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Composite Pipe Design And Analysis

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Abstract— *Traditional building materials have their place. But for harsh,corrosive environments and working conditions, metal reinforced plastics are a smart choice. Conventional material pipes are in need of corrosion protection as well as sufficient structural strength. Besides, they are subject to attack from the substance being transported through the pipe and environment outside. Metals might offer better corrosion resistance than plastic but very expensive materials. The maximum pressure for plastic pipes are limited and pipes made from plastic require more supports. The combination of metal and plastic gives strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material which is called as metal reinforced plastic. Finite element analysis is pursued as a analytical tool while physical experimentation is conducted for validation of the work.*

Keywords-
PP-Polypropylene.
PVC-Polyvinyl chloride.
UTM-Universal testing machine.
EG-Epoxy Glass

1.Introduction-

1.1 Introduction to composites:

Recent technological breakthroughs and the desire for new functions generate an enormous demand for novel materials. Many of the well-established materials, such as metals, ceramics or plastics cannot fulfill all technological desires for the various new applications. Scientists and engineers realized early on that mixtures of materials can show superior properties compared with their pure counterparts. So the new material comes into play called composite materials.

A composite is commonly defined as a combination of two or more distinct materials, each of which retains its own distinctive properties, to create a new material with properties that cannot be achieved by any of the components acting alone. Using this definition, it can be determined that a wide range of engineering materials fall into this category. For example, concrete is a composite because it is a mixture of Portland cement and aggregate. Fiberglas sheet is a composite since it is made of glass fibers imbedded in a polymer.

Composite materials are said to have two phases. The reinforcing phase is the fibers, sheets, or particles that are embedded in the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile, or tough, material.

Some of the common classifications of composites are Reinforced plastics, Metal-matrix composites,Ceramic-matrix composites, Sandwich structures Concrete.

Composite materials can take many forms but they can be separated into three categories based on the strengthening mechanism. These categories are dispersion strengthened, particle reinforced and fiber reinforced. Dispersion strengthened composites have a fine distribution of secondary particles in the matrix of the material. These particles impede the mechanisms that allow a material to deform. Many metal-matrix composites would fall into strong and light. This property is why composites are used to build airplanes—which need a very high strength material at the lowest possible weight.

1.2 Problem definition:

The conventional pipe for carrying fluids is typically made of Steel. The sp.density of steel being higher (7.85gm/cc), the weight of the pipe for long and complex piping system becomes a matter of concern. Besides, underground applications possess a challenge of wear and tear due to corrosion while being buried in the soil. Though the structural strength of steel is best in its class, the strength to weight ratio is not favorable for applications demanding lower cost and/or lower weight of the entire piping system. Since the pipe is a major element in any given piping system, the focus of this dissertation work would be to identify alternative/s to the conventional pipe while keeping it `light' on weight to sustain the load of 500Kg without visible crack on exterior surface.

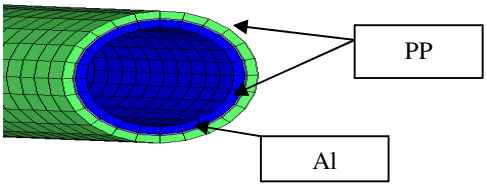
1.3 Advantages of composite materials:

Light Weight - Composites are light in weight, compared to most woods and metals. Their lightness is important in automobiles and aircraft, for example, where less weight means better fuel efficiency (more miles to the gallon.

High Strength - Composites can be designed to be far stronger than aluminum or steel. Metals are equally strong in all directions. But composites can be engineered and designed to be strong in a specific direction.

Strength Related to Weight - Strength-to-weight ratio is a material strength in relation to how much it weighs. Some materials are very strong and heavy, such as steel. Other materials can be strong and light, such as bamboo poles. So we are finding the alternative for steel.

2. Design of composite pipe:(PP-Al-PP)



The composite pipe is designed by taking into the consideratios the requirement of application strength to weight ratio, weight saving and costing.According to these parameter composite pipe with three variants is designed.

2.1 Composite ply configurations:

Table1: Composite ply configuration

			THICKNESS(mm)			INNER RADIUS	OUTER RADIUS
PP	EG	PP	1.75	0.5	1.75	16	20
PVC	EG	PVC	1.75	0.5	1.75	16	20
PP	AL	PP	1.5	0.3	1.5	16.7	20
STEEL				3.68		20.5	24.12

The diamensions are taken as per DN40.

