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Analysis Of A Composite Drive Shaft For An Electric Vehicle

Niresh J[1], Neelakrishnan S[2], Dharun D S[3], Subramanian M[4]

[1,2,3,4]*Department of Automobile Engineering PSG College of Technology Coimbatore, India*

Email: [1]jnr.auto@psgtech.ac.in,[3]stharunst@gmail.com

Abstract: The weight decrease of the drive shaft can have a specific part in the overall weight decrease of the vehicle and is an exceptionally higher objective. The steel that are used to manufacture these kinds of the shafts leads to consumption of energy due to its weight. To avoid these kinds of energy loss, composite materials are used. It is realized that energy protection is one of the main targets in vehicle plan and decrease of weight is one of the best measures to acquire this good range of electric vehicles. In this project, examination is done on drive shaft with various composite materials with various proportion mixtures and concludes that the utilization of composite materials for drive shaft would induce less amount of stress which furthermore decreases the weight of the vehicle. CATIA is the modelling software used to design the drive shaft assembly and ANSYS is the analysis tool used to carry out analysis with different composite materials.

Keywords: Drive shaft, Composite materials, E-glass, E-carbon, CATIA, ANSYS

1. INTRODUCTION

The mix of various kinds of materials to shape or to breed another material with intriguing attributes and required properties for different applications are known as composite materials. Composite materials have been created all through this decade under different areas like material science, nano innovation and so on. Out of the multitude of various methods of executions of composite materials in different fields, the auto ventures give a tremendous arrangement of utilization situated use of the composite material. The auto is large equipment that has loads of parts in it. Every one of the parts give loads of weight, hence takes lots of fuel to make the vehicle to move. The weight of the auto likewise establishes the measure of the fuel utilization. A thought of diminishing the heaviness of the parts in the vehicle and to give the very effectiveness as that of the unique segments is being conferred. The answer for this materialistic approach is given by the composite material. Out of all different parts in the vehicle, the shaft is essentially centered in this investigation.

1.1. Drive shaft

The drive shaft of a vehicle refers to the gathering of components that works to deliver power from transmission to the driving wheels of a vehicle. The ability to run a vehicle begins in the crankshaft. It is then conveyed to the clutch, by means of the flywheel (in a manual transmission), or to a torque converter (in an automatic transmission). Power at that point goes to the transmission, where it is diverted to the drive shaft (likewise called prop shaft, driveline or propeller shaft). The drive shaft guides the ability to the drive axle, which contains both a final drive gear, and a differential. The final drive gear associates the drive shaft to the differential, which at that point guides power to each wheel. The shafts are the important components in an automobile for the purpose of transmission of power from the engine to the drive wheels. It delivers power from the prime mover of the vehicle (engine/electric motor) to the central differential, transmission system and axle. The drive shafts are longitudinal sections that carry torque for vehicle propulsion. The drive shaft that helps in the torque transmission are subjected to shear stress and tends to have a lot of power consumption. The objective of the drive shaft is to move the motor force to the drive wheels. It should likewise make up for all varieties in point or length coming about because of moving and deflection for ideal synchronization between joints. Drive shafts for vehicles with front wheel drive comprise of the outboard fixed joint, the inboard constant speed joint and the associating shaft.

1.2. Composites

A composite material is a blend of two materials with various physical and chemical properties. At the point when they are combined together, they make a material which is particular to make a specific job, for example to get more stronger, lighter or resistance to various properties. They can likewise improve strength and stiffness. The explanation behind their utilization over conventional materials is because that they improve the properties of their base materials and are applicable in many situations. Composites, otherwise called Fiber-Reinforced Polymer (FRP) composites, are produced using a polymer matrix that is reinforced with a designed, man-made or natural fiber (like glass, carbon or aramid) or other reinforcing material. The matrix protects the fibers from environmental and external damages and transfers the loads between the fibers. The fibers, thus, give better strength and stiffness to reinforce the matrix—and assist it with opposing failures and cracks.

