International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 05 | May 2019 www.irjet.net p-ISSN: 2395-0072
National Conference on "Advances in Mechanical Engineering [AIME-2019]"
Organised by - Department of Mechanical Engineering, Rajeev Institute of Technology, Hassan, Karnataka, India

Crash Analysis of Composite Drive Shaft

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Abstract - *During last decade many research works have been carried out to replace two piece steel drive shaft with single piece hallow composite drive shaft for automotive driveline application. In this context, a comprehensive approach to analyze the single piece composite drive shafts material is found to be essential as crash analysis is a very important in the design of composite drive shaft, since the failure due to crash is more prominent rather than material failure. In this research work, Crash analysis has been carried out on conventional steel and Kevlar49/Epoxy drive shaft for automotive drive application for optimally designed using particle swarm optimization (PSO) technique. Obtained energy balance graphs from ABAQUS/CAE 6.12-1 have been compared with the experimental energy balance graph. Results show that the Kevlar49/Epoxy drive shaft is better for crash comp actability over steel drive shaft.*

Keywords: FEA, Full-Width Frontal Impact Crash Analysis, Energy Balance Graph

1. INTRODUCTION

Any contact made by a body in motion with an object either fixed or moving at any speed in which kinetic energy is measurably transferred or dissipated is called crash. A crash analysis is a form of destructive testing, usually performed in order to ensure safe design standards in crash compatibility. Bedewi et al. [5] (1996), have performed a detailed multi-purpose FEA of a 1994 Chevrolet C-1500 pick-up truck. Thacker et al. [6] (1998), have developed a finite element (FE) automobile model through reverse engineering for frontal crash safety studies. Kenneth et al. [2] (2008), have performed a frontal crash analysis for 1994 Chevrolet C2500 pick-up truck. Manjunath et al. [3] (2011) have proposed an optimization procedure to design a multilayered single piece composite drive shaft using particle swarm technique. From the literature survey, it is observed that crash analysis of drive shaft has not been carried out, but it is a critical component to transmit torque from engine to gearbox which is subjected to frontal crash.

2. PROBLEM DESCRIPTION

The body of a car has been classified into two zones, i.e., safety cell zones in red color and crumple zones in yellow color as shown in Fig. 1. The safety cell zones are stronger than crumple zones. The crumple zones are located in front part of the vehicle in order to absorb the impact of a head-on collision, though they may be found on other parts of the vehicle as well. These are designed to slow down the collision and to absorb the energy of an impact (kinetic energy) by deformation during collision.

Fig-1: Cross Section of Different Strength of the Metal in a Saab 9000 [4]

The propeller shaft comes under safety cell, one end of shaft is pinned to engine and other end to gear box. Since engine comes under crumple zone, some amount of impact energy faced by engine will be transferred to propeller shaft and deformation occurs. So there is a need to carry out the crash analysis of designed propeller shaft.

3. CRASH ANALYSIS

Frontal impact crash analysis has been carried out for optimized results obtained from particle swarm optimization (PSO) technique using ABAQUS V 6.12-1 for Steel and Kevlar49/Epoxy composite drive shafts. Rigid wall is meshed with a quadratic rigid element R3D4 which is a 4-node 3-D bilinear rigid quadrilateral as shown in Fig.2. Drive shaft is meshed with a quadratic shell element S4R which is a 4-node doubly curved thin or thick shell, reduced integration, hourglass control, finite membrane strains, as shown in Fig.3. Boundary Conditions (BC's) are assigned by constraining the DOF of control points as shown in Fig.5 and a kinetic energy of 1.12 × 107 mJ [2] is applied at one end of shaft.

