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Study the Static Stiffness of a Propeller Shaft of a Car for a Maximum Torque Load to Evaluate the Shear Stress

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Abstract:- Steering feel and vehicle steering motion is affected by wheel torques from propulsion, especially for front wheel drive cars. Often these problems are referred to as "torque steer". Many systems interact to cause these problems: propulsion, steering and suspension. Torque steer supporters are not just the differential (contact, self-locking impact, Torsion differential), yet additionally the contribution from the beginning auto geometry, for example, street conditions (grating and surface), the vehicle state (cornering, moving, increasing speed) and weight dispersion (stacking). Also, the suspension configuration contributes too, similar to the suspension geometry (boss balance, camber, caster, (resiliences), the tire quality (conicity, wear, profile) and wheel geometry (estimate, consistency, wheel counterbalance). At long last, with respect to the transmission patrons, the motor (torque, arrangement) and drive shafts (arrangement, length, symmetry) are benefactors also. The term, Drive shaft is utilized to allude to a pole, which is utilized for the exchange of movement starting with one point then onto the next. Though the poles, which impel (drive the question ahead) are alluded to as the propeller shafts. Propellers are typically connected with boats and planes as they are pushed in water or air utilizing a propeller fan. However the drive shaft of the car is likewise alluded to as the propeller shaft in light of the fact that separated from transmitting the rotating movement from the front end to the backside of the vehicle, these poles additionally move the vehicle forward In car, driveshaft is the association between the transmission and the back hub are utilized by two-piece steel drive shaft comprises of three all inclusive joints, an inside supporting bearing and a section, which expands the aggregate weight of a car vehicle and declines fuel effectiveness. In this paper the research has been carried out for the designing and Finite Element Analysis of Propeller shaft. Analysis includes Structural Analysis (Linear static stress and Modal) and. Tortional load is required to calculate for the Static Stress Analysis and natural frequency of the system. CATIA V5 R17 is used for generating Geometric CAD modeling of the gear box housing. Hypermesh 3D is used as a Preprocessor for meshing and generating FE Model. ANSYS has been used as a Solver and Postprocessor. The results obtained from the FEA is as discussed in details.

***Keywords**:- Propeller shaft, Solid Works 14.0, Hypermesh, LS-Dyna.*

I. INTRODUCTION

A car may utilize a longitudinal shaft to convey control from a motor/transmission to the opposite end of the vehicle before it goes to the wheels. A couple of short drive shafts is usually used to send control from a focal differential, transmission, or transaxle to the wheels. Drive shaft (Propeller shaft) is a mechanical piece of transmission framework which is utilized to exchange the power from motor to the wheel. The development of vehicles can be given by exchanging the torque created by motors to wheels after some change. The exchange and alteration arrangement of vehicles is called as power transmission framework and have diverse productive highlights as per the vehicle's driving write. Most cars today utilize unbending driveshaft to convey control from a transmission to the wheels. A couple of short adaptable driveshaft is ordinarily utilized as a part of autos to send control from a differential to the wheels. In autos, pivot shafts are utilized to associate haggle at their closures to transmit control and rotational movement. In activity, pivot shafts are by and large subjected to tortional stress and twisting worry because of self-weight or weights of parts or conceivable misalignment between diary heading..

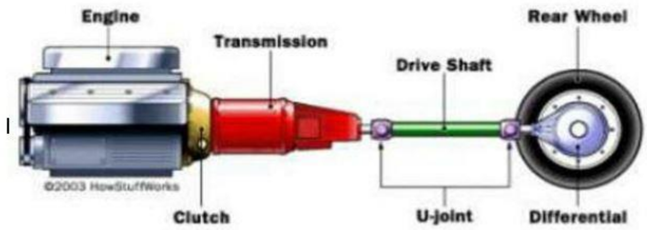

Fig 1:- Schematic of Drive Shaft used in passenger car

A. Function of Propeller Shaft

Propeller shaft is used to transmit the power from the engine to the rear axle. Hollow propeller shaft is used to reduce weight and inertia losses. It is subjected to torsional shear stress. So they need to be strong enough to withstand this stress.

B. Operational condition for the propeller shaft:

- Propeller shaft transmit power coming out from the gear box to the differential and then the axle. It transmits the torque either positive or negative (in reverse gear). It uses to transmit the angular torque; it also permits the vertical movement of the wheels while transmitting the torque; the propeller shaft stands with axial thrust, bending moment; torsional shear stress.

