Chapter 2

Modelling and Stress Analysis of Shaft used in Hydraulic Steering Pump

T.Vinod Kumar[a], S.Arunkumar[b*], M.Chandrasekaran[c], R.Muraliraja[a], S.Ajith Arul Daniel[b]

[a] *Associate Professor, Department of Mechanical Engineering, Vels Institute of Science, Technology and Advanced Studies (VISTAS),Chennai, India.*

[b] *Assistant Professor, Department of Mechanical Engineering, Vels Institute of Science, Technology and Advanced Studies (VISTAS),Chennai, India.*

[c] *Professor, Department of Mechanical Engineering, Vels Institute of Science, Technology and Advanced Studies (VISTAS),Chennai, India.*

**Corresponding Author: gct.arunkumar@gmail.com*

Abstract

This work deals with the stress analysis of a shaft used in hydraulic steering pump, which helps to transmit motion between two gears used in the pump. Suitable material (20NiCrMo2) with a greater tensile strength and similar chemical composition is also recommended. This suitable material thus found out is also being used for making the high speed shaft of steering pumps used in an automobile. This material is also being suggested to the industry as an alternate material used for making high speed shafts. Step by step process performed by us is explained in detail. Additionally included are the results and the examination of the shaft. It is possible to thoroughly analyze the shaft's substance by keeping an eye on these values. The report's conclusion demonstrates that the stated goal has been fulfilled and provides the parameters needed to increase endurance life. Relevant transfer functions and the power steering system's underlying control structure have been derived and examined with the aid of the linear model.

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1. INTRODUCTION

This work deals with the stress analysis of a shaft used in hydraulic steering pump, which helps to transmit motion between two gears used in the pump. To carry out analysis of a case hardened pump shaft, used in hydraulic power steering pump. To find the weakest zone in a shaft of a steering pump[1,3] To find the factor of safety for the zone and to suggest methods of improving the fatigue life of the shaft used.

1.1 Components of Power Steering

A power steering system in an automobile has several components such as rack and pinion, gears, hydraulic pump, hose, pump and rotary valve. Of the above mentioned parts pump and rotary valve which play a major role in the working of the power steering has been explained in detail below.

1.1.1 Pump

The pump must be designed to provide adequate flow when the engine is idling. As a result, the pump moves much more fluid than necessary when the engine is running at faster speeds. The pump contains a pressure-relief valve to make sure that the pressure does not get too high, especially at high engine speeds when so much fluid is being pumped.

1.2 Characteristics of fatigue

The process starts with dislocation movements, eventually forming persistent slip bands that Nucleate short cracks. The greater the applied stress, the shorter the life. In recent years, researchers have found that failures occur below the theoretical fatigue limit at very high fatigue lives (10^9 to 10^{10} cycles) [4, 5] an ultrasonic resonance technique is used in these experiments with frequencies around 10-20 kHz. High cycle fatigue strength (about 10^3 to 10^8 cycles) can be described by stress based parameters. Low cycle fatigue (typically less than 10^3 cycles) is associated with widespread plasticity, thus a strain based parameter should be used for fatigue life prediction. Testing is conducted with constant strain amplitudes at 1-5 Hz [6].

Table 1.1 Comparison between materials

Composition (weight %)	20NiCrMo2
Carbon (%)	0.17-0.23
Silicon (%)	0.17-0.40
Manganese (%)	0.65-0.85
Chromium (%)	0.35-0.7
Iron (%)	96-97
Tensile strength (Mpa) after tempering	925-1100

2. EXPERIMENTAL PROCEDURE

2.1 Material 20NiCrMo2

Characteristics: Case hardened alloy steel generally supplied as roll to HB 255 max. Application: Arbors, Cam shafts, kingpins, ratchets, Gears, shafts, splined shafts etc.

DIN number: 1.6523.Recommended quenching temperatures vary from 780-820̊c in the case of case quenching. About 860 to 900°C for 4 to 5 hours, in the case of core quenching.

Annealed to a maximum hardness of 212 HB for any purpose.

Tempering: Recommended tempering temperatures vary from 150-200̊c

Cost of the material is 800-1000 $ / ton for high quality.

