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Comparative Studies on Ladder Structures made up of CRP and GRP Composite Rods

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Abstract:
Ladders are mechanical structure used in many engineering and domestic applications to transfer materials in vertical direction with human being intervention. The main design requirements of ladder are low weight and high strength .The internal crossed rods across four legs of ladder should have more stiffness. The choice of the composite materials for the fabrication of ladders fulfils the requirements of low weight , high strength and stiffness. The paper discusses the structure of the ladder with CRP(Carbon Reinforced Plastics) and GRP(Glass Reinforced Plastics) pultruded rods in place of steel rods. This paper mainly deals with the studies on geometric modelling and stress analysis of ladder structure with the material properties of CRP and GRP. The CREO and ANSYS softwares have been used to model and stress analysis of ladder structure that is built up with CRP and GRP composite circular rods. With the help of ANSYS studies, a comparative study on stresses developed in both CRP and GRP ladder structure is made . The results are evaluated by placing the different loads on the ladder.

Keywords: *CRP, GRP, Pultruded, Epoxy*

I. Introduction

A composite is usually made up of at least two materials out of which one is the binding material,also called matrix and the other is the reinforcement material(fiber,kevlar). Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix).Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical Properties; yet together they produce a combination of qualities which individual constituents would be in capable of producing alone. The reinforcement may be Platelets, Particles or fibers and are usually added to improve mechanical Properties such as stiffness, strength and toughness of the matrix material. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and aramid fibers.The advantage of composite materials over conventional materials are largely from structural design to be more versatile. It finds application in automotive, aerospace, electronic equipment, sport goods, furniture, medical equipment & packaging Industry. Composite materials used as an industrial material for their outstanding resistance to chemicals and most forms of corrosion. This property of composite material conventionally important is hardly the only useful property. There are many important and useful properties are, low mass, low weight unequalled manufacturing and processing possibilities, complex material body are easily produced, appropriate to very small products and very large product, tooling cost is very low, satisfactory surface finish can be an integral feature. Composites have four to six times tensile strength as compare to steel or aluminium (depending on the reinforcements). Composites have less noise and lower vibration transmission than metals at the time of operations. Composite materials have torsional stiffness and impact properties. Composites have high fatigue strength, impact, environmental resistance and reduce maintenance, higher fatigue endurance limit (up to 60% of ultimate tensile strength). Composites exhibit fire retardancy and good corrosion resistance.

In this paper, the ladder analysis is carried out. The structure of the ladder with CRP(Carbon Reinforced Plastics) and GRP(Glass Reinforced Plastics) pultruded rods in place of steel rods. This paper mainly deals with the studies on geometric modelling and stress analysis of ladder structure with the material properties of CRP and GRP.

The paper is organised in the following manner, section 2 gives the details of geometry of the ladder. Section 3 includes the modelling and the different views of the ladder. The stress and deflection analysis is carried out with FEM approach and is given in the section 4. Section 5 discusses the analysis results and finally conclusions drawn in section 6.

II. Geometry of the Ladder

The geometry of the ladder is shown in the below figure. The structure consists of the four vertical circular rods with diameter 50mm.There are 24 internal crossed rods across the four legs of the ladder with diameter 30mm. A square plate is attached to the four vertical legs for standing purpose.

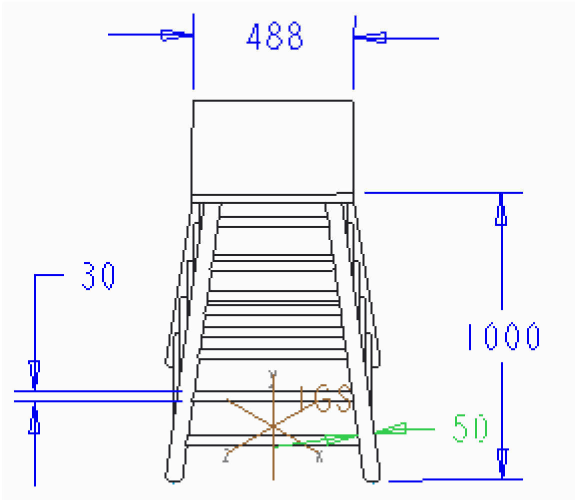


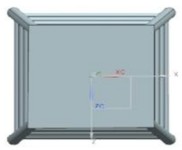
Figure 2.1: Line diagram of Ladder

III. Modelling of The Ladder Structure

3D modelling of the ladder is done by using PRO-E software. PRO-E software is one the cad software mostly used in India now a day. It is mostly used in small industries due to its limited applications.