2. PROBLEM IDENTIFICATION

The main issue in automobile is the vehicle's weight. The higher weight of the vehicle requires higher acceleration to propel the vehicle. The drive shaft is subjected to high torsional and shear stress. To withstand these forces, steel was used in manufacturing of the drive shaft. The usage of steel leads to increased drive shaft weight which leads to increase in overall weight of the vehicle. This leads to increase in consumption of fuel in case of IC engine vehicle and consumes more battery power in case of electric vehicle. Due to its weight. Also, the steel when subjected to moisture climate regularly, it has the possibility of iron oxide formation. In the present study, the various is things that is prepared are exploring composite materials by replacing the conventional one for weight reduction, weight reduction of the drive shaft can have a certain role in the general weight reduction of the vehicle and increasing life of the component by reducing iron oxide formation. Based on several previous studies, usage of composite materials on replacing conventional one would reduce in overall weight, the strength, stiffness and other parameters can be increased on introducing composite materials in the manufacturing of drive shaft, overall reduction in the weight of electric motor and the drive line on manufacturing the components with composite materials would result in efficient battery usage thereby increasing the range of the vehicle, carbon fiber reinforced epoxy composite cylinders produced by filament winding represent a weight reduction of up to 47% compared to a steel-based drive shaft.

3. MATERIALS AND METHODS

3.1. Materials

E-Glass or electrical evaluation glass was initially created for remain off encasings for electrical wiring. It was subsequently found to have fantastic fiber shaping abilities and is presently utilized only as the building up stage in the material generally known as fiberglass. E-Glass / Epoxy Resin, Borosilicate Glass Reinforced Epoxy Composites are extremely strong materials used in roofing, automobiles, and pipes with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics. E-glass ("E" due to initial electrical application), is soluble base free, and was the main glass detailing utilized for nonstop fiber development. It currently makes up the majority of the fiberglass creation on the planet, and furthermore is the single biggest purchaser of boron minerals all around the world. It is vulnerable to chloride particle assault and is a helpless decision for marine applications. Epoxy resins to any of the fundamental segments or restored finished results of epoxy gums, just as an informal name for the epoxide useful group. Epoxy resins, otherwise called poly epoxides, are a class of responsive prepolymers and polymers which contain epoxide groups. Vinyl ester resin, or frequently vinyl ester, is a resin created by the esterification of an epoxy resin with acrylic or methacrylic acids. The "vinyl" groups allude to these ester substituents, which are inclined to polymerize. The diester item is then broken down in a reacting agent, like styrene, to around 35–45 percent content by weight. Polymerization is started by free radicals, which are created by UV-illumination or peroxides. These vinyl esters are used in homebuilt airplanes that use vinyl ester fiberglass-reinforced structures. These are also commonly used in marine industry as it has high property of corrosion resistance and also it has the ability to withstand water absorption. The FRP tanks are manufactured with the use of these vinyl ester resin as the manufacturing follows the standard BS4994. This vinyl ester is treated with methyl ethyl ketone peroxide for laminating purpose so that it is capable of producing higher strength and mechanical properties than any polyester and epoxy resin. Araldite glue sets by the connection of an epoxy RESIN with a hardener. Blending an epoxy RESIN and hardener together beginnings a synthetic response that produces heat. This is called an exothermic reaction. After relieving, the joint is professed to be impenetrable to bubbling water and all regular natural solvents. It is accessible in a wide range of sorts of pack, the most well-known containing two unique cylinders, one each for the gum and the hardener. Different varieties incorporate two-fold needle type bundles which naturally measure equivalent parts.

4. MODELLING AND ANALYTICAL STUDY

4.1. Assumptions

- The drive shaft has a uniform, circular cross section
- The drive shaft is considered to rotate at a constant speed at its longitudinal axis

To design a drive shaft, one must know about how much of torque it has to be transfer, torsional buckling capacity, length of drive shaft, diameter of drive shaft, bending natural frequency and mass. We can easily compute the required data by knowing some essential parameters.

4.2. Selection of cross section of the drive shaft

For the choice of cross section of the drive shaft solid round or hollow round about are for the most part thought of. In this study hollow shaft cross section is picked due to following benefits:

- The solid circular shafts are more fragile in per kg weight than the hollow circular shaft.
- The stress distribution will be more at the outer surface of the solid circular shaft and at center, the stress distribution will be zero.
- In case of hollow circular shaft, the stress variation will be smaller.
- In the solid circular shaft, the material at its center is not being used. It only increases the weight of the shaft.