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2.2 Stress analysis

Stress analysis was carried out using analysis software ANSYS 12.1 for a load of 1471.9 N. Detail reports with stress acting on different planes are given below. (Refer Fig 1)

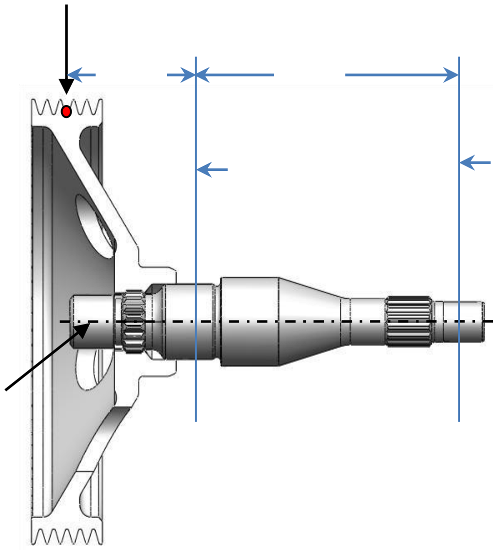

Fig 1: Load details required for analysis

2.3. Algorithm for the analysis

Step 1: Required structural analysis is selected from the preferences option

Step 2: The element type is selected for the given shaft: preprocessor ->element type ->add/edit/delete ->add ->solid quad 4 node 42 -> ok.

Step 3: Material is selected and suitable young's modulus and poison's ratio is selected i.e. young's modulus = 2.1e5 and poison's ratio = 0.3

Step 4: The pro E model is imported using the following commands: find -> file -> import -> pro E. the required file is selected in the available format (.igs)

Step 5: The 3D model that has been imported is meshed: mesh -> mesh attribute -> select material plane. Once the material plane has been selected, the mesh size is specified with element length of 0.5

Step 6: Tetrahedron mesh type is selected followed by selecting a mapped mesh option from the mesh attribute option.

Step7: For applying loads, define loads ->apply ->structural ->deformations. The constraint points are selected which the two are bearing positions on the shaft.

Step 8: The given force is applied on the shaft: force/moment -> (points for load is selected).

Step 9: The required direction of force is specified, i.e. in the negative F_y direction.

Step 10: the problem is solved through the following steps: solution -> solve -> current LS -> ok

Step11: The result is plotted using the following commands: generate post processor -> plot result -> contour plot -> nodal solutions -> solution -> stress. The stress values are found out for the required planes.

Step12: The required analysis has been carried out on the shaft.

3. RESULTS AND DISCUSSION

The below shaft analyzed diagram shows the point on the shaft where maximum stress acts when the design load is applied on the specified point on the shaft.

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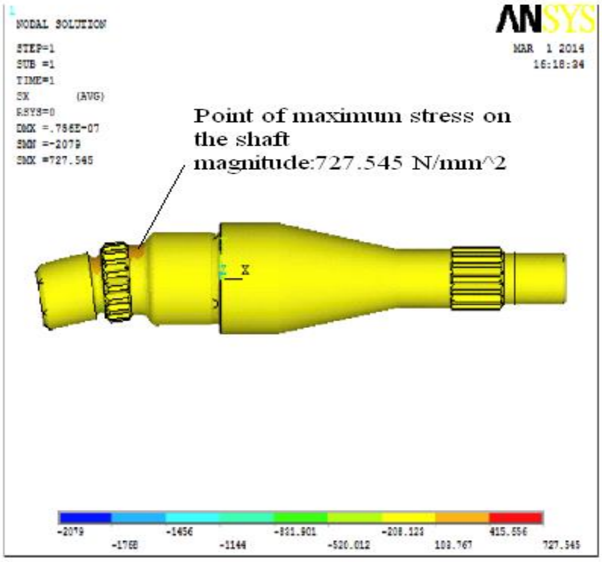

