hollow} = \frac{\Pi}{2}(R^4 - r^4) \tag{6}$$

$$J_N = 0.655 \times 10^{-6} m^4$$

Similarly the strength and stiffness of the hollow tapered shaft of can be find applying same methodology and compiler to find the strength and stiffness of the hollow tapered shaft.

$$T_N = 0.64 \times 10^{-3} p$$

$$S_N = 0.7241 \times 10^{-6} G \, {}^{N}\!/_{m}$$

T_N is strength of shaft i.e, the load carrying capacity of the shaft,torsional strength is the max torque that the shaft can transfer without deformation and S_N stands for stiffness of shaft.

TABLE III. SOLID AND HOLLOW TAPERED SHAFT COMPARISON OF PARAMETERS

Parameters	**Solid Shaft**	**New Shaft**
Weight Ratio	1	0.533
Strength Ratio	1	0.69
Stiffness Ratio	1	0.667
Polar Moment Ratio	1	0.64

ISSN: 2233-7857 IJFGCN

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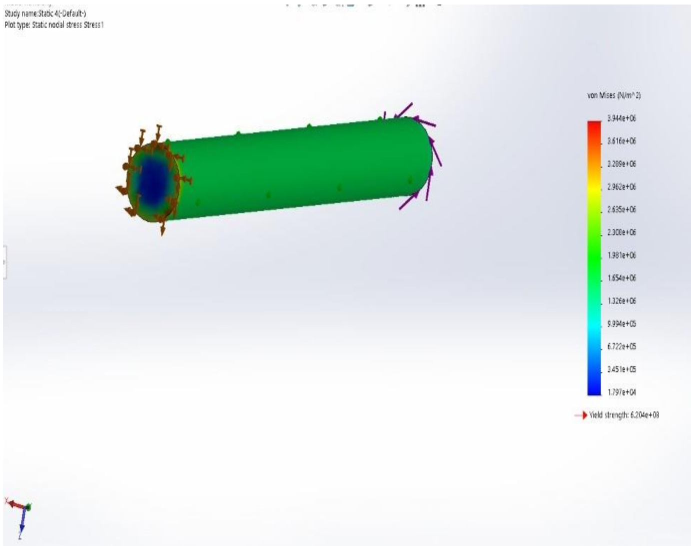
Stimulation

The theoretical analysis of the both solid and the hollow tapered shaft states that their is considerable account of difference in the properties of the shaft,keeping in mind that the weight of the hollow tapered shaft is almost reduced to the 50% of the solid shaft because the limiting dimension such as length and max diameter of shaft is taken same for both shafts because of the limiting guidelines of original shaft,to analysis the both the shaft in stimulation,rather than analytical evaluation will help the result,as we have taken some assumption calculating the properties, the following stimulation is done at the point when secondary end of the shaft is fixed Fig.(8) i.e, the rear wheels are at rest and max permissible torque applied to the shaft.And also shows the polarity change in the shaft either to place bigger end of hollow tapered shaft at rear wheel side Fig.(9) or the smaller end of Fig.(10),which shows that it is better to use smaller end for rear wheel side and transfer through bigger to smaller end.



