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Weight Optimization And Fatigue Analysis Of Front Axle With Composite Reinforcement

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Abstract: *This Paper Accessible About Failure Of Drive Shaft In Conventional Passenger Vehicles. Alto Car Front Wheel Drive Shaft Was Chosen As The Sample Of This Analysis. This Paper Deals With Analysis Of Von-Mises Stress Was Done Using Finite Element Method. The Solid Model Of The Drive Shaft Was Constructed Using CATIA Software. Steel (SM45C) Material Was Selected For The Analysis Of Shaft. Tetrahedral Type Of Meshing With Minimum Element Size Of 4mm Was Used For The Analysis. The Boundary Conditions Were Applied At The Bearing And Geared Location Of Front Wheel Drive Shaft And Von-Mises Stresses Were Found. The Similar Analysis Was Done For Glass Fiber Material And Results Were Compared With That Of Steel (SM45C). The Comparison Has Shown Increased Stress And Deformation For Glass Fiber Material Under Same Loading Conditions. The Result Of Comparison Indicated That For Obtaining Required Weight Optimization Of Front Wheel Drive Shaft Without Strength Loss, Composite Reinforcement Should Be Used.*
Keywords - *Alto Car, Drive Shaft, Finite Element Method, Composite Reinforcement*

I. INTRODUCTION

A Drive Front Axle Is The Connection Between The Transmission And The Front Wheel Of The Car. The Performance Of Car Is Measured By Power To Weight Ratio. In Order To Get Better Performance The Emphasis Is Given On Reducing Weight Without Compromising Mechanical Strength. Today's Most Automobiles Use Rigid Drive Front Axle To Deliver Power From A Transmission To The Wheels. Machine Elements And Assemblies In The Cases Of The Two Variable Loads Are Subject To Stress, Which Under Certain Circumstances Can Lead To Fractures And Ultimately Machine Failure. Power Transmission System Of Four Wheeler And Failures Caused By Dynamic Loading Should Be Analyzed In Order To Optimize The Performance. Hence, Optimization Of Drive Shaft With Composite Reinforcement Should Be Done For Reduction In Weight.

OBJECTIVES

- To Find Out Failure Parameters Of Existing Drive Shaft.
- To Analyze Drive Shaft For Static And Dynamic Loading Conditions For Steel And Glass Fiber Material.
- To Compare Obtained Results Of Stress Analysis.

II. Literature Review

S.A. Mutasher: A Hybrid Aluminum/Composite Is An Advanced Composite Material That Consists Of Aluminum Tube Wound Onto Outside By Layers Of Composite Material. The Result From This Combination Is A Hybrid Shaft That Has A Higher Torque Transmission Capability, A Higher Fundamental Natural Bending Frequency And Less Noise And Vibration.

P. Satheesh Kumar Reddy And Ch. Nagaraju: This Work Aims At The Suitability Of Composite Materials Usage For The Drive Shafts In Almost All Automobiles At Least Those Which Correspond To Design With Rear Wheel Drive And Front Engine Installation. The Weight Reduction Of The Drive Shaft Can Have A Certain Role In The General Weight Reduction Of The Vehicle And Is A Highly Desirable Goal, If It Can Be Achieved Without Increase In Cost And Decrease In Quality And Reliability.

O. Montagnier, Ch. Hochard: This Study Deals With The Optimization Of Hybrid Composite Drive Shafts Operating At Subcritical Or Super- Critical Speeds, Using A Genetic Algorithm. A Formulation For The flexural Vibrations Of A Composite Drive Shaft Mounted On Viscoelastic Supports Including Shear Effects Is Developed.

Harshal Bankar, Viraj Shinde, P.Baskar: The Objective Of The Drive Shaft Is To Connect With The Transmission Shaft With The Help Of Universal Joint Whose Axis Intersects And The Rotation Of One Shaft About Its Own Axis Results In Rotation Of Other Shaft About Its Axis.

Bhirud Pankaj Prakash, Bimlesh Kumar Sinha: Substituting Composite Structures For Conventional Metallic Structures Has Many Advantages Because Of Higher Specific Stiffness And Strength Of Composite Materials.