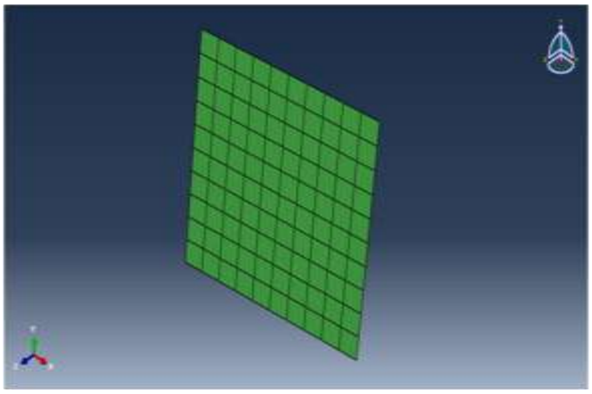

Fig-2: Meshed Rigid Wall

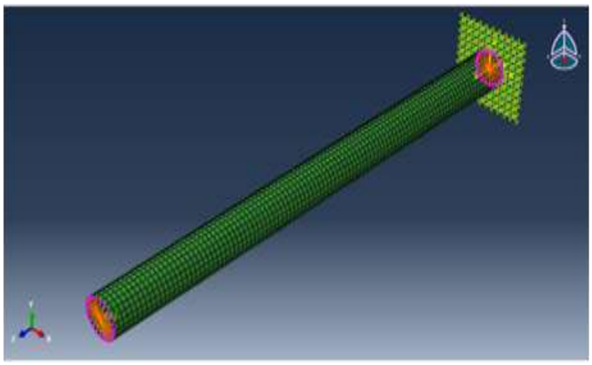

Fig-3: Boundary Conditions for Crash Analysis

The vonmises and shear stress distribution results obtained for steel and Kevlar49/Epoxy drive shafts are shown in Fig. 4 to 7 respectively.

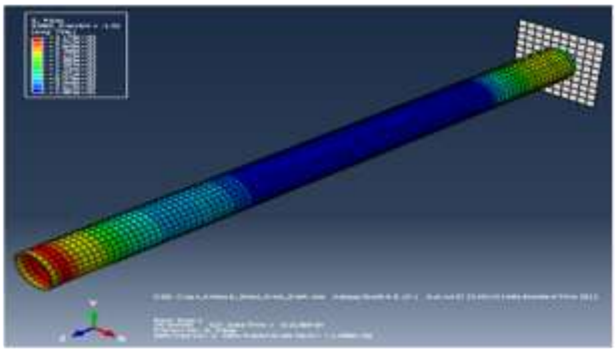

Fig-4: Vonmises Stress Distribution of Steel Shaft

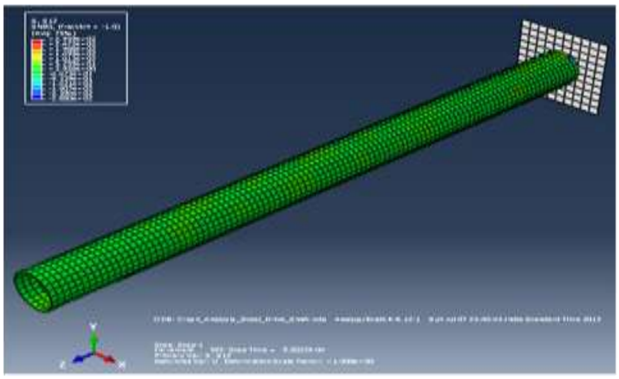

Fig-5: Shear Stress Distribution of Steel Shaft

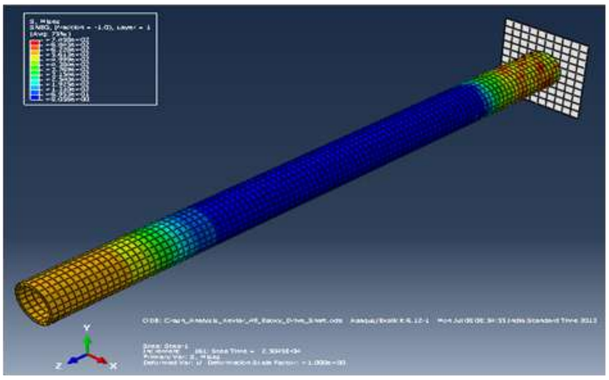

Fig-6: Vonmises Stress Distribution of Kevlar49/Epoxy Shaft

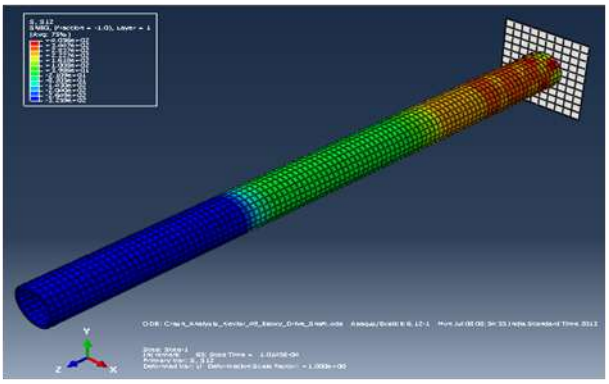

Fig-7: Shear Stress Distribution of Kevlar49/Epoxy Shaft

Table-1: Comparison of Vonmises Stress Results

Description	Steel	Kevlar49/ Epoxy
Theoretical Vonmises Stress (MPa)	370	1400
Maximum Vonmises Stress (MPa)	3175	745.8
Factor of Safety	0.12	1.88