Fig 2: Stress acting on the shaft in X plane

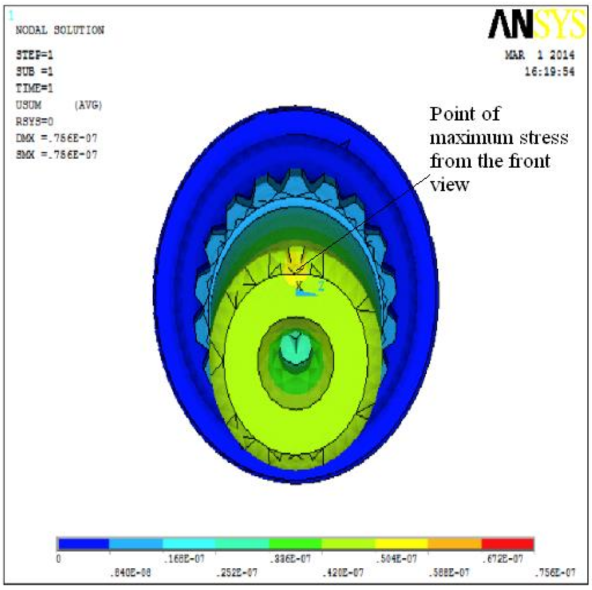

Fig 3: Stress acting on the shaft in X plane left

The above analyzed diagram shows the front view of the shaft along with the point of maximum stress acting on it.

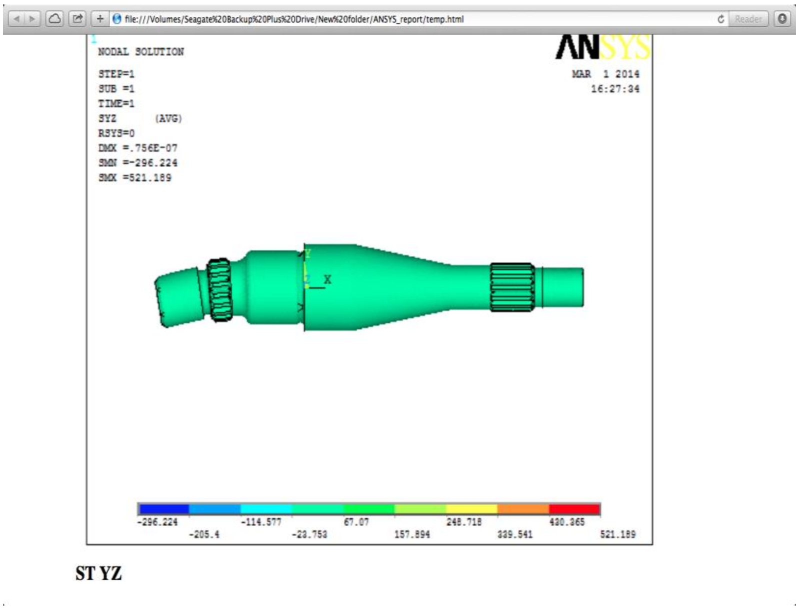

Fig 4: Stress acting on the shaft in YZ plane

The above image depicts the stress acting on the shaft along the YZ plane.

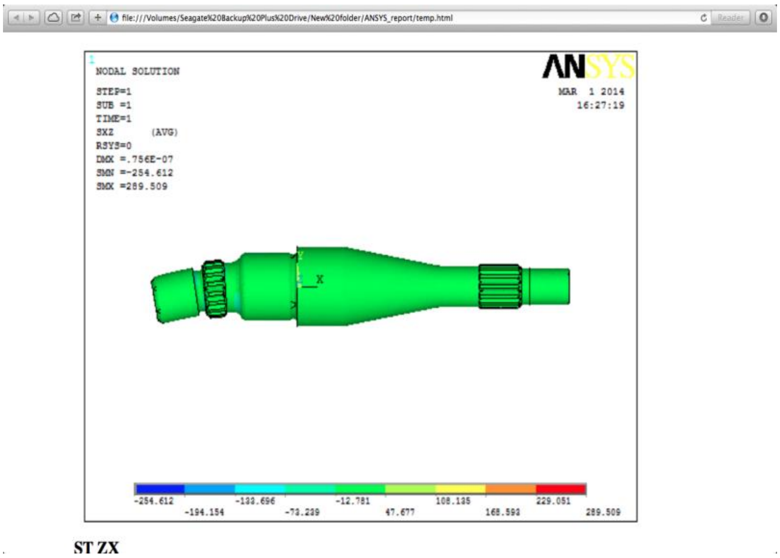

Fig 5: Stress acting on the shaft in ZX plane

The above image depicts the stress acting on the shaft along the ZX plane.