Pandurang V Chopde: Composite Material With Higher Specific Stiffness, Low Weight, High Damping Capacity Has Greater Torque Capacity Than Conventional Drive Shaft. The Advanced Composite Materials Such As Carbon And Glass With Epoxy Resin Are Widely Used Because Of Their High Specific Strength And High Specific Modulus.

M.Arun, K. Somasundara Vinoth: A Drive Shaft, Also Known As 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

Chaitanya G Rothe, A.S. Bombatkar: A Drive Shaft Is A Rotating Shaft That Transmits Power From The Engine To The Differential Gear Of A Rear Wheel Drive Vehicles. Generally An Alloy Steel Drive Shaft Is Used In Automotive, Nowadays This Steel Drive Shaft Is Replaced By Composite Material Drive Shaft. The Advanced Composite Materials Such As Graphite, Carbon, Kevlar And Glass With Suitable Resins Are Widely Used Because Of Their High Specific Strength And High Specific Module.

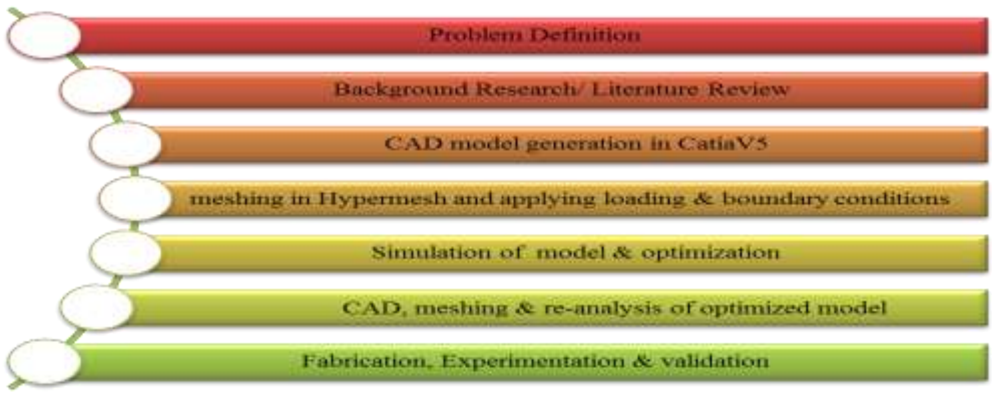
S V Gopals Krishna, B V Subrahmanyam, And R Srinivasulu: The Weight Reduction Of The Drive Shaft Can Have A Certain Role In The General Weight Reduction Of The Vehicle And Is A Highly Desirable Goal. Substituting Composite Structures For Conventional Metallic Structures Has Many Advantages Because Of Higher Specific Stiffness And Strength Of Composite Materials.

V. S. Bhajantri: Substituting Composite Structures For Conventional Metallic Structures Has Much Advantage Because Of Higher Specific Stiffness And Strength Of Composite Materials. This Work Deals With Replacement Of Conventional Two Piece Steel Drive Shaft With A Single-Piece E-Glass/Epoxy, High Strength Carbon/Epoxy And High Modulus Carbon/Epoxy Composite Drive Shaft For Automobile Shaft For An Automotive Application.

Belawagi Gireesh: In The Present Work An Attempt Is Made To Evaluate The Suitability Of Composite Material Such As E-Glass/Epoxy And HM-Carbon/Epoxy For The Purpose Of Automotive Transmission Applications.

III. Methodology

Flowchart Of Methodology:



Specifications Of Alto Car

Fig. Specifications Of Alto 800

IV. INDENTATIONS AND EQUATIONS

Force Calculations

In This We Calculate Torque On Drive Shaft

Design Constraints (From Alto Car Specifications Mentioned Above)

1. Maximum Horsepower = 47 Bhp At 6000 Rpm

2. Maximum Torque=Engine Torque = 62 Nm At 3000 Rpm
3. Gross Vehicle Weight = 1140 Kg

Gear Ratio For Alto Car

Gear	Ratio	Final	Wheel	1500 RPM	3000 RPM	4500 RPM	6000 RPM	Max.Speed
Reverse	3.583	3.589	12.859	116.646	233.293	349.939	466.585	47.5
First	3.416	3.589	12.260	122.349	244.698	367.047	489.395	49.9
Second	1.894	3.589	6.798	220.667	441.334	662.002	882.669	89.9
Third	1.280	3.589	4.594	326.519	653.037	979.556	1306.074	133.1
Fourth	0.914	3.589	3.280	457.269	914.538	1371.807	1829.075	186.4
[illegible]	[illegible]	3.589	2.717	552.105	1104.211	1656.316	2208.421	225.0