4.3. Calculations:
The composite drive shaft should satisfy three designs specifications such as,
1.Torque Transmission Capability
2.Buckling Torque Capability
3.Bending Natural Frequency.
For the taken vehicle, Maximum power is 37bhp@5000rpm.
P = 37bhp = 27.5kW; N= 5000rpm

$$P = \frac{2\pi NT}{60*1000}$$

T = 52.52Nm = 5. 35kgf.m;
From the design data book, for the given torque, the diameter of the shaft is 17mm.
Material = C45 steel; Maximum shear stress = $400\frac{kgf}{cm^2}$

STEEL SHAFT:
Torque transmitted capacity:

$$\frac{T}{J} = \frac{\tau}{R}$$

$$J = \frac{\pi}{32} * d^4$$

$$\tau = 50.83 * 10^6 \frac{N}{m^2}$$

For steel, shear stress is $50.83 * 10^6 \frac{N}{m^2}$

Torsional buckling capacity of the drive shaft

$$\tau cr = \frac{E}{3\sqrt{2}*(1-\mu^2)^{\frac{3}{4}}} * \left(\frac{t}{r}\right)^{\frac{3}{2}}$$

For solid shaft, t = r

$$\tau cr = 5312.54 * 10^6 \frac{N}{m^2}$$

$$Tb = \tau cr * 2\pi r3 = 21980.6Nm$$

Tb > T.

Design is safe

Bending natural frequency

$f_{nb}= \frac{\frac{\pi}{2}\sqrt{ExIx}}{m\,l^4}$

$I = 405*10^9\ m^4$
$m = 1.87\ kg/m$
$f_{nb} = 215.37Hz > 80Hz$

Critical speed
$N_{cr} = 60*f_{nb} = 12922rpm > N$
W = Density * Volume = 2.26Kg

Bending stress:
$\sigma b\ =\ \frac{32M}{\pi d^3}$

Bending moment: $M = \frac{W*L}{4} = 2.21Nm$

$\sigma b = 4.27 * 10^6\ N/m^2$

FIBRE = EGLASS; MATRIX = EPOXY RESIN:
$E_C = E_F V_F + E_M V_M$,
also ($V_M + V_F$) = 1 or $V_M = (1 - V_F)$.
$E_F = 78GPa$ $E_M = 3.5GPa$ $V_F= 0.6$
Ec = 48.2 GPa
$\nu_C = \nu_F\ \nu_F + \nu_M \nu_M$
$\nu_f = 0.25; \nu_m = 0.34$
$\nu_f = 0.286$
$\rho_c = \rho_f V_f + \rho_m V_m$
$\rho_f = 2540\ kg/m^3$; $\rho_m = 1200\ kg/m^3$
$\rho_c = 2164\ kg/m^3$

$$Q_{11} = \frac{E_1}{1-\nu_{12}\nu_{21}}, Q_{22} = \frac{E_2}{1-\nu_{12}\nu_{21}}$$

$$Q_{12} = \frac{\nu_{12}E_2}{1-\nu_{12}\nu_{21}}, Q_{66} = G_{12}$$

$$\nu_{21} = \frac{E_2}{E_1}\nu_{12}$$

$$[A] = \sum_{k=1}^{N}[\overline{Q}]^k(z_k - z_{k-1})$$

$$E_x = \frac{1}{t}[A_{11} - \frac{A_{12}^2}{A_{22}}]$$

$$E_h = \frac{1}{t}[A_{22} - \frac{A_{12}^2}{A_{11}}]$$

$E_x = 60.39Gpa$
$E_h = 60.39GPa$

FIBRE = CARBON; MATRIX = EPOXY RESIN
$E_C = E_F V_F + E_M V_M$,

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also ($V_M + V_F$) = 1 or $V_M = (1 - V_F)$.
$E_F = 220GPa$ $E_M = 3.5GPa$ $V_F = 0.6$
Ec = 133.4 GPa
$\nu_C = \nu_F \; \nu_F + \nu_M \nu_M$
$\nu_f = 0.22$; $\nu_m = 0.34$
$\nu_f = 0.268$
$\rho_c = \rho_f V_f + \rho_m V_m$
$\rho_f = 2540\ kg/m^3$; $\rho_m = 1200\ kg/m^3$
$\rho_c = 1690\ kg/m^3$