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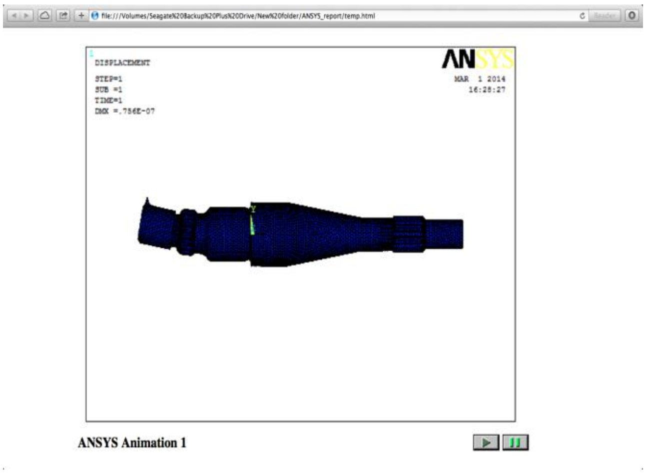

Fig 6: Stress acting animation 1

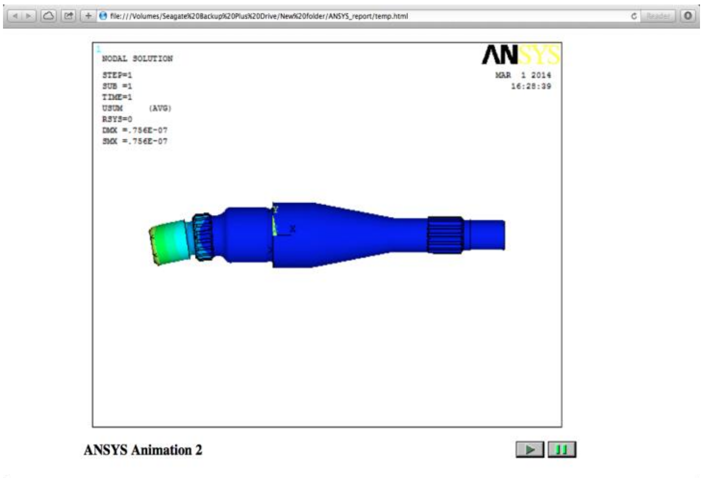

Fig 7: Stress acting animation 2

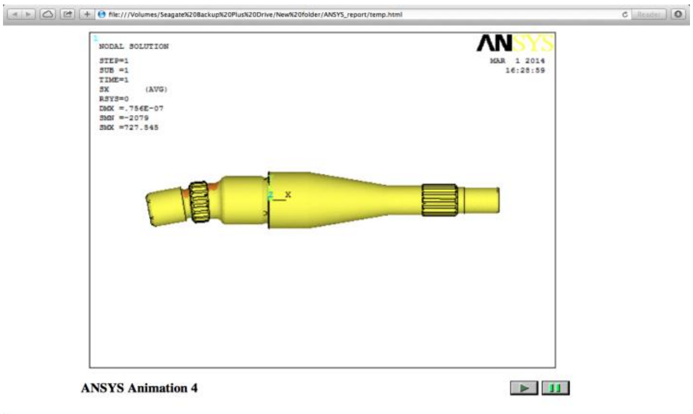

Fig 8: Stress acting animation 4

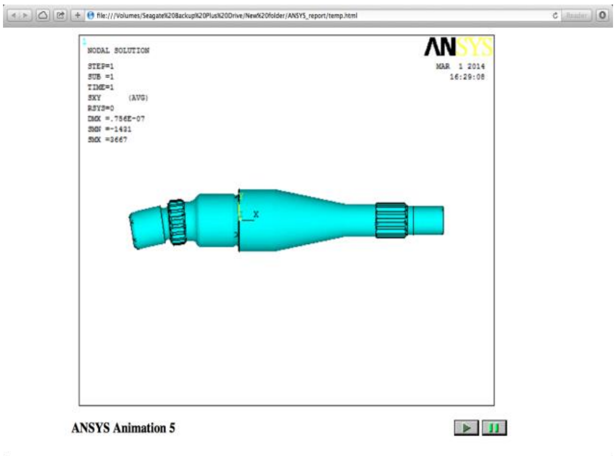

Fig 9: Stress acting animation 5

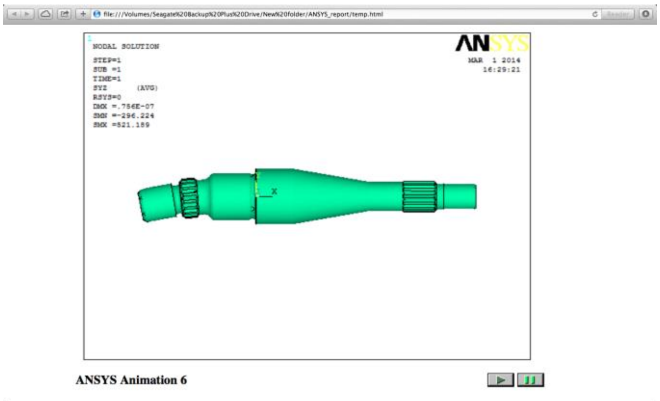

Fig 10: Stress acting animation 6

3.1 Calculations

Factor of Safety Calculation:

Factor of Safety for current material (16MnCr5)

Factor of Safety = YIELD STRESS / DESIGN STRESS

= 822.57 / 727.5

Factor of Safety = 1.130

Here,

Yield stress is taken @ 45 HRC ZONE

Design stress is calculated by analysis.

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Tensile strength for the same material after heat treatment is 975 N/mm^2

Therefore the Factor of Safety = 975 / 727.54

Factor of Safety = 1.27

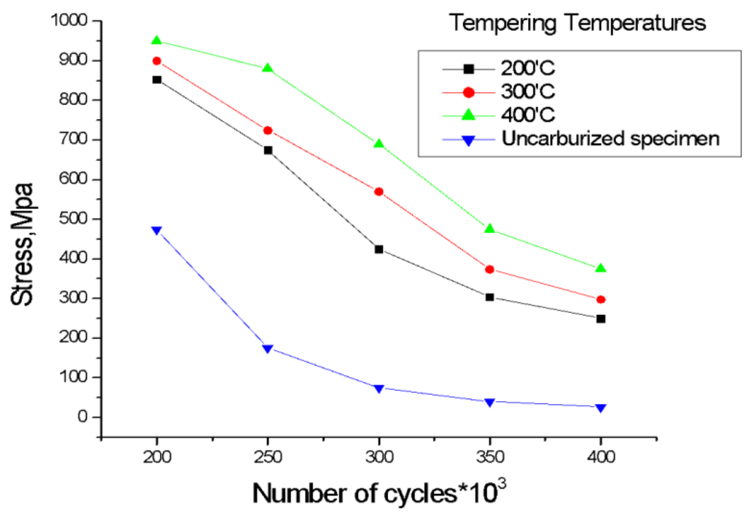

Fig 11: Stress vs. number of cycle curve with tempering temperature

Since the Factor of Safety for the recommended material is higher than the current material, while taking the yield stress into consideration the recommended material is a an appropriate material for the shaft used in the steering pump.

4. CONCLUSION

- ANSYS12.1 was thus employed to analyse a case-hardened pump shaft, which is utilised in hydraulic power steering pumps. It was discovered that the greatest stress applied to the shaft was 727.54 MPa.
- The weakest zone in a shaft of steering pump i.e. maximum stress acting was in zoneII
- The factor of safety for the zone was also found to be 1.13.
- With a greater tensile strength of 925–1100 Mpa, 20NiCrMo2 was also recommended as a viable material.

- According to material science, materials with lower factor of can also be recommended based on the application.

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