Views of Ladder:

Figure3.1: Front view



Top view

Side view

Isometric view

IV. Analysis of The Ladder

The analysis of the ladder is done by using ANSYS. The model is to be imported from CREO to ANSYS in the form of parasolid file. The loads were applied on the ladder. Displacement, stress and factor of safety were calculated for three materials.
The following material properties are required for analysis of ladder structure.

Properties of steel material:

Young's modulus = 200 GPa
Density = 7850 kg/m^3
Yield strength =250 MPa

Properties of E-glass/Epoxy material:

Young's modulus = 50 GPa
Density = 2000 Kg/m^3
Yield strength =757MPa

Properties of Carbon/Epoxy material:

Young's modulus = 134 GPa
Density = 1600 Kg/m^3
Yield strength =880 MPa

By using above properties static structural analysis is done by using ANSYS software.

Figure4.1: Infinite model of Ladder

Figure4.2: Finite model of Ladder

V. Results

Calculation of weight of the ladder:
The weight of the ladder is calculated by using the formula:
Weight(W)=Mass(m)*Gravitational force(g)

For steel:
Weight (W)=Mass*Gravitational force
Mass=density*volume
Mass=7850*22084104*10^{-9}
Mass=173.36Kg
Weight=173.36*9.81
Weight of the ladder=1700.66N

For E-Glass/Epoxy:
Weight (W)=Mass*Gravitational force
Mass=density*volume
Mass=2000*22084104*10^{-9}
Mass=44.16Kg
Weight=44.16*9.81
Weight of the ladder=433.2N

For Carbon/Epoxy:
Weight (W)=Mass*Gravitational force
Mass=density*volume
Mass=1600*22084104*10^{-9}
Mass=35.33Kg
Weight=35.33*9.81
Weight of the ladder=346.63N

The weights of the ladder for three materials i.e Steel,E-Glass/Epoxy,Carbon/Epoxy are calculated and the weights are 170Kgs for steel material,43Kgs for E-Glass/Epoxy and 34Kgs for Carbon/Epoxy.

Results for steel material:

Load at 10KN:

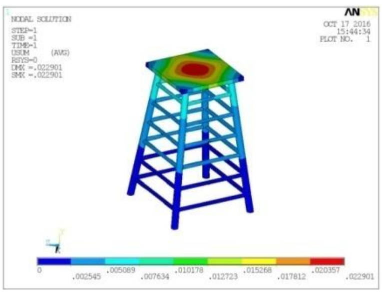


Figure5.1: Total displacement on the Ladder

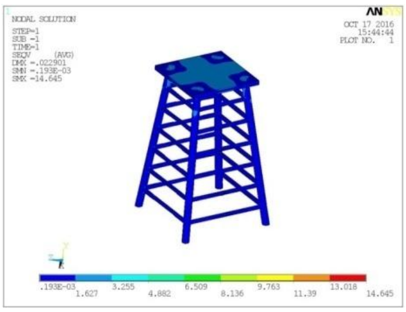


Figure5.2: Von misses stress observed on the Ladder

Load at 100KN:

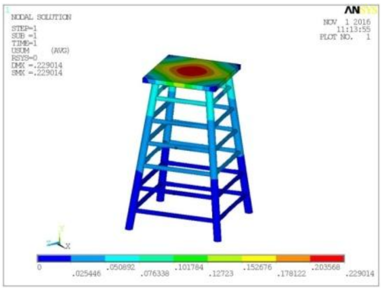


Figure5.3: Total displacement on the Ladder

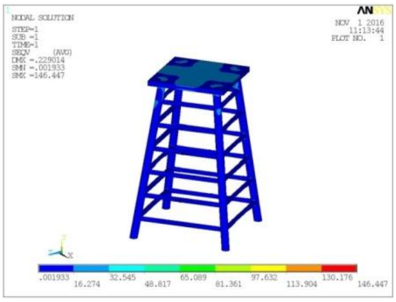


Figure5.4: Von misses stress observed on the Ladder

Load at 200KN:

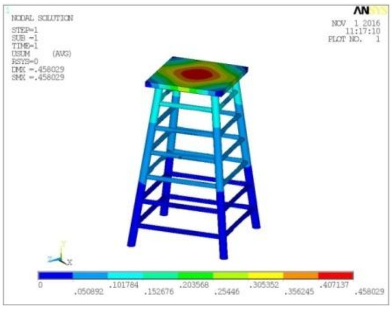


Figure5.5: Total displacement on the Ladder

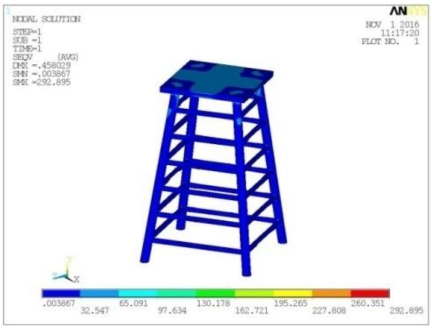


Figure5.6: Von misses stress observed on the Ladder

Table 5.1: Displacements and stresses at different loads

Load(KN)	Displacement(mm)	Stress(MPa)	Factor of safety
10	0.022	14	17
100	0.22	146	1.7
200	0.45	292	0.8

The yield strength of the steel material is 250Mpa**.**At the loads of 10KN and100 KN the Von misses stress of Ladder is less than the yield strength of the material. So at that point of loads the design is safe. But at 200KN the Von misses stress of Ladder is more than the yield strength of the material. Hence from the obtained results, it has been observed that the steel ladder can withstand a maximum load of below 200KN.

By using the interpolation method the steel ladder can withstand a maximum load of 171.23KN.

For E-Glass/epoxy:

Load at 200KN:

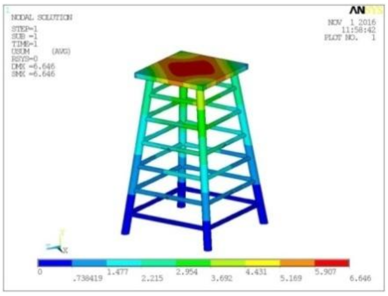


Figure5.7: Total displacement on the Ladder

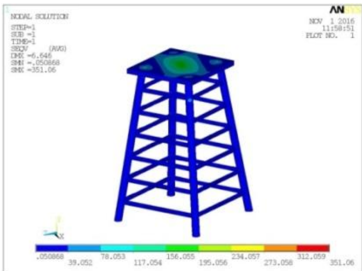


Figure5.8: Von misses stress on the Ladder

Load at 500KN:

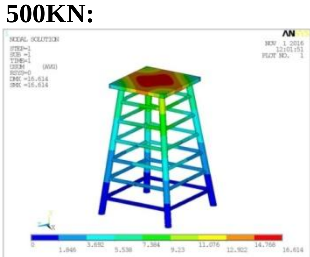


Figure5.9: Total displacement on the Ladder

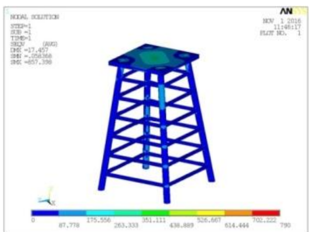


Figure5.10: Von misses stress on the Ladder

Table5. 2: Displacements and stresses at different loads

Load(KN)	Displacement(mm)	Stress(MPa)	Factor of safety
200	6.6	351	2
500	16.6	790	0.9

The yield strength of the E-Glass/Epoxy material is 757MPa. At the load of 200 KN the Von misses stress of Ladder is less than the yield strength of the material. So at that point of loads the design is safe. But at 500KNthe Von misses stress of Ladder is more than the yield strength of the material.Finally, it has been observed that the E-Glass/Epoxy ladder can withstand a maximum load of below 500KN.

By using the interpolation method the E-Glass/Epoxy ladder can withstand a maximum load of 477.4KN.

