NOVATEUR PUBLICATIONS
International Journal of Research Publications in Engineering and Technology [IJRPET]
ISSN: 2454-7875
VOLUME 3, ISSUE 6, Jun.-2017

FAILURE ANALYSIS AND DESIGN MODIFICATION OF BRACKET OF CENTER BEARING OF PROPELLER SHAFT OF ST BUS

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ABSTRACT:

In the heavy transport vehicles basically front engine rear wheel drive type a propeller shaft is one of the most important component in transmitting power from the engine to the rear wheel drive. This propeller shaft is supported by the bracket fixed to the chassis. The center bearing bracket share about half overhanging portion of propeller shaft along with ball bearings. It enables reducing the length of propeller shaft to some extent.Fatiogue failure is a concern which may lead to the operational failure of the propeller shaft which ultimately results into the failure of transmission. Some common causes of failure are manufacturing ,design maintenance, raw material and the operating conditions. The aim of the this project is to find out the probable reason of the failure of bracket by analyze it with CAD software and to provide a satisfactory solution to this failure by changing dimension and material. This paper research is divided into two parts first to conduct survey amongst the buses & examine the causes of failure and second is to design and analyzed is recommended best possible alternatives of propeller shaft with the aid of advance design tool like CAD. Propeller shaft failure is one of the major problems facing for MSRTC workshop supervisors and Engineers.

This paper represents the available literature of failure analysis of a propeller shaft mounting bracket and analyzes the premature failure in center bearing bracket. Creo elements /Proe software is used for modeling and with the help of Ansys the stress and strain analysis were carried out. Base on the results of existing bracket dimensions the new bracket is designed and found that the stresses are within the allowable range.

KEYWORDS: Propeller shaft, center bearing bracket, transmission system, failure analysis, Creo, elements FEM, Ansys etc.

INTRODUCTION:

In an automobile the power is developed in an I.C. engine after combustion of fuel in combustion chamber. In case of rear wheel drive or four wheel drive vehicle this power is to transmit to the driving wheels. An element propeller shaft is used to transmit the power to the rear axle. The requirement is that the propeller shaft should maintain it at proper position while it is rotating itself and vehicle propel on the road. It can only be possible with the use of center bearing.

It enables the smooth rotation of propeller shaft with negligible friction and less vibration. To carry this center bearing along with the frame of the vehicle a component; known as 'Bracket' is required, which assemble the center bearing & frame together.

There are different forces and vibrations are transmitted to the bracket through the centre bearing .In spite to the bracket is provided with rubber bush to minimize the vibrations

bracket fails to sustain the stresses and can be damaged.

LITERATURE REVIEW:

Sachin Shelke et al [1] This paper clears that various forces may act on the propeller shaft and bearing during power transmission from engine to the rear driving axle. These forces results into the frequent failure of the bearing carrying element known as bearing cup. This problem of bearing cup failure confirmed after critical analysis of drive shaft assembly. This paper focus on the methodology to be carried out to find the solution with the help of FE Analysis. Various heat treatment process are thoroughly compared to obtain ultimate solution. At the end it is found that no other than carbonitriding is the best solution which can reduce the bearing failure and overall cost simultaneously.

[2]Dhananjay S.Kolekar et al [2] To control the direction of the vehicle the steering wheel along with steering wheel system plays a vital role. The intermediate shaft is used to connect the steering shaft to the steering pinion together. Due the vehicle design limitations steering shaft and steering pinion cannot be arrange on the same axis. All these parts are joined together with the universal joints. The joints may fail due to the stresses induced in the either direction, while turning the vehicle either left or right.

This paper discusses various probable solutions to the problem of universal joint failure. They prepared a model of yoke web using Finite element technique. The mathematical evolutions are suggested to maximize responses to the significant parameters under observations .They set certain standards in the sake of evaluating results towards validation.

Bhirud Pankaj Prakash et al [3] This study concentrates towards replacement of conventional metallic structures by composite structure. Which have many advantages due to its higher specific stiffness and strength. In these days there is an increasing demand for light weight material. The fiber reinforces polymer composites seems to be a promising solution to this arising demand. The importance to this material raise due to its wide range of applications in the field of automotive, aerospace, sports, goods, medicines and household appliences.To analyse a composite drive shaft for power transmission is the sole objectives of the work. In this work replacement of stell drive shaft with a Kelvin /epoxy or E glass polythene resin composite drive shaft for an automotive application. The objective of this study is to minimize the weight of drive shaft.