$E_x = 133.45$Gpa
$E_h = 133.45$GPa

$$\frac{50.77*10^6}{R} = \frac{51.86*10^9*0.028}{0.4}$$

R = 0.014m
D = 27.8mm

$$(f_{nb}) = \frac{\pi}{2}\sqrt{\frac{E_x I_x}{m' L^4}}$$

	Steel	E glass	Carbon
Diameter	17.4mm	49mm	28mm
Critical speed	12922 rpm	56275 rpm	36374 rpm
Mass	2.26Kg	1.6Kg	0.4Kg
E	210GPa	60.3GPa; 60.3GPa	133.45GPa; 133.45GPa
σ_b	$4.27 * 10^6\ N/m^2$	$0.9*10^5 N/m^2$	$0.203*10^5\ N/m^2$
ν	0.3	0.286	0.268
ρ	7850 kg/m^3	2164 kg/m^3	1690 kg/m^3
Stress	$50.77*10^6 N/m^2$	$6.38*10^6 N/m^2$	$12.18*10^6\ N/m^2$

M = 1.025kg/m

$I_x = 2.93*10^{-8}\ m^4$

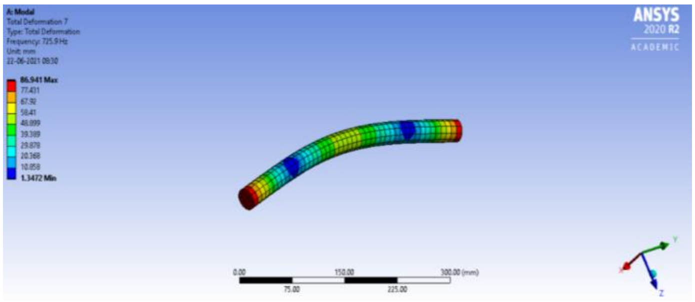
F_{nb} = 606.24 Hz > 80 Hz

N_{cr} = 36374.8 rpm > N

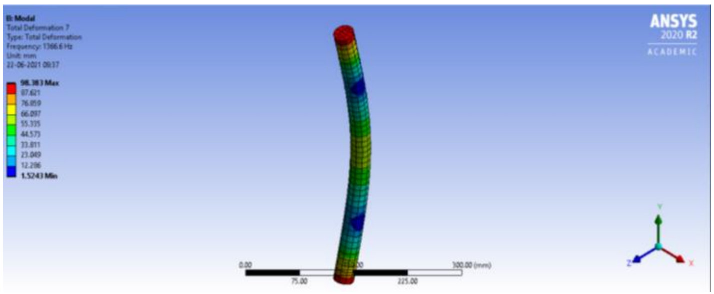
W= 0.4kg

5. ANALYSIS

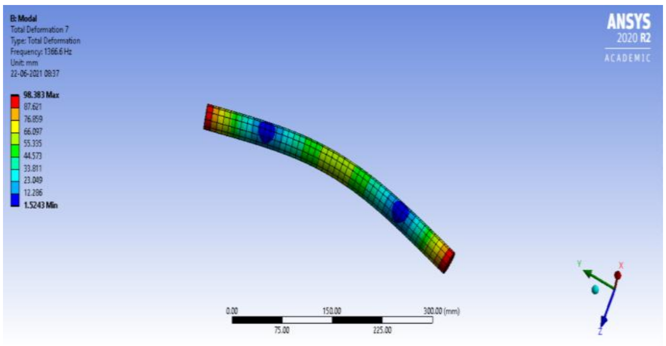
5.1. Total deformation in modal analysis:



STEEEL

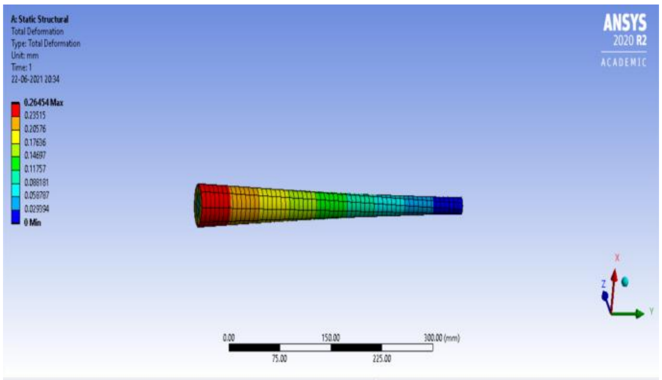


EGLASS

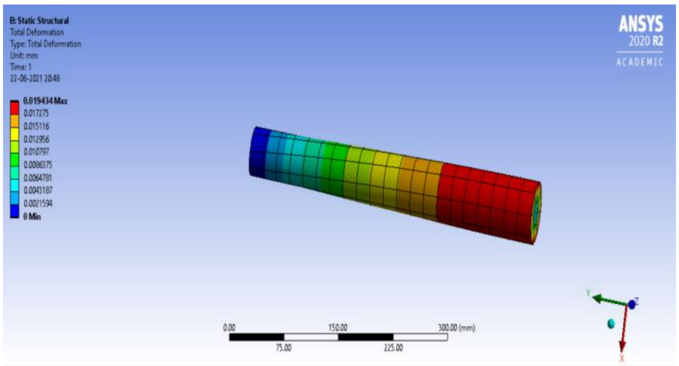


ECARBON

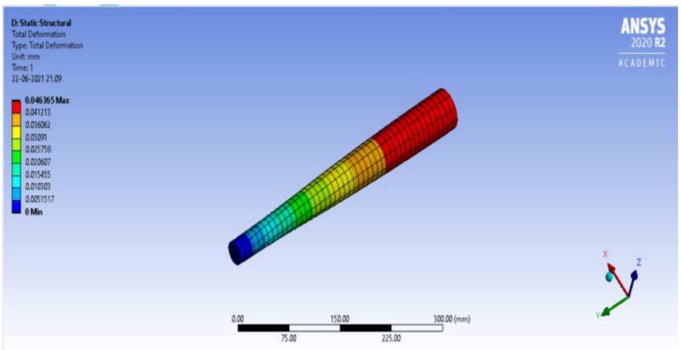
5.2. TOTAL DEFORMATION IN STRUCTURAL ANALYSIS:



STEEL

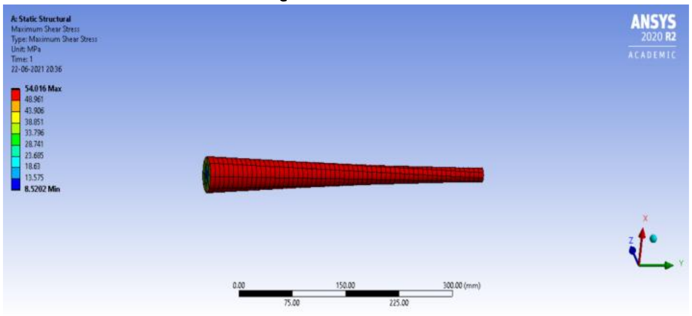


EGLASS

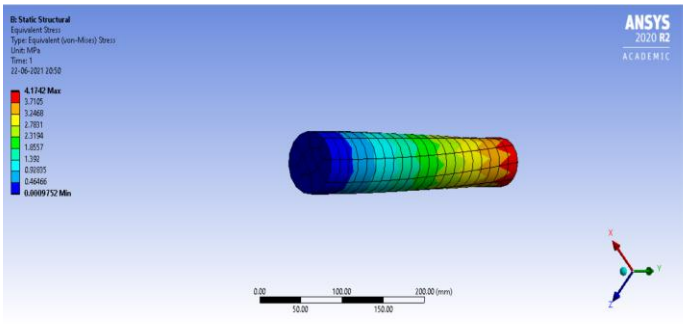


ECARBON

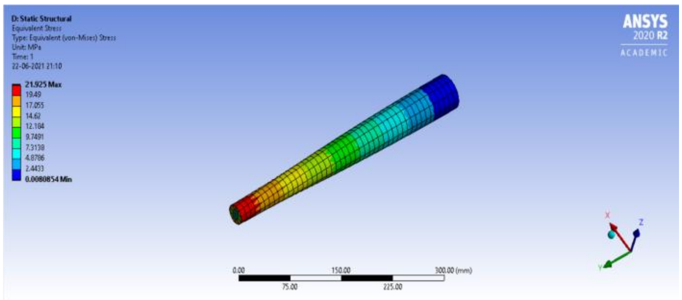
5.3. EQUIVALENT STRESS:



STEEL



EGLASS



ECARBON

6. CONCLUSION

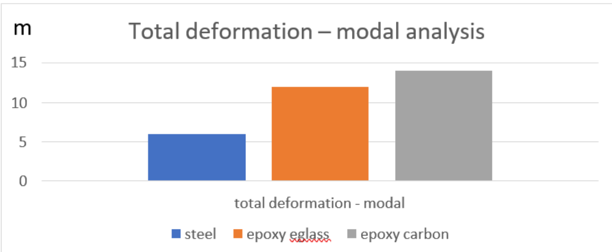


FIG 6.1. TOTAL DEFORMATION – MODAL ANALYSIS

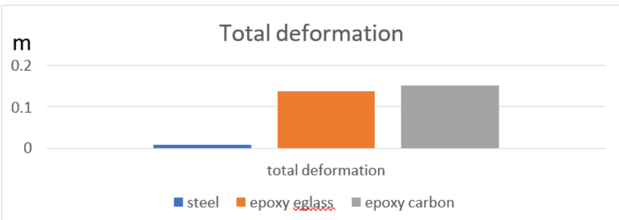


FIG 6.2. TOTAL DEFORMATION – STRUCTURAL ANALYSIS

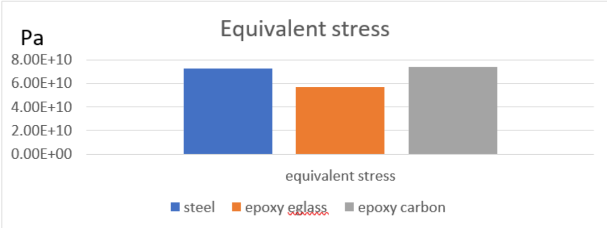


FIG 6.3. EQUIVALENT STRESS

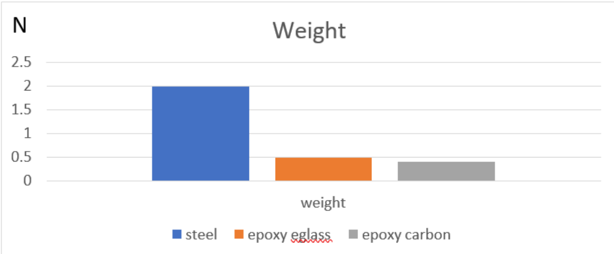


FIG 6.4. WEIGHT

From the results obtained, it is seen that the drive shaft made of composite material of e-glass and resin has the ability to withstand higher stress and in calculation it also resulted in 40% of weight reduction.

On considering all these results, I conclude by saying that epoxy glass with 60% resin ratio could be used for manufacturing driveshaft to reduce weight and thus the stress induced in the driveshaft could also be reduced. This weight reduction would have certain amount of weight reduction in overall weight of the vehicle, which would have certain role in increasing fuel efficiency and increasing range of electric vehicle.

7. REFERENCES

[1] G. Suresh, L.S. Jayakumari, “Analyzing the mechanical behavior of E-Glass fibre reinforced interpenetrating polymer network composite pipe”, J. Comp. Mater. 50, 3053–306, 2016.
[2] G. Suresh, A. Abdul Munaf, R.M. Akash, S. Bharani Kumar, K. Kanagaraja, “Analyzing the mechanical behaviour of carbon fiber reinforced spur gear with IPN as matrix material”, SSRN 1 (11), 1–4, 2019.
[3] Almeida JHS Jr, Faria H, Marques AT, et al. “Load sharing ability of the liner in type III composite pressure vessels under internal pressure”. J Reinf Plast Compos. 33, 2274–2286, 2014.
[4] Almeida JHS Jr, Ribeiro ML, Tita V, et al. “Damage and failure in carbon/epoxy filament wound composite tubes under external pressure: experimental and numerical approaches”. Mater Des. 96, 431–438, 2016.
[5] Lo H-C and Hyer MW. “Fundamental natural frequencies of thin-walled elliptical composite cylinders”. J Compos Mater. 46, 1169–1190, 2011.
[6] Satyajit S. Dhore1, Hredeya Mishra. “Material optimization and weight reduction of drive shaft using composite material”. IJARIIE 5, 53-60, 2015.
[7] Polychronis Spanoudakis, Nikolaos C. Tsourveloudis, Lefteris Doitsidis and Emmanuel S. Karapidakis. “Experimental Research of Transmissions on Electric Vehicles’ Energy Consumption”. MDPI Energies 12, 388 – 403, 2019.