Fig. Gear Ratio For Alto Car

Torque In Drive Shaft

In First Gear The Speed Is 3000rpm= 50 Rev/Sec

We Assume Ground Speed Of Alto Car Is 37 Km/Hr = 10.27 M/S = Π DN

Where N = Revolutions Of Tire , D= Dia Of Tire = 0.3048 M

Revolutions Of Tire = N = $\frac{10.27}{3.14*0.3048}$ = 10.73 Rev/Sec [V = Π DN]

Gear Ratio = 3.416

Drive Shaft Speed = Revolutions Of Tire* Gear Ratio= 10.73 * 3.415 =36.64 Rev/Sec

Torque In Drive Shaft = $\frac{\text{engine torque}*\text{speed of first gear}}{\text{drive shaft speed}} = \frac{62*50}{36.64}$ = 84.60 Nm=84600 N-Mm

(Force Calculation Reference= Http://Slideplayer.Com/Slide/8382302/#)

V. Figures And Tables

Fig 1 (Conventional Drive Shaft)

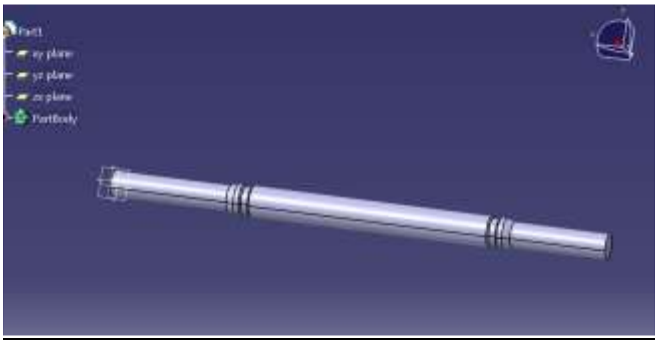


Fig.2 3D Model

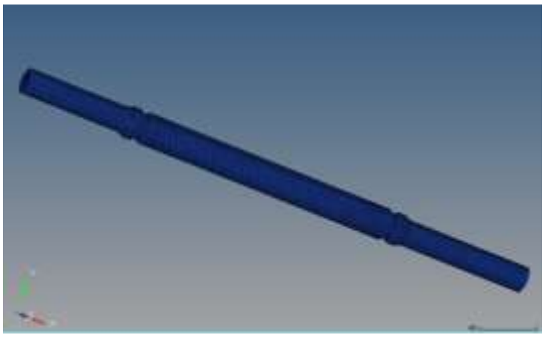


Fig.3 Tetra-Hedral Meshing On Drive Shaft

Number Of Nodes: 3937
Number Of Elements: 15858
Element Size = 4 Mm

Finite Element Analysis Of Existing Drive Shaft (Steel)

Torque Has Applied From One Side Of The Steel Drive Shaft The Other Side Has Been Fixed.

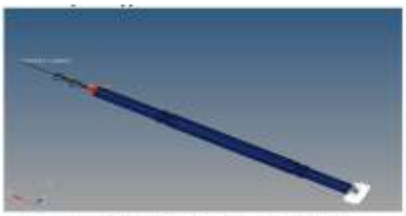


Fig 5 Meshed model with applied boundary condition

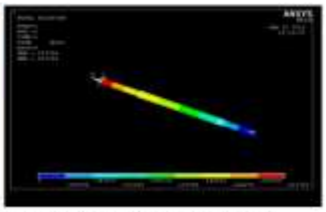


Fig.6 The maximum deformation of 0.2137 mm observed which is very less.