- Most of the time the propeller shaft transmits the power at some angle, it is not horizontal mounted, but some cars have propeller shaft in horizontal position rather than angled. Propeller shaft is connected by the universal joints to the transmission shaft and differential. In small cars the shaft is in horizontal position it and generally connected with the flange the other end to connect the transmition shaft. Some of the cases are explained below that the propeller shaft contains higher torsional shear stress. Mostly it is depend on the road condition. The propeller shaft experiences the maximum torsional shear stress or twisting,

II. PROBLEM DEFINITION

Propeller shaft is used to transmit the power from the engine to the rear axle. Hollow propeller shaft is used to reduce weight and inertia losses. It is subjected to torsional shear stress. So they need to be strong enough to withstand this stress. Some of the cases, the propeller shaft contains higher torsional shear stress. Mostly it is depend on the road condition.

Considering the starting condition of the car as worst load case, the maximum torque is experience by the propeller shaft. As the first gear has high gear ratio increases the torque transmitted at the gear box and at less rpm. So the starting condition that is vehicle in first gear and just about to move will input the high torsional shear stress in the propeller shaft, hence this condition is taken to model and analyzed.

III. METHODOLOGY TO MEET THE OBJECTIVES

- To review the existing literature on Propeller Shaft
- Based on application and reviewed literature design specifications were arrived.
- Geometrical modelling of Propeller Shaft will be created using Catia Software
- Finite element model was created using the Hypermesh Software.
- FE analysis performed using ANSYS Software
- Design calculation has been carried out to evaluate the Stress criteria.

IV. GEOMETRICAL MODELING

A geometrical model is created in with 1:1 scale in CATIA V5-R17 (figure no.). A geometrical model is created with universal joint yoke at one end and splines of slip joint at other end. This model as to be meshed for analysis, so considering time constrains, and to make geometry simple some simplification are made.

Simplifications with justification:

- All fillets are removed: fillets are difficult for meshing.
- Splines are removed: meshing is complicated in spline area.
- Yoke: yoke dimensions are simplified to avoid the complicated curved as it is difficult in meshing and also yoke is not area of interest. It reduces the time required for meshing.
- Welding area: welding area avoided in model, as welding is not uniform in area so it is difficult and critical to mesh.
- Flange is not considered for the modeling because of the time constrains.

A. *Geometric Modelling of Propeller Shaft*

The modelling is finished utilizing Catia with the assistance of standard measurements that we overcame the cautious survey. The Catia is one of the renowned demonstrating programming accessible in the market which empowers us not exclusively to do the displaying of the segments yet in addition the investigation of the same. Hence it is one of the ideal software for modeling and analysis problems. The following diagram is the model of the Propeller Shaft which is created using the Catia Software.

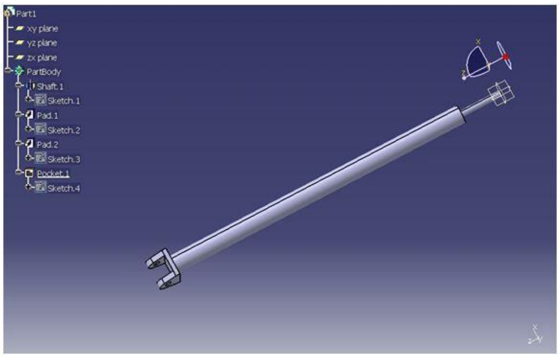

Fig 2:- Propeller Shaft Geometric Model

B. *Design Assumptions of Mono Crankshaft*

Propeller shaft transmit power coming out from the gear box to the differential and then the axle. It transmits the torque either positive or negative (in reverse gear). It uses to transmit the angular torque; it also permits the vertical movement of the wheels while transmitting the torque; the propeller shaft stands with axial thrust, bending moment; torsional shear stress.

Most of the time the propeller shaft transmits the power at some angle, it is not horizontal mounted, but some cars have propeller shaft in horizontal position rather than angled. Propeller shaft is connected by the universal joints to the transmission shaft and differential. In small cars the shaft is in horizontal position it and generally connected with the flange the other end to connect the transmition shaft.

V. FINITE ELEMENT MODELING

In this chapter a geometric model is converted into a Finite Element Model, selection of element type, assumption of loading and boundary condition are discussed as below:

The limited component is a scientific strategy for settling common and halfway differential conditions, due to its numerical technique it has a capacity to take care of complex issues which are spoken to as differential condition. These sorts of conditions happen normally in all fields of the physical science and application shrewd it is boundless as concern the arrangement of handy plan issues. Commonly FEA is described as a discretization technique.

