Analysis of Notched Shaft of ATV using Composite Material

Mr. Pravin A. Desai[1] Mr. S.S.Patil[2] Mr. M.L.Harugade[3]
[1]P.G. Student [2,3]Associate Professor
[1,2,3]Department of Mechanical Engineering
[1,2,3]P.V.P.I.T.Budhagaon

Abstract— Notched shaft is the most important component to any power transmission application; automotive notch Shaft is one of this. A notch shaft, also known a s a propeller shaft or Cardan shaft, it is a mechanical part that transmits the torque generated by a vehicle's engine into usable motive force to propel the vehicle. Substituting composite structures for convention al metallic structures has many advantage s because of higher specific stiffness and strength of composite materials. This work deals with the replacement of conventional steel notched shafts with fiber glass epoxy composite notched shaft for an automotive application. The design parameters were optimized with the objective of minimizing the weight of composite notched shaft. The design optimization also improves the performance of notched shaft. Present work deals with FEA analysis of composite shaft with different degree of orientation of glass fibers. It includes the modeling of shaft in CATIA. The meshing and boundary condition application will be carried using Hypermesh, Stuctural analysis and modal analysis of composite shaft will be carried out using ANSYS.

Key words: Analysis of Notched Shaft, ATV using Composite Material

I. INTRODUCTION

An all-terrain vehicle (ATV), also known as a quad, quad bike, three-wheeler, or four-wheeler, is defined by the American National Standards Institute (ANSI) as a vehicle that travels on low-pressure tires, with a seat that is straddled by the operator, along with handlebars for steering control. As the name implies, it is designed to handle a wider variety of terrain than most other vehicles. Although it is a street-legal vehicle in some countries, it is n ot street-legal within most states and provinces of Australia, the United States or Canada.

Fig. 1: A TV vehicle

Rapid technological advances in engineering design field result in finding the alternate solution for the conventional materials. The design engineers brought to a point to finding the materials which are more reliable than conventional materials. Researchers and designers are constantly looking for the solutions to provide stronger and durable materials which will answer the needs of fellow engineers. Notched shafts are used as power transmission. In the design of metallic shaft, knowing the torque and the allowable shear stress for the material, the size of the shaft's cross section can be determined. In the today's days there is a heavy requirement for lightweight materials vehicle. The rear shaft of the ATV vehicle is as shown in below figure.

Combined cyclic tension, bending and torsional loads during operations in service. These complex cyclic loadings are defined as multiaxial loadings, where principal stresses rotate and change non-proportionally their magnitudes during a loading cycle.

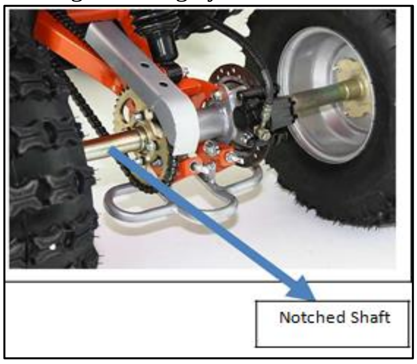

Fig. 2: Location of notched shaft in ATV

Fig. 3: Notched shaft (Sample Drawing)

In addition, many of machine components contain notches and geometrical irregularities because of design requirements. These geo- metric discontinuities cause significant stress concentrations. Multiaxial loading paths produce complex stress and strain states near notches and can cause a fatigue failure even without any evident large-scale plastic deformation. Unfortunately, the combination of multiaxial loading paths and complex geometries of mechanical components is unavoidable in practice and experiments performing durability test are often not feasible because of time and cost considerations Due to the abundance of engineering components with stress concentrations being subjected to complex multiaxial loading histories, studying multiaxial loading of notched members is of great practical importance. In addition, due to the relatively high strength to weight ratio of aluminum, an increasing number of components in key industries, such as automotive and aerospace, are being manufactured from various aluminum alloys. Therefore, it is of special interest to be able to understand the multiaxial loading behavior of these materials. Despite the significance of understanding multiaxial notched loading behavior, limited literature exists on the subject due to the synergistic complexities involved in studying this topic.