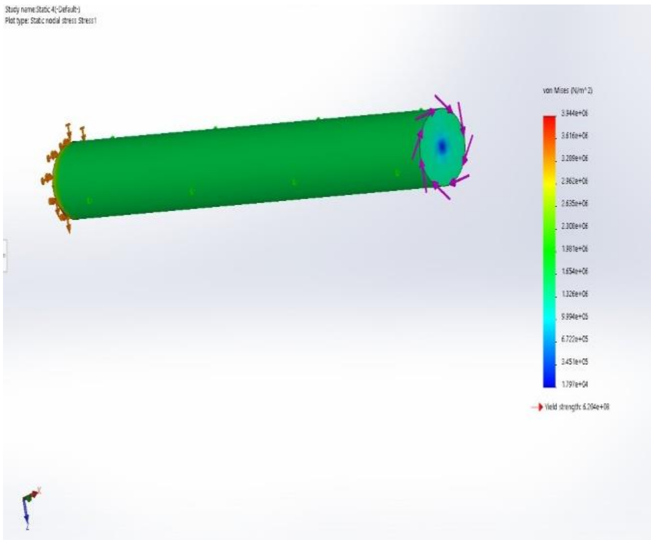


Fig.8

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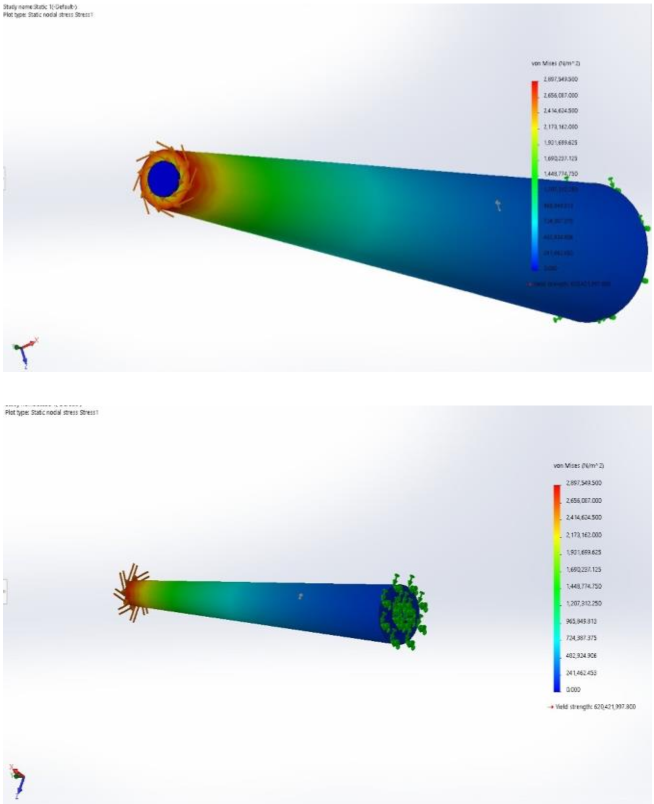

Fig. 9

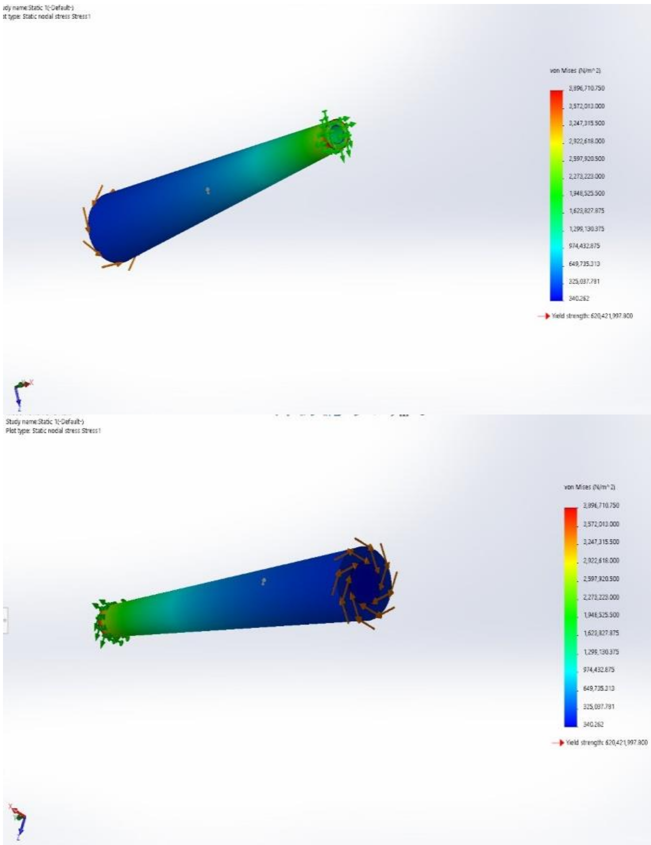

Fig. 10

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III. CONCLUSION

This paper shows that the new designed shaft or hollow tapered shaft has the feasibility to withstand the limiting condition at max applied torque,and can be taken in use if need the properties of designed shaft to be utilized, their are some parameters where hollow tapered shaft lags from solid shaft but, also posses some properties which are considerably good by big margin,shows that the hollow tapered shaft is replaceable to solid shaft when need .

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ISSN: 2233-7857 IJFGCN