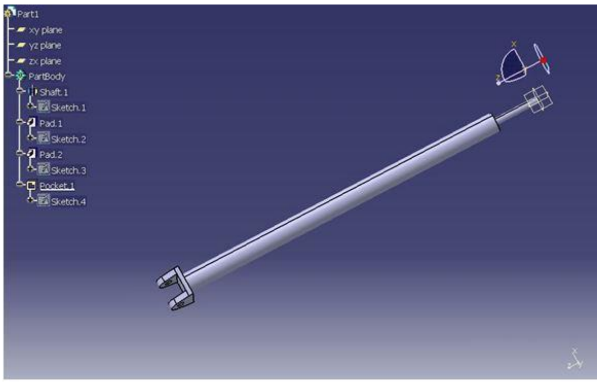

Fig 3:- Geometric Model of the Mono crankshaft

A. Defining the element connectivity's (meshing the model)

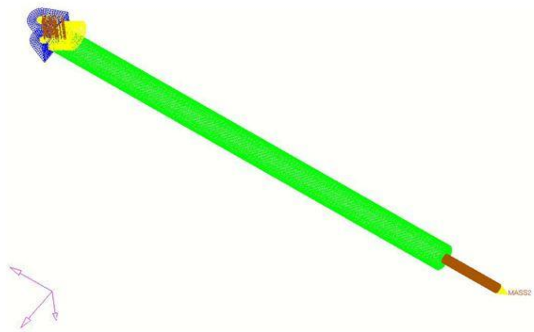

Fig 4:- Finite Element model of a mono crankshaft

Basically geometry have a various entities like point, lines, curves, areas, surfaces, volume & solids. But in the FEA we have only two entities i.e, nodes & elements. FEA entities are build with respect to the geometric entities & for the simulation only FEA entities are considered.

Finite element modeling of the Propeller Shaft is done in the Hypermesh 10.0 software. And the mesh model of the crankshaft is as shown in the figure 4.

B. Meshing Details

Sl.No	Description	Required Quality Parameter	Achieved Parameter
1	Warpage	<5	0.65
2	Aspect ratio	<5	4.98
3	Jacobian	>0.65	0.67
4	Min. Angle	>45	45.56
5	Max. Angle	<135	132.55
6	Total No. Elements	-	161840
7	Total No. Nodes	-	174709

Table 1. Element Quality Parameters for a 3D Solid Elements

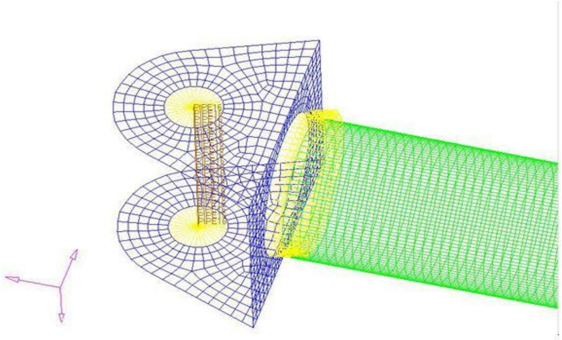

Fig 5:- Meshing of Yoke and Shaft Area with pipe element & rigid connection

Fig 6:- Meshing of Spline Shaft and mass element

VI. MATERIALS PROPERTIES

The material properties used for the Sheet metal and its mechanical properties is as shown below

SL No.	Description	
1.	Components	Crankshaft
2	Material	Steel
3.	Young's Modulus	2.1e5Mpa
4.	Poisson's Ratio	0.3
5.	Yield Strength	250Mpa

Table 2. Materials properties

VII. DEFINING THE PHYSICAL CONSTRAINT (BOUNDARY CONDITIONS)

The propeller shaft has flange at one side and yoke at other, so this shaft remains horizontal while working;. The propeller shaft is subjected to following boundary condition while working as shown in fig.4 from figure.5 Z is the longitudinal direction of the shaft, while Y is the vertical and X is the transverse direction.

Torque coming out of the engine is transmitted trough gear box to flange. At this end the flange is fixed to the flange of transmission box shaft, because of that one degree of freedom is remains free, which is at flange rotating about its own axis (Z axis).

A. Defining the Loading conditions and Calculations

For this assignment the starting case 1 is consider for loading in FE model that is the vehicle is at the starting from the rest condition . For this case consider the rated torque which is less than the maximum torque. That is 135 Nm. So 120 Nm torque is supposed to be applied when vehicle is in the first gear and it is about to move.

This is the torque coming out of the engine shaft, and then there is the gear ratio for the first gear is 3.736:1, there for actual torque transmitted by the gear box to the propeller shaft = 110 x 3.376= 410.96 Nm = 410960 N-mm.

Momentum experienced by the shaft at its centre is 410960 N.mm, so torque applied at the splines face to get that momentum is = 410960 / 11.25 = 36529.7 N.mm, as shown in fig. () torque applied at point P 39861.3 N.mm gives momentum of 448440 Nm.

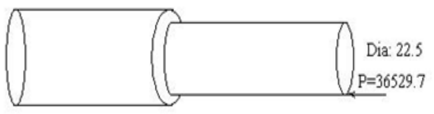

Fig 6:- Torque applied at splines on the shaft

Consider the vehicle is moving from the rest; engine torque has to overcome the inertia force of the vehicle that is, it has to overcome rolling resistance. This force acts as the torque in the opposite direction of the torque coming from the engine shaft at the universal joint at the final drive side. The vehicle has C.G. position at 55:45 of wheel base. That is load at rear wheel is 55% of the gross vehicle weight.