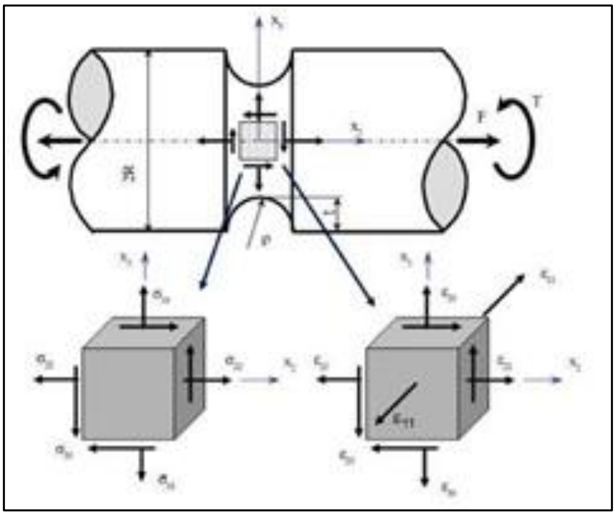

Fig. 4: Stress and strain state at a notch tip.

II. FUNCTIONS OF NOTCH SHAFT

First, it must transmit torque from the transmission to the rear wheels.

The notched shaft must also be capable of rotation at the very fast speeds required by the vehicle.

During the operation, it is necessary to transmit maximum low-gear torque developed by the engine

As the rear wheels roll over bumps in the road, it must be capable of handling the axle move up and down

III. COMPOSITE SHAFT

The advanced composite materials such as Graphite, Carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/density). Advanced composite materials seem ideally suited for long, power driver shaft (propeller shaft) applications. Their elastic properties can be tailored to increase the torque they can carry as well as the rotational speed at which they operate. The drive shafts are used in automotive, aircraft and aerospace applications. The automotive industry is exploiting composite material technology for structural components construction in order to obtain the reduction of the weight without decrease in vehicle quality and reliability. It is known that energy conservation is one of the most important objectives in vehicle design and reduction of weight is one of the most effective measures to obtain this result. Actually, there is almost a direct proportionality between the weight of a vehicle and its fuel consumption, particularly in city driving.

IV. CLASSIFICATION OF COMPOSITES

Composite materials can be classified as Polymer matrix composites Metal matrix composites Ceramic Matrix Technologically, the most important composites are those in which the dispersed phase is in the form of a fiber. The design of fiber-reinforced composites is based on the high strength and stiffness on a weight basis. Specific strength is the ratio between strength and density. Specific modulus is the ratio between modulus and density. Fiber length has a great influence on the mechanical characteristics of a material. The fibers can be either long or short. Long continuous fibers are easy to orient and process, while short fibers cannot be controlled fully for proper orientation. Long fibers provide many benefits over short fibers. These include impact resistance, low shrinkage, improved surface finish, and dimensional stability. However, short fibers provide low cost, are easy to work with, and have fast cycle time fabrication procedures. The characteristics of the fiber reinforced composites depend not only on the properties of the fiber, but also on the degree to which an applied load is transmitted to the fibers by the matrix phase.

The principal fibers in commercial use are various types of glass, carbon, graphite and Kevlar. All these fibers can be incorporated into a matrix either in continuous lengths or in discontinuous lengths as shown in the Figure. The matrix material may be a plastic or rubber polymer, metal or ceramic. Laminate is obtained by stacking a number of thin layers of fibers and matrix consolidating them to the desired thickness. Fiber orientation in each layer can be controlled to generate a wide range of physical and mechanical properties for the composite laminate.

A. Advantages of Fiber Reinforced Composites

The advantages of composites over the conventional materials are [1, 2]

- High strength to weight ratio High stiffness to weight ratio High impact resistance
- Better fatigue resistance
- Improved corrosion resistance Good thermal conductivity
- Low Coefficient of thermal expansion. As a result, composite structures may exhibit a better dimensional stability over a wide temperature range.
- High damping capacity.

