Design and Analysis of Notched Shaft of ATV using Composite Material

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Abstract— This paper discusses geometry generation used for finite element analysis of composite notch shaft used in ATV. Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. Mesh generation and its convergence are also discussed. Using proper boundary conditions and type of loading are important since they strongly affect the results of the finite element analysis. Identifying appropriate boundary conditions and loading situation are also discussed. A finite element model of one component is analyzed. This facilitates proper comparison of this component made from two different manufacturing processes. The results of finite element analysis for this shaft are discussed in this paper. Above mentioned FE models are used for static analysis considering the boundary conditions according to the mounting of the shafts in the engine.

Key words: Composite Material, ATV

I. Introduction

Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. Composite materials have a long history of usage. Their precise beginnings are unknown, but all recorded history contains references to some form of composite material. The key is the macroscopic examination of a material wherein the components can be identified by the naked eye. Different materials can be combined on a microscopic scale, such as in alloying of metals, but the resulting material is, for all practical purposes, macroscopically homogeneous, i.e the components cannot be distinguished by the naked eye and essentially act together. The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. Some of the properties that can be improved by forming a composite material are

- Strength -fatigue life
- Stiffness
- temperature-dependent behavior
- Corrosion resistance -thermal insulation
- Wear resistance -thermal conductivity
- Attractiveness -acoustical insulation
- weight

Modern composites using fiber-reinforced matrices of various types have created a revolution in high-performance structures in recent years. Advanced composite materials offer significant advantages in strength and stiffness coupled with light weight, relative to conventional metallic materials. Along with this structural performance comes the freedom to select the orientation of the fibers for optimum performance. Modern composites have been described as being revolutionary in the sense that the material can be designed as well as the structure.

A. Glass Fibers

Glass fibers with polymeric matrices have been widely used in various commercial products such as piping, tanks, boats and sporting goods. Glass is by far the most widely used fiber, because of the combination of low cost, corrosion resistance, and in many cases efficient manufacturing potential. It has relatively low stiffness, high elongation, and moderate strength and weight, and generally lower cost relative to other composites. It has been used extensively where corrosion resistance is important, such as in piping for the chemical industry and in marine applications. It is used as a continuous fiber in textile forms such as cloth and as a chopped fiber in less critical applications. (Swanson S.R; 1997; 3) Glass fibers are strong as any of the newer inorganic fibers but they lack rigidity of on account of their molecular structure. The properties of glasses can be modified to a limited extent by changing the chemical composition of the glass, but the only glass used to any great extent in composite materials is ordinary borosilicate glass, known as E-glass. E glass is available as continuous filament, chopped stable and random fiber mats suitable for most methods of resin impregnation and composite fabrication. S glass, originally developed for aircraft components and missile casings, has the highest tensile strength of all fibers in use. However, the compositional difference and higher manufacturing cost make it more expensive than E-glass. A lower cost version of S glass, called S-2 glass, has been made available in recent years

1) *Material properties for glass fiber*

Property	Value
E_1	40 GPa
E_2	6 GPa
E_3	40 GPa
Poisson's Ratio ,ν	0.24
G_{xy}	15 GPa
G_{yz}	2.3 GPa
Gz_x	15 GPa
Density, ρ	2000m^3

II. Design of Notch Shaft Based on Conventional Parameters

This chapter design and analysis of notch shaft of dissertation includes design and analysis of existing notch shaft. Dimensions of the existing notch shaft have been extracted from the reverse engineering and CAD model has been prepared in CATIA V5. The finite element analysis is carried out by using Hypermesh and ANSYS.

A. CAD Model Generation

The Notch shaft is measured by hand as the geometry is simple and can be easily measured. The Notch shaft of the

ATV is then modeled using CATIA. Shaft dimensions were taken by vernier caliper.

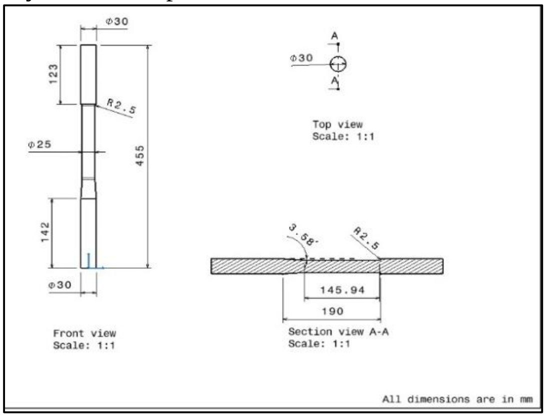

Fig. 1: Model Generation

B. *Force Calculation*

1) *Inputs:*

- Wheel base: 47.9 inches ≅ 1.22 m
- Curb weight: 408 pounds ≅ 185 Kg
- C.G: 22 inches ≅ 0.55m
- Total weight including rider: 255 kg
- Weight distribution: Generally, weight distributions on two axles are in the ratio of 45:55. So, 55% of the curb weight will be on rear axle i.e. notched shaft. Therefore, static weight can be calculated as:
- Static weight on front axle (W_1) = 0.45 X 185 = 83 kg
- Static weight on rear axle (W_2) = 0.55 X 185 =102kg = 1000N

C. *Dynamic Loads*

Dynamic loads on front and rear axles are found by considering acceleration at 2.5 m/s^2.