RESEARCH METHODOLOGY:

1) Conventional Analysis.
2) Computer Aided Analysis.
3) Computer Aided Design for Manufacturing and Optimization.

WORK DONE:

MATERIALS PROPERTIES:

In this project, we can use different types of material are as:

1. SM 45 C   3. AISI 409
2. Fe 540 Alloy   4. NiCr Alloy

1. FE 540 ALLOY:

- Density = 7850 Kg/m^3
- Young's Modulus = 200 Gpa
- Poisson's Ratio = 0.31
- Tensile Yield Strength = 240 Mpa
- Compressive Yield Strength = 240 Mpa
- Tensile Ultimate Strength = 540 Mpa

2. NICR ALLOY :

- Density = 7750 Kg/m^3
- Young's Modulus = 210 Gpa
- Poisson's Ratio = 0.32
- Tensile Yield Strength = 170 Mpa
- Compressive Yield Strength = 170 Mpa
- Tensile Ultimate Strength = 330 Mpa

TORQUE CALCULATION:

Consider that propeller shaft rotates with 2500 RPM at top gear or higher gear and power at this RPM is 93.43×10^3 W.

We have,

$$P = \frac{2\pi NT}{60}$$

Where, P = power developed in an IC engine of ST bus.
N = Speed of the propeller shaft at top gear.
Te =Torque available at engine.

Therefore,

$$Te = \frac{P\times 60}{2\pi N}$$

Where, Te = Engine Torque

$$= \frac{93.43\times 10^3 * 60}{2\pi \times 2500}$$

$$Te = 356.87 \text{ kN-m} \qquad \text{......... (At top gear)}$$

As we know that torque and speed are inversely proportional to the each other, so at top gear speed will be high and torque should be less. Therefore considering maximum torque at first gear when propeller shaft may be loaded maximum.

$\therefore$ $T_{Prop.} = T_e \times$ Gear ratio at first gear

Where gear ratio at first gear is 7.51

$\therefore$ $T_{Prop.} = 356.87 \times 7.51$
$= 2533.82$ N-m

While propelling on abnormal road, vehicle may experience impact loading. Therefore while calculating the maximum torque , we take value for impact factor is 2.

$\therefore$ $T_{max} = T_P \times$ Impact factor
$= 2533.82 \times 2$
$= 5067.64$ N-m

Let us find mean diameter of crown wheel,

Mean diameter $D_m = \frac{D+d}{2}$

Where D_m is mean diameter of crown wheel D is the bigger diameter and d is smaller diameter.

Therefore,

$$D_m = \frac{370+260}{2}$$
$$= 315 \text{ mm}$$
$$D_m = 0.315 \text{ m}$$

Now the tangential force acting on the crown wheel,

$$f_t = \frac{T_{max}}{\frac{D}{2}}$$
$$= \frac{5067.64}{0.157}$$
$$f_t = 32175.49 \text{ N}$$

To find radial force we have,

$$f_c = f_t \tan \Phi$$

Where, pressure angle Φ is 20^0

$$f_c = f_t \tan \Phi$$

By putting value of f_t and Φ we get,

$$f_c = 32175.49 \tan 20^0$$

$$f_c = 11710 \text{ N}$$

By putting the value of f_c in following equation

$f_r = f_c \tan \Phi \cos \gamma$

Where γ is half of cone angle which is equal to 54^0

$= 11710 \tan 20^0 \cos 54^0$

$f_r = 2505.39$ N

To find axial forces acting at crown wheel

$f_a = f_c \tan \Phi \sin \gamma$

$= 11710 \tan 20^0 \sin 54^0$

$= 3448.10$ N

By taking M @ A,

Where,

f_t is the tangential forces acting on the crown wheel.

f_{Bv} is vertical force acting on the bracket B

$f_t * (L_{AB}+L_{BC}) = f_{Bv} * L_{AB}$

$f_t * (1.574+1.905) = f_{Bv} * 1.574$

$32175.49 * 3.479 = f_{Bv} * 1.574$

$f_{Bv} = 71117.23$ N

Now taking summation of all vertical forces we get,

$\varepsilon f = 0$

$f_{Av} + f_{Bv} + f_t = 0$

$f_{Av} = - f_t - f_{Bv}$

$= - 32175.49 - (-71117.23)$

$f_{Av} = 38941.74$ N

By taking M @ A,

Where,

F_r is the radial force acting on the crown wheel.