Gross vehicle weight is 1650 Kg that is (1650 x 9.81) N = 16186.5 N. The rolling resistance is (WR x μ x cosθ), condition the vehicle is standing on straight θ is zero, μ is 0.015, [4].

- So the rolling resistance = (16186.5 x 0.015) = 242.79 N.
- So rolling resistance for rear wheel is 2.4279 x 0.55 = 133.5 N

This can be mentioned as 133.5 N-mm torque. This force acts in the opposite direction of the torque coming out of the engine. Finally with boundary conditions shaft is like as shown in fig.7.

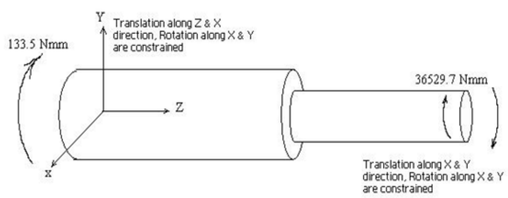

Fig 7:- Shaft with boundary conditions

VIII. STRESS ANALYSIS & RESULT REVIEW OF A PROPELLER SHAFT

Stress analysis is carried out based on the Static or steady state condition, where the solution is independent of time. Inertial forces are either ignored or neglected and so there is no requirement to calculate actual time derivatives.

Before analysis the basic assumptions are made as shown below:

- All deformations and strains are little.
- Structural disfigurements are relative to the heaps connected.
- All materials act in a direct versatile manner. Henceforth, the material twists along the straight line part of the pressure strain bend. Very confined pressure fixations are typically allowed insofar as gross yielding does not occur.
- Loads are on the whole static. This implies the heaps are connected to the structure in a moderate or enduring style and in a way that influences them to time autonomous
- No limit condition differs with time or utilization of load.

To perform a stress analysis of a crankshaft ANSYS 10 software is used, meshed model of Mono-Crankshaft with steel as a material property as shown in the table2.2, is imported from the HYPERMESH 8 software.

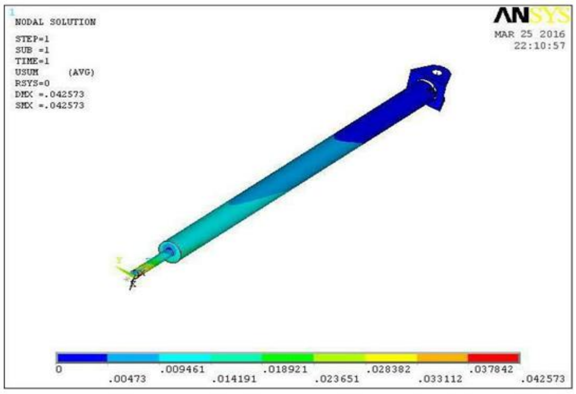

Fig 8:- Displacement vector sum of the steel propeller shaft

The graphical representation of the above figure 8 shows the displacement variation on several location of the Propeller Shaft. The maximum displacement observed due to surface load is 0.0425 mm

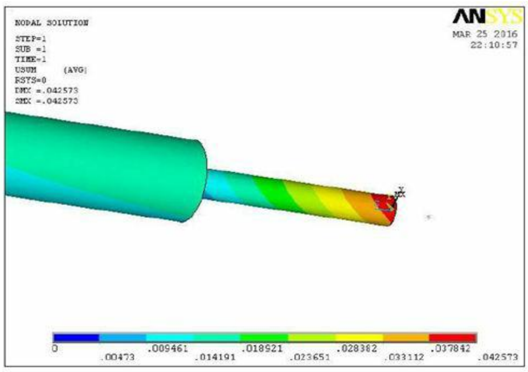

Fig 9:- Closer view of displacement vector sum of steel propeller shaft

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From the above figure (8) and figure (9) it is clear that maximum displacement is in the solid shaft and the displacement is occurring in the plane inclined almost at 40-450 to the plane XY. Displacement vector sum is the sum of the displacement sum in X, Y, and Z direction. And the maximum displacement in the shaft is 0.0425 mm.

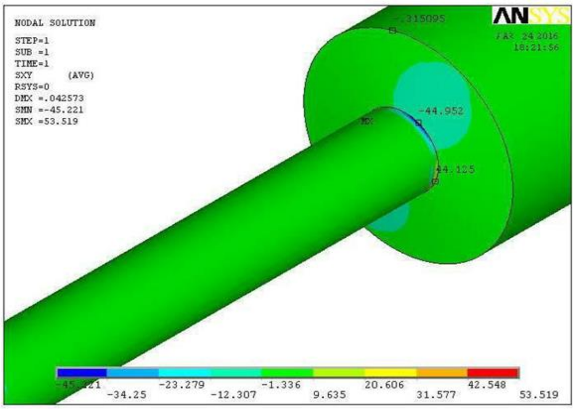

Fig 10:- Shear stress in XY plane of steel propeller shaft

It is in the splines, as the torque is applied at the perimeter of the solid shaft at the splines end. So the area in red color in fig. (9) is nearer to the torque applied, also diameter against the torque is less, hence showing high displacement.