Von-Mises Stresses

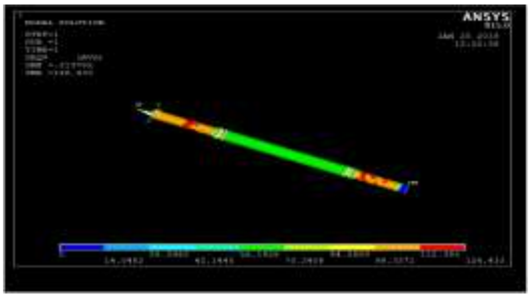


Fig.7 Von Mises Stress Of 126.433Mpa Observed Which Is Less Than Yield Stress Of Steel.

As The Deformation Is Very Low And Stress Produced Is Less Than Yield Stress Of Steel Hence There Is Scope For Optimization. After This Optimization Is Done By Doing Finite Element Analysis Using Composite Material.

Fibers:

- Specific Gravity
- Tensile Strength And Modulus
- Compressive Strength And Modulus
- Fatigue Strength And Fatigue Failure Mechanisms
- Electric And Thermal Conductivities
- Cost

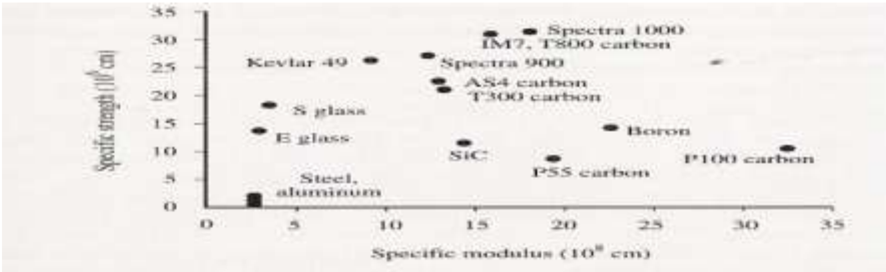


Fig 8 Specific Modulus And Specific Strength For Various Engineering Materials And Fibers (Swanson S.R; 1997; 3)

Table 1.1 Mechanical Properties of Typical Fibers

Fiber	Fiber Diameter (μm)	Fiber Density (lb/in³)	Fiber Density (g/cc)	Tensile Strength (ksi)	Tensile Strength (GPa)	Tensile Modulus (Msi)	Tensile Modulus (GPa)
E-glass	8–14	0.092	2.54	500	3.45	10.5	72.4
S-glass	8–14	0.090	2.49	665	4.58	12.5	86.2
Polyethylene	10–12	0.035	0.97	392	2.70	12.6	87.0
Aramid (Kevlar 49)	12	0.052	1.44	525	3.62	19.0	130.0
HS Carbon, T300	7	0.063	1.76	514	3.53	33.6	230
AS4 Carbon	7	0.065	1.80	580	4.00	33.0	228
IM7 Carbon	5	0.065	1.80	785	5.41	40.0	276
XUHM Carbon	—	0.068	1.88	550	3.79	62.0	428
GY80 Carbon	8.4	0.071	1.96	270	1.86	83.0	572
Boron	50–203	0.094	2.60	500	3.44	59.0	407
Silicon Carbide		0.115	3.19	220	1.52	70.0	483

Sources: From [1.1, 1.2] and product literature.

Table 1: Mechanical Properties Of Typical Fibers (Swanson S.R; 1997; 5)

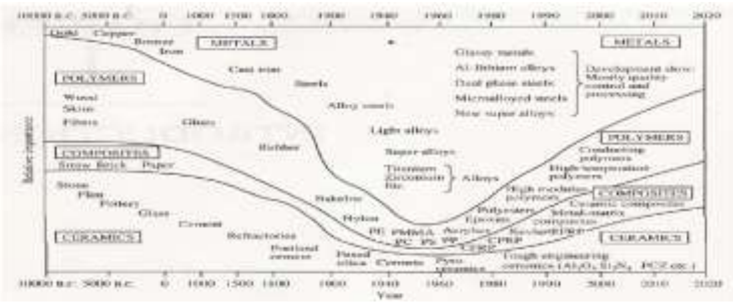


Figure 9 The Relative Importance Of Metals, Polymers, Composites And Ceramics As A Function Of Time. (Gibson. R.F; 1994; 2)