f_{Bh} is horizontal force acting on the bracket B

$f_t * (L_{AB}+L_{BC}) = f_{Bv} * L_{AB}$

$f_r * (1.574+1.905) = f_{Bh} * 1.574$

$2505.39 * 3.479 = f_{Bh} * 1.574$

$f_{Bh} = 5536.78$ N

Now taking summation of all vertical forces we get,

$\varepsilon f = 0$

$f_{Ah} + f_{Bh} + f_r = 0$

$= - f_r - f_{Bh}$

$= - 2505.39 - (-5536.78)$

$f_{Ah} = 3031.78$ N

Resultant force at bearing A

$f_{AR} = \sqrt{f_{Av}\,2 + f_{Ah}\,2}$

$= \sqrt{38941.74^2 + 3031.78^2}$

$= 39059.58$ N

Resultant force at bearing B.

$f_{BR} = \sqrt{f_{Bv}\,2 + f_{Bh}\,2}$

$= \sqrt{71117.23^2 + 5536.78^2}$

$= 71332.43$ N

As value for resultant force is more at bracket B than the value at bracket A, hence bracket B is considered for further calculation.

PRESSURE CALCULATION:

As the resultant force is to apply on bracket on its surface it needs to convert into pressure, therefore we have,

Pressure $P = \frac{\text{Resultant force}}{\text{Bracket Area}}$

Where resultant force on bracket B is 71332.43 N

And bracket area = Length of bracket * Width of bracket

$= 445 * 50$

$= 22500$ mm^2

Therefore,

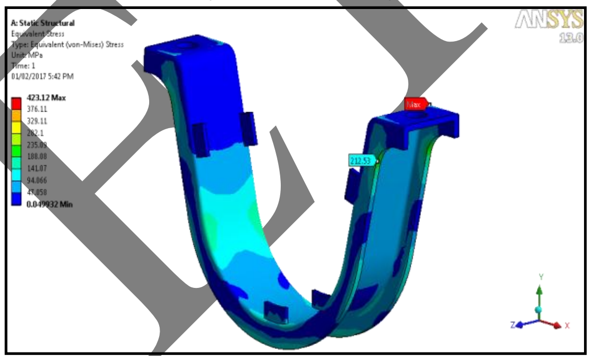
Pressure $P = \frac{\text{Resultant force}}{\text{Bracket Area}}$

$= \frac{71332.43}{22500}$

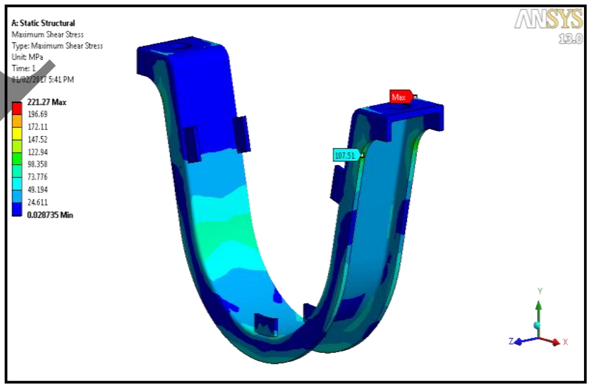
$P = 3.17$ N/mm^2

The above calculation gives the required input for the analysis of given bracket component by using ANSYS software.

STATIC ANALYSIS OF BEARING BRACKET WITH ANSYS SOFTWARE (FE 540 ALLOY);

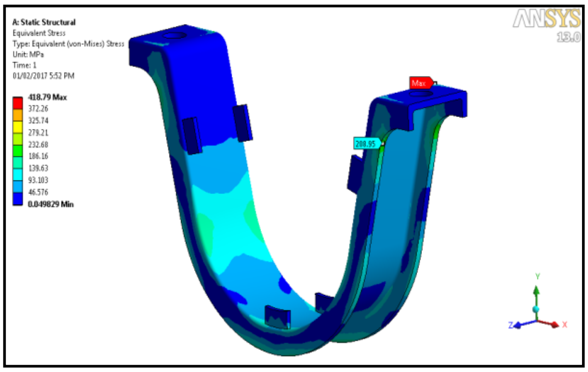


Equivalent Von Mises Stress

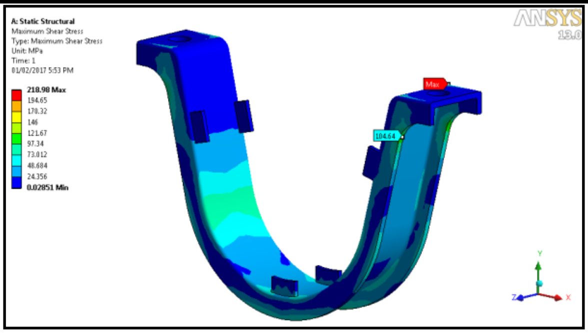


Maximum Shear Stress

AISI 409 ALLOY:

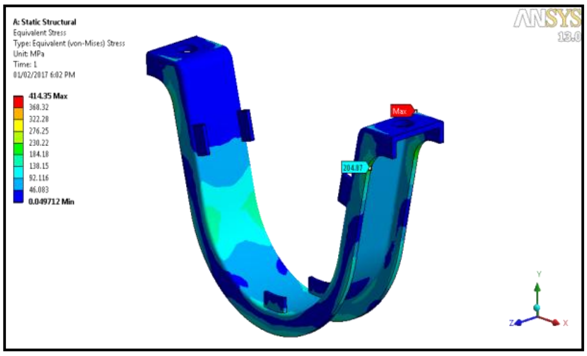


Equivalent Von Mises Stress

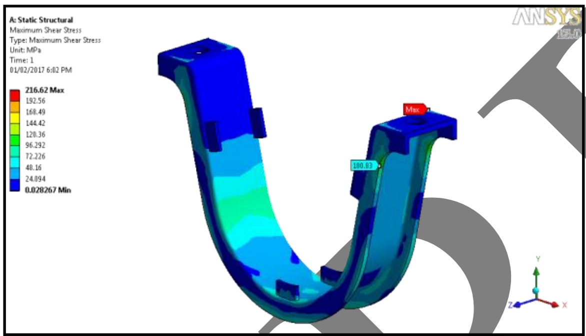


Maximum Shear Stress

NI CR ALLOY

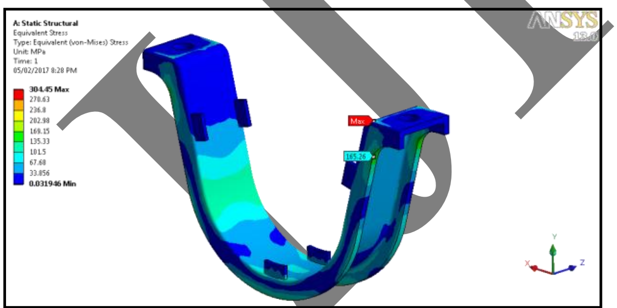


Equivalent Von Mises Stress

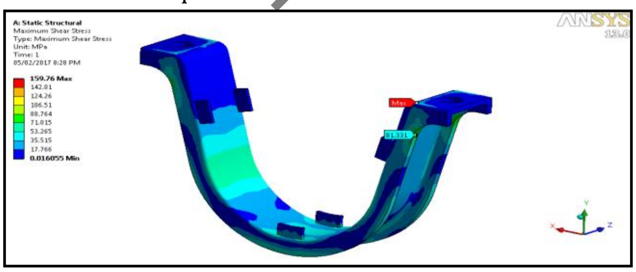


MAXIMUM SHEAR STRESS:

NICR ALLOY--THICKNESS 5 MM:



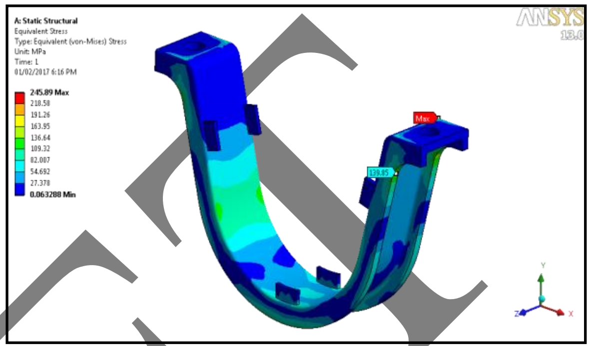
Equivalent Von Mises Stress



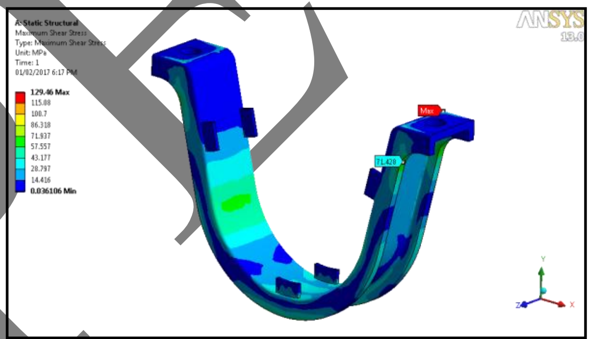
Maximum Shear Stress

Material	Case Studies	Total Deformation (mm)		Von-Mises Stress (Mpa)			Max Shear Stress (Mpa)		
		Min	Max	Min	Max	at Bends	Min	Max	at Bends
Fe 540 Alloy	Existing Material (4 mm)	0	0.212	0.049	423.12	212.53	0.028	221.27	107.51
AISI 409	Modified Material (4 mm)	0	0.207	0.049	418.79	208.95	0.028	218.98	104.64
NiCr Alloy	Modified Material (4 mm)	0	0.202	0.049	414.35	204.87	0.028	216.62	100.83
NiCr Alloy	Modified Material (5 mm)	0	0.152	0.031	304.45	165.26	0.016	159.76	81.33
Fe 540 Alloy	Modified Thickness (6 mm)	0	0.128	0.063	245.89	139.85	0.036	129.46	71.42

THICKNESS 6 MM:



VON MISES STRESSES



MAXIMUM SHEAR STRESS:

ECONOMICAL VIABILITY :

The divisional ST workshop handles about 2400 buses every year for repair and maintenance. Around 1000 bearing bracket have to be replaced every year due to high failure rate. Cost of replacement of bracket is about 2.5 lakh and additional labour charges are about 1 lakh. The total cost of replacement reaches upto 3.5 lakh per annum. As per the market value the new selected Ni Cr material is costlier by 20% than the Fe 540 alloy, till using Ni Cr alloy for bracket may be economical as design analysis reveals reduction in failure rate up to 50%..

RESULT AND DISCUSSION:

As per the calculations have been performed, following value of forces observed on bearing and bearing bracket. Which is incidentally converted into pressure for finite element analysis.

The load on bracket A= 39509.58 N and

Load on bracket B=71332.43 N

Since the bracket B is critically loaded the design and ANSYS done for bracket B and same bracket is used at both the locations.

As a step of analysis the properties of the existing bracket material were obtained by testing the bracket in the material testing laboratory. The chemical composition of existing material is obtained.

Chemical Composition by weight	
Element	Weight %
Mn	1.60
P	0.040
S	0.040
Si	0.45
CE	0.44

Since the shape of the bracket is complex the CAD technique is used for 3 D modeling of the bracket. The 3 D model is created on Creo 2.0 which is then imported to ANSYS for FE analysis.

The FE analysis considering proper loading and boundary conditions has been performed and the result has been tabulated as below.

The result tabulated in terms viz. total deformation, Von mises stress and maximum shear stresses. Case study is carried out for existing material and for modified material and modified dimension of bracket for original material. Value for deformation decreases starting from Fe 540 alloy with thickness 4 mm to the same material with thickness 6 mm respectively as shown in table. For material AISI 409 alloy and NiCr alloy deformation is less than existing bracket material. Value for Von Mises stress and max shear also decreases starting from Fe 540 alloy to Ni Cr alloy material.

The deformation value for existing bracket was comparatively more. The changes in thickness by only 2 mm, deformation value decreases. Similarly values for Von- Mises stress and max shear stress varies significantly. When material of bracket replaced with Nickel Chromium, not only deformation but also value of Von-mises and max shear stress varies considerably. Therefore NiCr Alloy with new dimension of 5 mm analyzed with ANSYS gives more acceptable results for stresses.

8. CONCLUSIONS AND FUTURE SCOPE:

In this project work, investigation on bracket failure used in ST bus. After investigation, it is revealed that existing bracket with original material and dimension tends to fail at given load condition.

A little dimension alteration can extend the life of bracket as its load carrying capacity increases. Then various metals, AISI 409 alloy and Ni Cr Alloy are tested under ANSYS for structural analysis. The properties of this material prove that these materials are more suitable for bracket design. The outcome with Nickel Chromium alloy with change in thickness by one mm found more economical in design point of view. Alteration in dimension gives most satisfactory value for stress. So solution on bracket failure can be suggested in two ways. Either material can be replaced with NiCr with modified thickness of 1 mm or by change the thickness of existing bracket by 2 mm.

Our study is limited up to failure analysis of existing material for given load condition and to suggest design modification. This study full fills the objectives. But the study can be extended in the way that the creating an actual model with suggested material and analysis carried out in lab by considering different load condition to find out the design validation for suggested material. If it gives valid result then that bracket can be checked for actual performance on ST bus. After all a detail study of composite material can done to find a suitable composite material with comparatively less weight, less cost and more durability.

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