[8] Ibrahim Fadil Soykok, Onur Sayman, Mustafa Ozen, Behiye Korkmaz. “Failure analysis of mechanically fastened glass fiber/epoxy composite joints under thermal effects”, Composites: Part B 45, 192–199, 2019.
[9] Barsoum I, Khan F and Barsoum Z. “Analysis of the torsional strength of hardened splined shafts”. Mater Des 2014; 54: 130–136.
[10] Jain, H. “Scope of Energy Conservation in Pumping System”, IARS’ International Research Journal. Vic. Australia, 10(2) 2020. doi: 10.51611/iars.irj.v10i2.2020.105.
[11] Chandrakant Panchani, Nayan Gosvami, “Design & Analysis of Composite Material Shaft in Automobile: A Review”, International Journal for Scientific and Research and Development, 2 (10), 149-151, 2014.
[12] Panduranga V Chopde, Prof. R.B Barjibhe, “Analysis of Carbon/Epoxy Composite Drive Shaft for Automotive Application”, International Journal of Latest Trends in Engineering and Technology, 5(1), 101-111, 2015.
[13] J.H.Park, J.H.Wang, “Stacking sequence design of composite Laminates for maximum strength using genetic algorithm”, Journal of composite structures, Vol 52, pp. 217 – 223, 2001.
[14] B Stanly Jones Retnam, M Sivapragash and P Pradeep, “Effects of fiber on mechanical properties of hybrid bamboo/glass fiber polymer composites”, 2012.
[15] K. Vasantha kumar, Dr. P. Ram reddy, Dr. D.V.Ravi shankar, “Effect of angle ply orientation on tensile properties bi directional woven fabric glass epoxy composite laminate”, International journal of computational research, Vpl. 3, pp. 55 – 61. 2013.
[16] Sachse S, Poruri M, Silva F, Michalowski S, Pielichowski K, Njuguna J. “Effect of nanofillers on low energy impact performance of sandwich structures with nanoreinforced polyurethane foam cores”, J. Sandwich struct Mater. Vol 16(2), pp. 173 – 194, 2014.
[17] Manjunath K, S. Mohan Kumar, Channakeshava K. R, “Optimization Of Ply Stacking Sequence Of Composite Drive Shaft Using Particle Swarm Algorithm”, Journal of Engineering Science and Technology, Vol. 6, No. 3, 2011.
[18] Mohammad Reza Khoshravan, Amin Paykani ,AidinAkbarzadeh, “Design And Modal Analysis Of Composite Drive Shaft For Automotive Application”, International Journal of Engineering Science and Technology, Vol. 3, No. 4, 2011.
[19] M.A.K. Chowdhuri, R.A. Hossain, “Design Analysis of an Automotive Composite DriveShaft”, International Journal of Engineering Science and Technology, Vol.2(2), 2010.
[20] Hak Sung Kim, Dai Gil Lee, “Optimal design of the press fit joint for a hybrid aluminum/composite drive shaft”, Composite Structure 70, 2005.
[21] Dai Gil Lee, Hak Sung Kim, Jong Woon Kim, Jin Kook Kim, “Design and manufacture of an automotive hybrid aluminum/composite drive shaft”, Composite Structure 63, 2004.
[22] , B.N.V.S. Ganesh Gupta K, Mritunjay Maharudrayya Hiremath, Bankim Chandra Ray, Rajesh Kumar Prusty, “Improved mechanical responses of GFRP composites with epoxy-vinyl ester interpenetrating polymer network”, Polymer Testing 93 (2021) 107008.
[23] Jain, S.; Palia, A. Opportunities and Challenges in Paper Printed RFID. IARS’ International Research Journal, Vic. Australia, v. 7, n. 2, 2017. DOI: 10.51611/iars.irj.v7i2.2017.82.
[24] Si-Yao Guo, Xu Zhang, Jie Ren, Ji-Zhou Chen, Tie-Jun Zhao, Ting-Wei Li, Lihai Zhang, “Preparation of TiO2/epoxy resin composite and its effect on mechanical and

bonding properties of OPC mortars", Construction and Building Materials 272 (2021) 121960.
[25] Ross F. Minty, Liu Yang, James L. Thomason, "The influence of hardener-to-epoxy ratio on the interfacial strength in glass fibre reinforced epoxy composites", Composites Part A 112 (2018) 64 – 70.