1) *Dynamic load on front axle*

$$W_f = W_1 + (a/g)\, W\, (h/L)$$
$$= 83 + (2.5/9.81) \times 255 \times (0.55/1.22)$$
$$= 112.3 \text{ Kg} \cong 1101.6 \text{ N}$$

2) *Dynamic load on rear axle*

$$W_r = W_2 - (a/g)\, W\, (h/L)$$
$$= 102 - (2.5/9.81) \times 255 \times (0.55/1.22)$$
$$= 72.7 \text{ Kg} = 713\text{N}$$

D. *Torque Calculation*

Specification:
Power = 41.3 Hp
Rpm = 4500
Power = $2\pi n t/60$
T = 65 Nm

Analysis on notch shaft by applying bending load

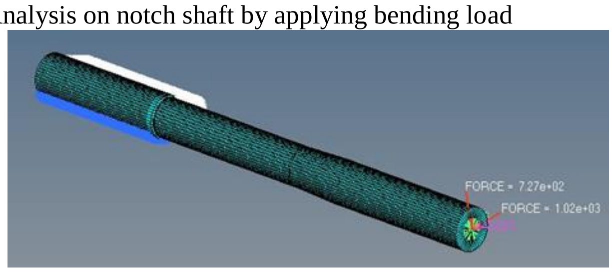

Fig. 2: meshed model of composite notch shaft with bending load.

1) *Following are the results displayed for stress and deformation:*

a) Von-mises stress for notch shaft

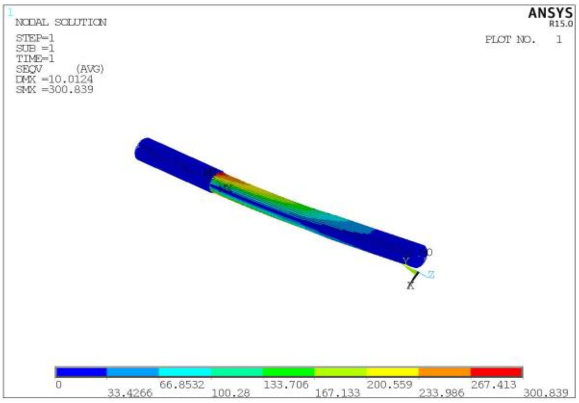

Fig. 3: von-mises stress for notch shaft

Stress value for composite notch shaft is 300.83 N/mm^2 which is well below the critical value. Hence, design is safe.

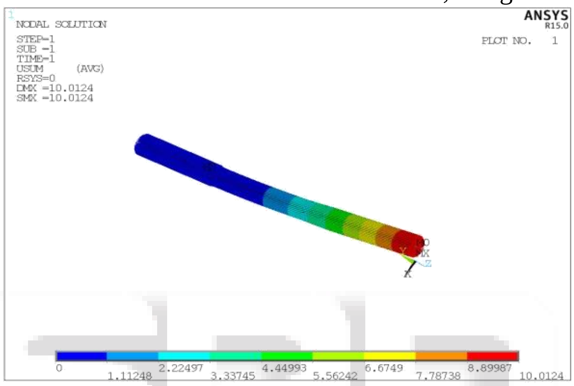

Fig. 4: Displacement result for notch shaft

From fig, deformation for composite notch shaft is 10.01 mm.

2) *Analysis on notch shaft by applying torque*

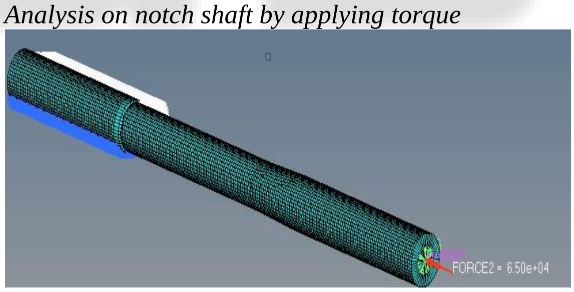

Fig. 5: meshed model of composite notch shaft with torque

3) *Following are the results displayed for stress and deformation*

a) Von-mises stress for notch shaft

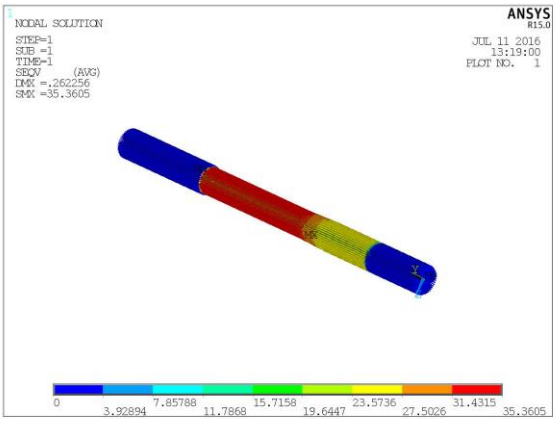

Fig. 6: von-mises stress for notch shaft

Stress value for composite notch shaft is 35.36 N/mm^2 which is well below the critical value. Hence, design is safe.