For carbon/epoxy:

Load at 200KN:

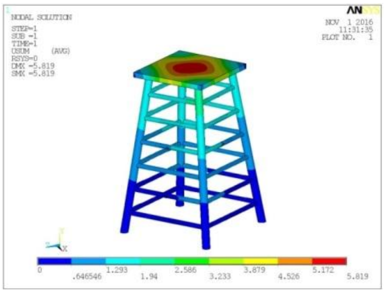


Figure5.13: Total displacement on the Ladder

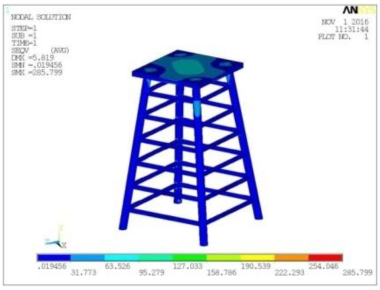


Figure5.14: Von misses stress on the Ladder

Load at 500KN:

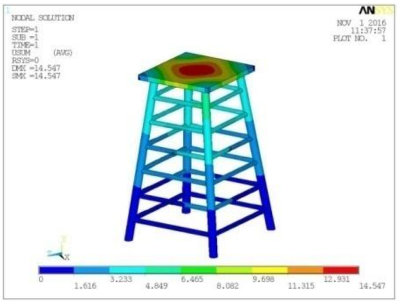


Figure5.15: Total displacement on the Ladder

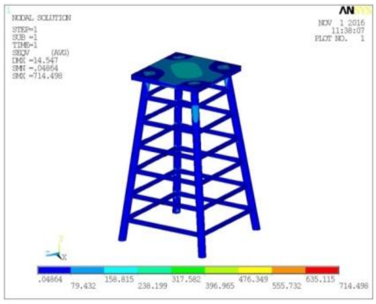


Figure5.16: Von misses stress on the Ladder

Load at 600KN:

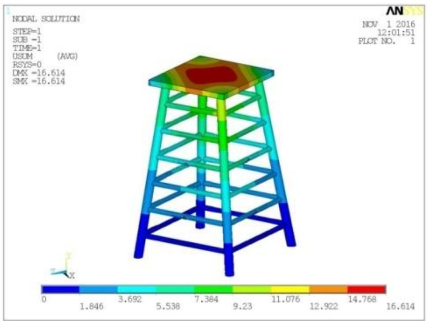


Figure5.17: Total displacement on the Ladder

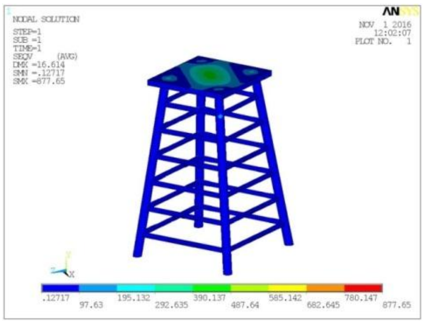


Figure5.18: Von misses stress on the Ladder

Table5. 3: Displacements and stresses at different loads

Load(KN)	Displacement(mm)	Stress(MPa)	Factor of safety
200	5.8	285	3
500	14.54	714	1.2
600	16.5	877	1

The yield strength of Carbon/Epoxy material is 880MPa. The Von misses stress of Ladder is less than the yield strength of the material. Hence the Ladder is a safe in design for Carbon /Epoxy material. So Carbon /Epoxy material can withstand a maximum load of 600KN.

VI. Conclusions

- It is observed that the weight of composite ladder is less than the weight of the steel ladder.
- The weight of the Steel ladder is 170kgs.The weight of the E-Glass/epoxy is 43kgs and the Carbon/epoxy is 34kgs.
- It can de concluded that the load carrying capacity of composite ladder is more than the steel ladder.
- The steel material can withstand a maximum load of upto171.2 KN. The e-glass/epoxy material can withstand a maximum load of 477.4KN.And the carbon/epoxy material can withstand a maximum load of 600KN.
- It is also found that the Factor of Safety is more for ladder made up of composite materials than steel ladder at maximum load carrying capacities. so the service condition and life of the ladder is more durable and stronger than steel..

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