Material Properties: Glass Fiber

Property	Value
Young's Modulus In X-Direction, Ex	40300 Mpa
Young's Modulus In Y-Direction, Ey	6210 Mpa
Young's Modulus In Z-Direction, Ez	40300 Mpa
Poisson's Ratio ,N	0.2
Density, P	$1.9\text{x}10^{9}$tonne/M3
Shear Modulus In XY Plane, G_{xy}	3070 Mpa
Shear Modulus In YZ Plane, G_{yz}	2390 Mpa
Shear Modulus In ZX Plane,G_{zx}	1550 Mpa

Table 2: Mechanical Properties For Glass Fiber

Finite Element Analysis Of Composite Drive Shaft

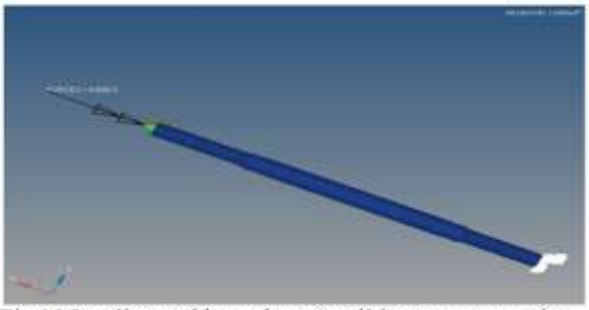


Fig.10 Loading and boundary conditions on composite which drive shaft

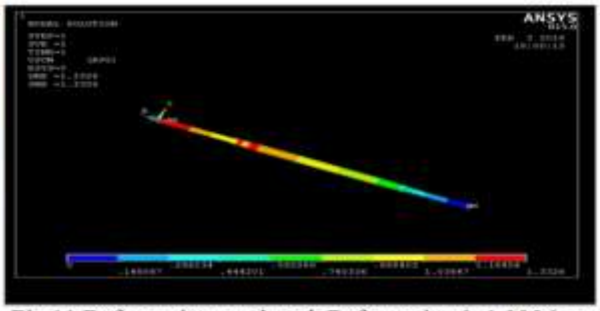


Fig.11 Deformation produced. Deformation is 1.3326 mm more than existing

Von-Mises Stresses

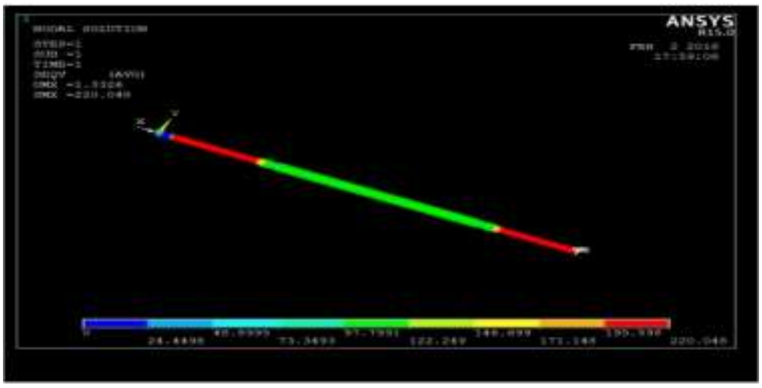


Fig.12 Von Mises Stress Produced. Stress Produced Is 220.04 Mpa

Compression Of Deformation And Stress

	Steel		Glass Fiber	
	Deformation(Mm)	Stress(Mpa)	Deformation(Mm)	Stress(Mpa)
Finite Element Analysis	0.2137	126.43	1.33	220.04

From This Table It Is Clear That Deformation And Stress In Composite Drive Shaft Is More. So It Is Not Feasible To Make A Total Drive Shaft From Composite Material. Instead Of This We Make A Drive Shaft With Composite Reinforcement And Analysis On Drive Shaft With Composite Reinforcement.

VI. Conclusion

As We Done The Analysis Of Existing Steel Material And Glass Fiber Material. But The Comparison Chart Shows Clearly That Only Glass Fiber Is Not Giving The Required Results So Composite Reinforcement Should Get Used. The Advantages Of Composite Reinforcement Material Are That It Will Optimize The Weight Without Compromising Mechanical Strength. It Will Increase The Cost But It Will Improve Performance By Improving Power To Weight Ratio.

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