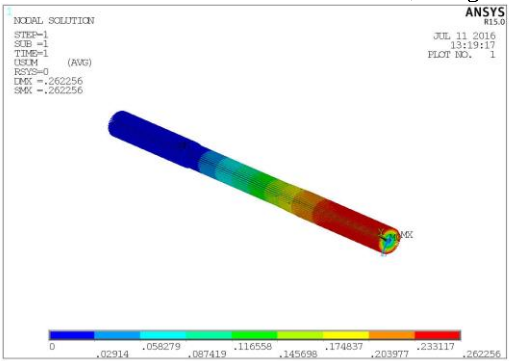

Fig. 7: Displacement result for notch shaft

From fig, deformation for composite notch shaft is 0.26 mm

4) Analysis on notch shaft with combined loading (bending load + torque)

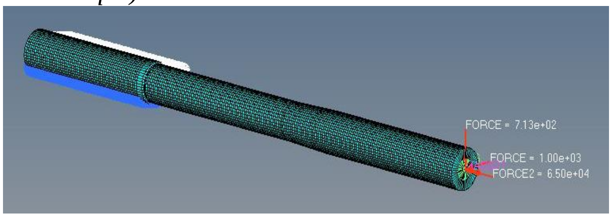

Fig. 8: meshed model of composite notch shaft with combined loading

E. Following are the results displayed for stress and deformation

a) Von-mises stress for notch shaft: Displacement result for notch shaft

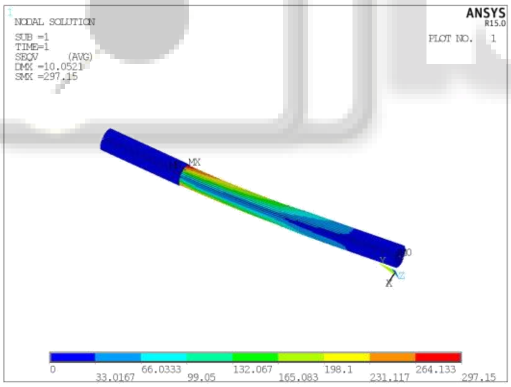

Fig. 9: von-mises stress for notch shaft

Stress value for composite notch shaft is 297.15 N/mm^2 which is well below the critical value. Hence, design is safe.

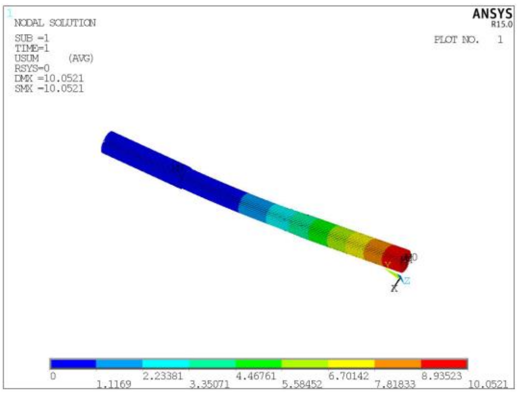

Fig. 10: von-mises stress for notch shaft

From fig, deformation for composite notch shaft is 10.05 mm

F. Comparison

Material	Steel	Glass Fiber
Young's Modulus (E)	210GPa	E1-40GPa E2-6Gpa
Poisson's Ratio(υ)	0.3	0.35
Density (ρ)	7850 kg/m^3	2000 kg/m^3
Yield Stress (σ_{yield})	390 MPa	1850 MPa
Ultimate Tensile Stress (σ_{uts})	450 MPa	2000 MPa

Table 1: Comparison Table

Material	Steel	Glass Fiber
Max. Stress	252.7 MPa	3.46 mm
Max. Displacement	297.15 MPa	10.05 mm

Table 2: Comparison Table

From results of finite element analysis it is observed that all the analysis have stress values less than their respective permissible yield stress values. So the design is safe.

From analysis results and comparison of properties of the materials, it is found that glass fiber is the material which is having the least density; also it is easily available and cheap as compared to other alternate materials. Also machining cost for glass fiber is less. Hence it is the best suited alternate material for notch shaft and is expected to perform better with satisfying amount of weight reduction.

G. Closure

For the dissertation work this chapter discusses about finite element based analysis of notch shaft and thus helped in finding out the appropriate alternate material to steel through which a prototype can be fabricated. This chapter includes the study of glass fiber, their properties, advantages and limitations. These materials have been compared with conventional steel and the analysis is done. From the analysis results glass fiber is found out to be the most suited alternate material for notch shaft.

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