B. Limitations of Composites

The limitations of composites are

- Mechanical characterization of a composite structure is more complex than that of a metallic structure
- The design of fiber reinforced structure is difficult compared to a metallic structure, mainly due to the difference in properties in directions
- The fabrication cost of composites is high Rework and repairing are difficult
- They do not have a high combination of strength and fracture toughness as compared to metals
- They do not necessarily give higher performance in all properties used for material selection

V. LITERATURE SURVEY

A. Mehmet Firat[1]

In this paper, a notch analysis model is presented for the numerical prediction of multiaxial strains of a notched 1070 steel specimen under combined axial and torsion loadings. The proposed model is based on the motion of a structural yield surface and uses a small-strain cyclic plasticity model to describe stress– strain relations. In this paper, a numerical model was presented to predict notch strains of a notched specimen under proportional and nonproportional cycling tension– compression–torsion loadings. The proposed model uses elastically calculated notch stresses and a notch stress–strain curve to describe material hardening at the notch root.

B. Mehmet Firat[2]

A notch analysis method using a finite element basis is integrated with two critical plane multiaxial fatigue criteria to simulate combined bending–torsion fatigue of SAE 1045 notched specimen. For both in-phase and out-of phase loading tests, predictions were in accord with experimental results and mostly conservative. .In this paper, a simplified method for the calculation of notch stresses and strains was presented and applied for numerical simulation of combined bending–torsion fatigue of a notched specimen.

C. Ayhan Ince[3]

A computational fatigue analysis methodology has been proposed here for performing multiaxial fatigue life prediction for notched components using analytical and numerical methods. The proposed multiaxial fatigue analysis methodology consists of an elastic-plastic stress/strain model and a multiaxial fatigue damage parameter. Results of the proposed multiaxial fatigue analysis methodology are compared to sets of experimental data.

D. Ayhan Ince, Grzegorz Glinka[4]

In this paper, two different forms of an original multiaxial fatigue damage parameter related to the maximum fatigue damage plane are proposed for performing fatigue life prediction under various loading conditions loadings. In addition, the damage parameters show reasonably acceptable correlations with experimental fatigue data of SAE 1045 steel notched shafts subjected to proportional and non-proportional loadings. Two different forms of the original damage parameter (the GSE and GSA) have been proposed to estimate the fatigue life for mechanical components under the multiaxial loadings.

E. AInce, G. Glinka, A. Buczynski[5]

In this paper, a computational modeling technique of the multiaxial stress–strain notch analysis has been developed to compute elasto-plastic notch tip stress–strain responses using linear elastic FE results of notched components. The simple and efficient multiaxial notch analysis model, which is based on the Garud cyclic plasticity model integrated with the multiaxial Neuber correction rule, has been developed to estimate the elastic– plastic notch tip material behavior of the notch components subjected to the multiaxial non-proportional loadings using linear-elastic FE stress solution.

F. Nicholas Gates, Ali Fatemi[6]

The effect of notches on multiaxial fatigue behavior was studied using thin-walled tubular 2024-T3 aluminum specimens with a circular transverse hole. Constant amplitude fully reversed axial, torsion, and in-phase and 90_ out-of-phase axial– torsion tests were performed in load control. Stress analysis was performed using both Neuber's rule and FEA to study local stress distributions.

VI. Conclusion from Literature

By using above case studies, we can determine the working and design of notch shaft which transmits the torque generated by a vehicle's engine into usable motive force to propel the vehicle. Modeling can be done on 3D software.

Based upon studies, we can apply boundary conditions to the model and carry out analysis.

Analysis can be done on FEA software to determine the nature of failure caused due to stresses developed.

Based on analysis modification in design will be recommended.

VII. Methodology

Preparing the CAD model in CATIA Application of boundary conditions structural Analysis on Notched shaft Displacement and stress plotting Modeling the composite notched shaft in Hypermesh static and modal analysis of composite shaft Comparing the results with conventional model Fabrication and testing of composite shaft Validating the results.

VIII. Conclusion

From the review of the Research papers it is concluded that the conventional notched shafts are heavy and can be improved using composite materials. Thus in the present study the focus is towards increasing its performance by reducing weight and increased strength.

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