From the fig.(9)we can conclude that shaft is in the alternate compressive and tensile stress as go on circular surface also of equal magnitude. figure (11) shows the values of the shear stress 44.952 N/mm2 in compressive nature and 44.125 N/mm2 tensile in nature. As we are interested in the shear stress as moves away from the radial direction, shear stress in XY plane is the point of interest.

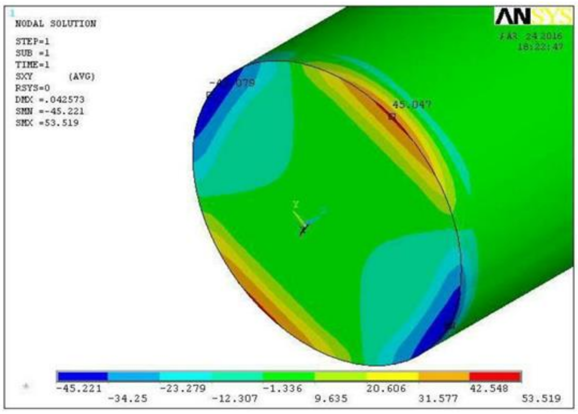

Fig 11:- Shear stresses in the XY plane of the steel shaft at the solid shaft end

Actually the spline could be the area of interest as the more changes in area, so that could be the area of high stress. Splines have less area against the torque so that should be highly stressed area. As shown in the fig. (11) nature of shear compressive and tensile stresses is with higher tensile value (53 N/mm2) at the spline end of the solid shaft, but here stresses are higher at the outer surface of the shaft. And goes on reduces as radius goes less.

IX. DESIGN CALCULATION

Under maximum load so first calculate the shear yield point, with this value we can ensure that the values are with the permissible range or it is more than limit.

$$\text{Shear yield point} = 0.58 \times S_{yp} = \boxed{0.58 \times \textit{tensile yield strength}}$$

Tensile yield strength of the material steel is **284** Mpa.

$$\text{Shear yield point} = 0.58 \times 284 = \mathbf{164.89\ N/mm^2}$$

$$\text{Ultimate shear strength} = \boxed{0.5 \times \text{Ultimate tensile strength of the material}}$$

$$\text{Ultimate shear strength} = 0.5 \times 385 = \mathbf{192.5\ Mpa.}$$

For calculating the shear stresses in the shaft. We have to calculate polar moment of inertia for the solid and hollow shaft.

$$J_{solid} = \frac{\Pi}{32} d^4 = \frac{\Pi}{32} \times 22.5^4 = 25161.12\ mm \ \ldots [3]$$

$$J_{hollow} = \frac{\Pi}{32}(D^4 - d^4) = \frac{\Pi}{32} \times (64^4 - 60^4) = 374754.13\ mm \ \ldots [3]$$

For calculate the angular deflection θ.

$$\theta = \frac{T}{J}\frac{L}{G} = \frac{T}{G}\left(\frac{l_{solid}}{J_{hollow}} + \frac{l_{hollow}}{J_{hollow}}\right)$$

T= Maximum torque = 160 N-mm; …..[3]

G = Modulus of rigidity = 80 GPa

$$\theta_1 = \frac{160000}{80081.63}\left(\frac{152}{25161.12} + \frac{1090}{374754.13}\right) = \mathbf{0.0179\ rad}$$

The inertia toque also applied on the reverse direction so that to get the actual deflection we have to take deduct this value from the opposite torque is also applied, so deflection due to that torque has to be calculated and then deduct that from that above deflection. θ1

$$\theta_2 = \frac{T}{J}\frac{L}{G} = \frac{133.5}{374754.13}\frac{1090}{80081.63} = 2.66 \times 10^{-6}\ \text{rad}$$

The stresses due to the maximum torque T in the solid shaft

$$D = 1.72\left(\frac{T_{max}}{\sigma_{max}}\right)^{1/3} \quad [4]$$

For this Tmax is 160000 N-mm and D is 22.5 mm, therefore σmax 71.41 N/mm is the maximum shear stress in the solid shaft.

Maximum torque T in the hollow shaft can calculate by:

$$T = \Pi/16\, f_s \left(\frac{D^4 - d^4}{D}\right) \quad [4]$$

T = 160000 N-mm,
D is outer diameter of the shaft= 64 mm
d is inner diameter of the shaft = 60 mm.
So the fs = 13.66 N/mm.