Table-2: Comparison of Shear Stress Results

Description	Steel	Kevlar49 /Epoxy
Theoretical Shear Stress (MPa)	175	461
Maximum Shear Stress (MPa)	295.9	405.6
Factor of Safety	0.6	1.14

From table 1 and 2, it is observed that steel drive shaft has factor of safety less than one which fails to sustain the kinetic energy during crash and Kevlar49/Epoxy drive shaft has a factor of safety more than one, which has better strength to sustain the impact energy without failure during crash.

5. VALIDATION

The experimental energy balance graph obtained from crash analysis simulation of Chevrolet truck against a rigid wall [3] is shown in Fig.8. The simulation starts with an initial (maximum) kinetic energy and as the simulation progresses, the kinetic energy decreases, the internal energy increases, and the total energy remains constant in the simulation

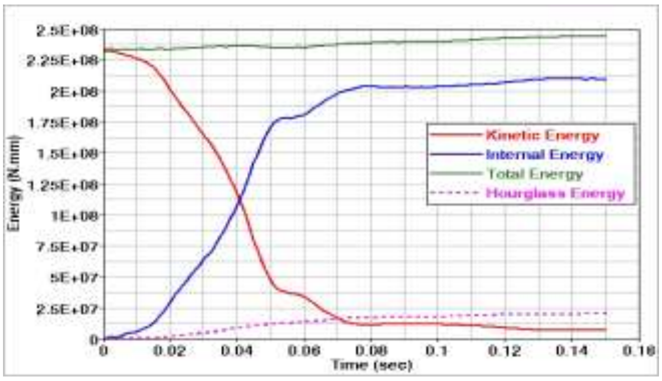

Fig-8: Energy Balance Graph [3]

The energy balance graph of steel and Kevlar49/Epoxy drive shafts are shown from Fig. 9 & 10 respectively.

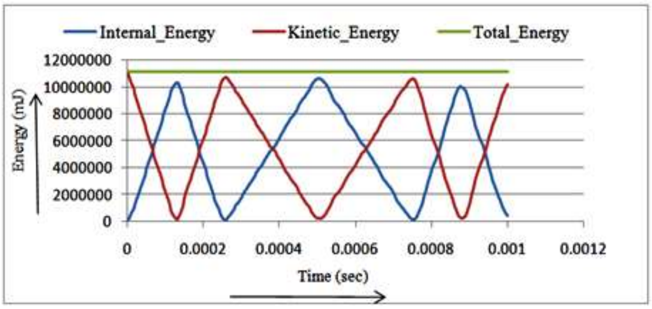

Fig-9: Energy Balance Graph of Steel Drive Shaft

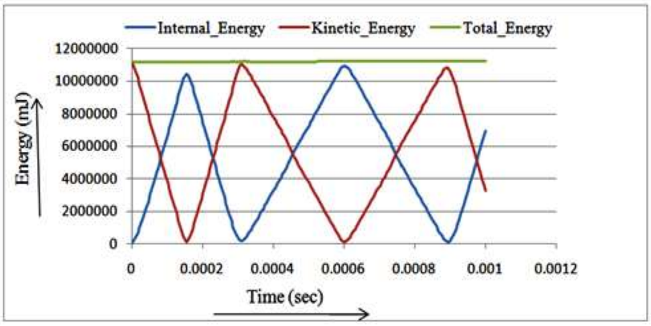

Fig-10: Energy Balance Graph of Kevlar49/Epoxy Drive Shaft

The graphs obtained for kinetic energy, internal energy and total energy from ABAQUS matches with the experimental energy balance graph. In steel drive shaft, internal energy decreases at 0.0009 sec showing that it is failing to face the impact energy but in Kevlar49/Epoxy drive shaft, internal energy increases till the end of simulation. Thus, Kevlar49/Epoxy material is able to resist the kinetic energy without failure during crash.

6. CONCLUSIONS

- Crash analysis for Steel and Kevlar49/Epoxy shaft is successfully carried out using ABAQUS V 6.12-1.
- Kevlar49/Epoxy material shows better internal energy to withstand the kinetic energy without failure during crash and have better factor of safety compared to steel shaft.

7. References

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