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X. MODAL ANALYSIS OF PROPELLER SHAFT

It is the technique used to determine a structur's vibration characteristics of a structure or machine components, mainly:

- Modal analysis is used to find the natural frequencies a structure
- The frequencies are calculated in increasing order of frequency magnitude. Users can define number of frequencies desired or a range of frequency magnitudes.
- Two things are important - mode shape and frequency. The actual values of displacement are not physically meaningful, only the shape of the deformation is important.
- The information modal analysis gives is extremely valuable - it can help to make design decisions without further vibration analysis required.[4]

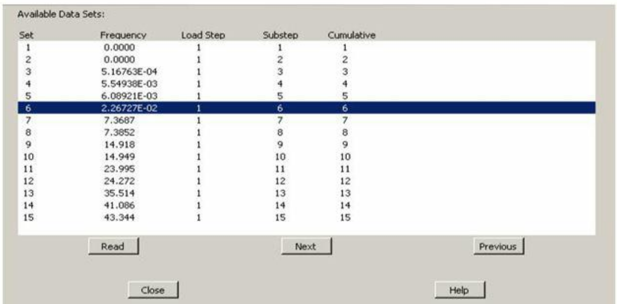
A. Modal Analysis results

Modal analysis is used to find out the natural frequencies and mode shapes of a structure. These are very important parameters in the design of structure for dynamic loading conditions.

In the ANSYS, modal analysis is a linear analysis. Modal analysis is done by the "Block Lancoz method". For this analysis meshed model is imported from Hypermesh software, and analysis is done. For the modal analysis material properties like Modulus of elasticity (2.1e5) and density (7.86e-6)of SM45C are necessary. Also we have to make a decision how many numbers of mode shapes to be extracted.

Natural frequency of the shaft is calculated when there is no load and no constrains, this analysis is called free-free analysis. In fixed-fixed analysis constrains are applied without load.

In this type of analysis no constrains are applied to the propeller shaft and first 15 modes are extracted within frequency range of 0-25 Hz. As maximum rpm of propeller shaft would be 5500 for this selected car, the frequency of maximum rotation is 14.59 Hz. For higher frequency shaft will not give that much response, so next higher frequencies are not the point of interest. Extracted natural modal frequencies are shown in table (3.1).



Available Data Sets:

Set	Frequency	Load Step	Substep	Cumulative
1	0.0000	1	1	1
2	0.0000	1	2	2
3	5.16763E-04	1	3	3
4	5.54938E-03	1	4	4
5	6.08921E-03	1	5	5
6	2.26727E-02	1	6	6
7	7.3687	1	7	7
8	7.3852	1	8	8
9	14.918	1	9	9
10	14.949	1	10	10
11	23.995	1	11	11
12	24.272	1	12	12
13	35.514	1	13	13
14	41.086	1	14	14
15	43.344	1	15	15

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Fig 12:- Natural frequencies in free-free conditions

We get the first two modes are exactly zero and next four are almost zero, because in free-free conditions first six modes have the natural frequency zero. The next one is 7.3687 Hz, and it is called as fundamental natural frequency. Mode shape for this frequency is shown in fig.12.

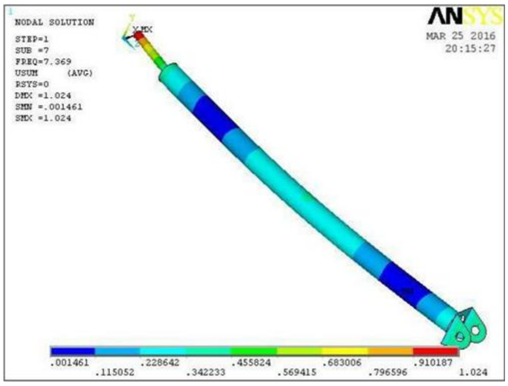


Fig 13:- Mode shape of fundamental natural frequency

We can observed that there are no fixed nodes on the hollow shaft, there for there is no zero displacement value is showing in fig. (13).

The ninth mode of vibration is 14.918 Hz and it is relative to the maximum rpm of the rotation of the shaft that is 5500 is shown in fig (14).

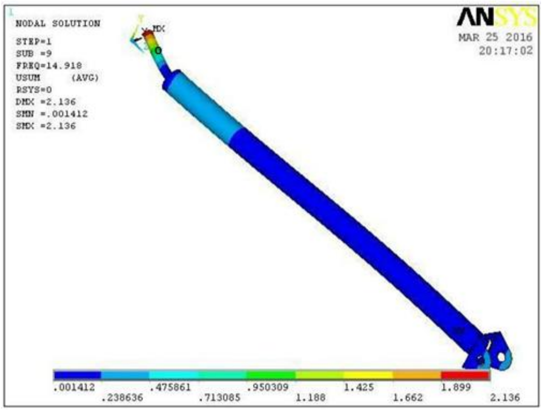
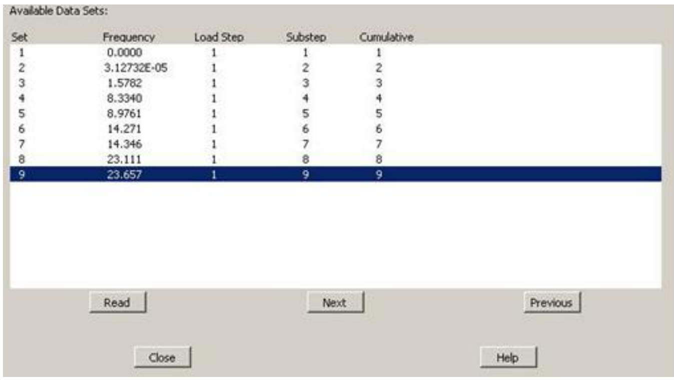


Fig 14:- Ninth mode of vibration of the shaft at 14.918 Hz

B. Modal Analysis results of fixed-fixed analysis:

In this type of analysis only constrains are applied to the propeller shaft and first 15 modes are extracted within frequency range of 0-1000 Hz. As maximum rpm of propeller shaft would be 5500 for this selected car, the frequency of maximum rotation is 875 Hz. Extracted model frequencies are shown in table (15).

From the fig () we can observed that first two modes are coming to almost zero. As the rotation along Z direction is set free the modal frequency in that direction is zero like other displacement along Z direction is set free at spline end of solid shaft second modal frequency is coming to zero. The frequency 1.578 Hz as shown in the fig. (15), that is the third mode of natural frequency.


Available Data Sets:

Set	Frequency	Load Step	Substep	Cumulative
1	0.0000	1	1	1
2	3.12732E-05	1	2	2
3	1.5782	1	3	3
4	8.3340	1	4	4
5	8.9761	1	5	5
6	14.271	1	6	6
7	14.346	1	7	7
8	23.111	1	8	8
9	23.657	1	9	9

Fig 15:- Natural frequencies in fix-fix conditions

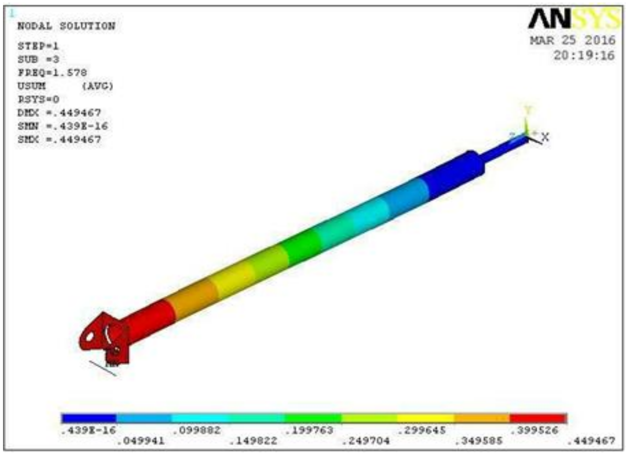


Fig 16:- The third mode of vibration of shaft in fixed-fixed condition at 1.578 Hz

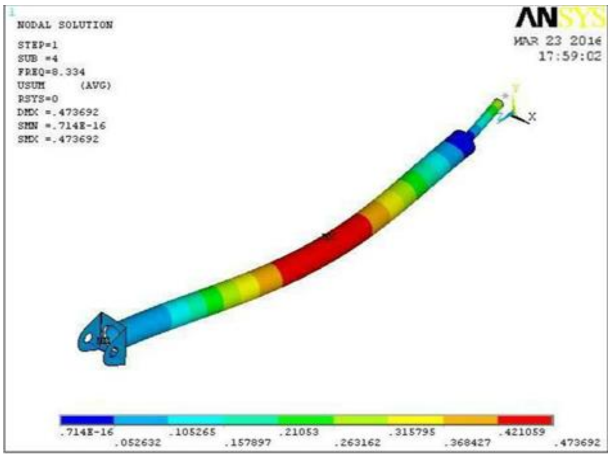


Fig 17:- Fourth mode of vibration of shaft in fixed-fixed condition at 8.334 Hz

The forth mode of frequency is shown in fig(17) that is 8.334 Hz. In fixed-fixed condition shaft is skipping its natural mode of vibration of 7.369 Hz.

- *Dynamic behaviour of the shaft*

Since we are only considering the As the fundamental natural frequency of the shaft is 7.369 Hz that is 2778 rpm, shaft will show resonance at this rpm of the shaft, but it will not break because when shaft get assembled and joined to the other parts its stiffness will increase, hence its natural frequency will increase. As 2778 rpm is its fundamental natural frequency shaft will show high response at this particular rpm. This will create problem of high vibrations and noise in the car.

Some times this effect will affect the other system not to work properly. Also its different modes of vibration will decrease the mechanical efficiency of the system or shaft. High response in the shaft will create fatigue type of loading in the shaft after long period of use. This may cause to break the shaft.

Different mode shapes may create axial trust at the joints of the shaft.

XI. REPLACE BY ALUMINUM MATERIAL

The values of the aluminum is edited the software and again run for the conclusion.

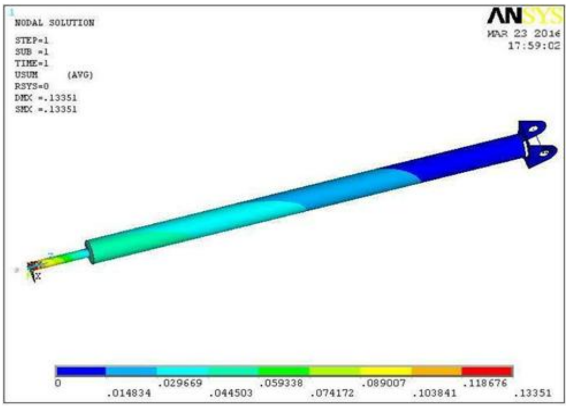


Fig 18:- Displacement vector sum in aluminum shaft

Comparing displacement vector sum in steel and aluminum shaft, displacement sum in aluminum shaft is almost 3 times that of steel.

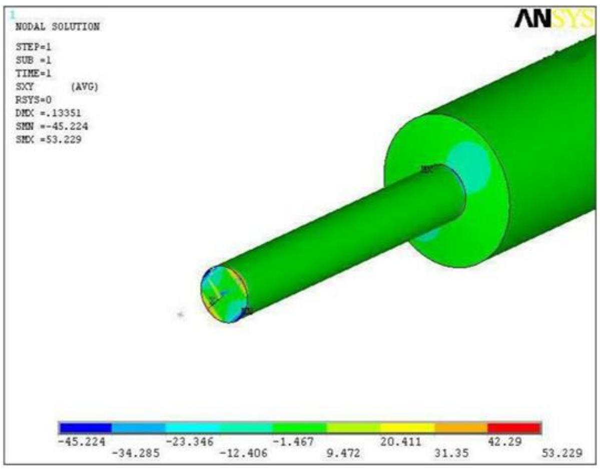


Fig 19:- Shear stress in X-Y plane of aluminum shaft.

Comparing the values shear stresses variation in aluminum and steel, values of shear stress both in compressive and tensile is almost same. But deflection in aluminum shaft is larger than steel material shaft.

By the calculation:
Shear yield point for aluminum is:

0.55 x Tensile yield strength = 0.55 x 40.04 = 22.0.3 N/mm^2 ... [2]

- Figure tells about the shear stress above 22.03 N/mm2 is measuring on solid shaft.
- For the same dimensions aluminum with tensile strength 40 MPa and shear modulus 27 GPa. Cannot able to uphold this load.
- Though the aluminum is failing on this load we can also use the aluminum alloy with the higher grade of tensile strength and shear with geometrical modifications. But there are certain drawbacks of using aluminum as a material for propeller shaft, listed below:
- Manufacturing with aluminum is difficult and costly
- Availability of aluminum is less than steel
- Welding is the big problem with aluminum

XII. CONCLUSION

- In this thesis an existing vehicle propeller shaft modeling is carried out in CATIA. And the iges file of the model is transfer to hypermesh and the meshing of the model is done and analysis of the model carried out in the Ansys.
- With the results plotted the existing design is safe for that torque and rpm.
- The exiting shaft can be further optimize by reducing the diameter of the shaft, but because the splines on the slip joint are not considered for analysis the design optimization is not done.
- Modal analysis is done to find the natural frequency and the mode shape of the shaft.

REFERENCES

[1]. Atul Kumar Raikwar, Prof. Prabhash Jain & Rajkumari Raikwar on ‘‘ Design and optimization of automobile propeller shaft with composite materials using FEM Analysis’’ in 2016 IJEDR | Volume 4, Issue 4 | ISSN: 2321-9939.
[2]. Lohitesh Jaga Kumar “Study of the static structural analysis of the mono crankshaft for bending and torsional load” in June 2018 |Volume 4,Issue 6.
[3]. Naveenkumar Dasanagouda and Vinayak Koppad on ‘‘ Numerical Analysis and Optimization of Passenger Car Drive Shaft’’ in International Journal for Research in Applied Science & Engineering Technology (IJRASET) in 2015.
[4]. Deepti kushwaha and Gaurav Saxena on ‘‘ Optimal Design And Analysis Of Composite Drive Shaft For A Light Commercial Vehicle’’ in International Journal of Advance Engineering and Research Development on 2016.
[5]. Vinodh Kumar S, Sampath V and Baskar P on ‘’Analysis of Propeller Shaft for Composite Materials’’ in Research Journal of Recent Sciences ISSN 2277-2502.