2.2 Weight calculation for the alternatives:

The weight for the alternatives is calculated from finding out the volume of perticular ply and multiplied by its specific weight.
Weight=Total volume*Specific weight

Table 2:Specific weights for alternative materials:

Alternative	Sp.wt(gm/cc)
PP	0.85
AL	2.80
PVC	1.2
EG	1.3
STEEL	7.85

2.3 Finite element analysis:

The CAD model of the pipe is,modelled in CATIA V5R19 and it is the imported into the hypermesh. Pipe constrained at both

ends, the solid or shell meshing is done with the element size of 3mm.The pressure of 10 bar is applied to every variant pipe.

2.3.1Quality checks:

Table 3:Quality checks.

Warpage	<5°
Aspect	<5
Skew	< 60°
interior angles	45°< Quad < 135°
	20°< Tri < 130°
Jacobian	> 0.7

2.4 Analysis results

And the results of von mises stress and corresponding strain and displacement is tabulated as follows:

Table 4:Analysis results

	Vonmises stress Mpa			Plastic Strain %			Disp mm
Varint	Inner	Mid	Outer	Inner	Mid	Outer	
PP-AL-PP	12.5	358.6	11.58	0.033	0.13	0.033	0.22
PVC-EG-PVC	63.63	234.8	63.6	14.72	12.2	14.53	3.57
PP-EG-PP	46.46	274.1	46.6	2.4	0.06	2.46	0.85
STEEL	45.48			0			0.005

2.5 Analytical results:

The analytical results i.e. the von mises stresses ,plastic strain and the displacement is calculated considering pipe as a cylinder and tabulated as follows:

Table 5:Analytical results:

	Vonmises stress Mpa			Plastic Strain %			Disp mm
Varint	Inner	Mid	Outer	Inner	Mid	Outer	
PP-AL-PP	11.78	348.6	13.07	0.02	0.9	0.02	0.19
PVC-EG-PVC	55.5	224.5	61.7	10.72	10.2	12.53	3.00
PP-EG-PP	40.04	267.1	38.04	1.7	0.04	2.00	0.65
STEEL	42.17			0			0.003

From the analysis table it is found that the von mises stresses in thePP-EG-PP is exceeding the yield strength of the materials so this variant is neglected for further experimentation.Also equivalent plastic strain and displacement values for the PP-EG-PP and PVC-EG-PVC are more than the steel and PP-Al-PP pipe.So these variants are eliminated for physical experimentation.

3. Experimentation:

Aim-To find the displacement recorded while subjecting the component to the given rate of loading.

Material type- PP-AL-PP

Apparatus-Universal compressive testing machine (UTM), Vernier callipers, stop watch, dial gauge.

Rate of loading-10mm/min

Introduction

A compression test is a method for determining the behaviour of materials under a compressive

load. Compression tests are conducted by loading the test specimen between two plates and then applying a force to the specimen by moving the crossheads together. The compression

test is used to determine elastic limit, proportionality limit, yield point, yield strength and compressive strength.

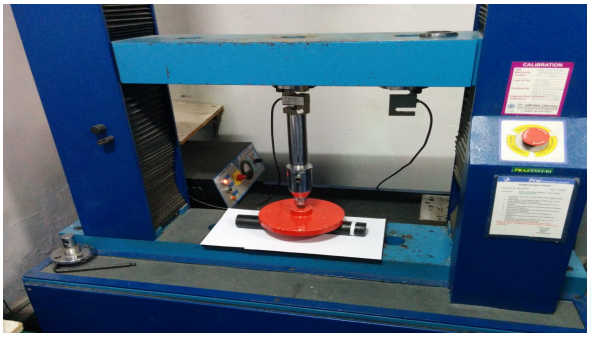
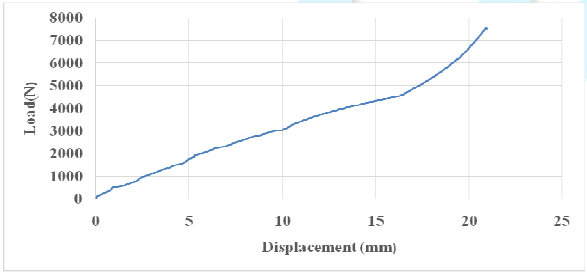


Fig 3.1:Universal Testing Machine

Table 6:Results of Load Vs displacement from UTM

Load(N)	Displacement (mm)
1000	2.49
1950	4.9
2619	7.971
3047	10
4016	13.25
4514	16
5707	18.50
7590	21



Graph 3.1: Load Vs displacement for PP-AL-PP from UTM

4. Analysis Of Test Specimen PP-Al-PP Pipe Under 7590N

The 40mm diameter pipe of 150 mm length is selected for the experimentation and is kept on platform and external load is applied through applicator up to breakage or 7590 N

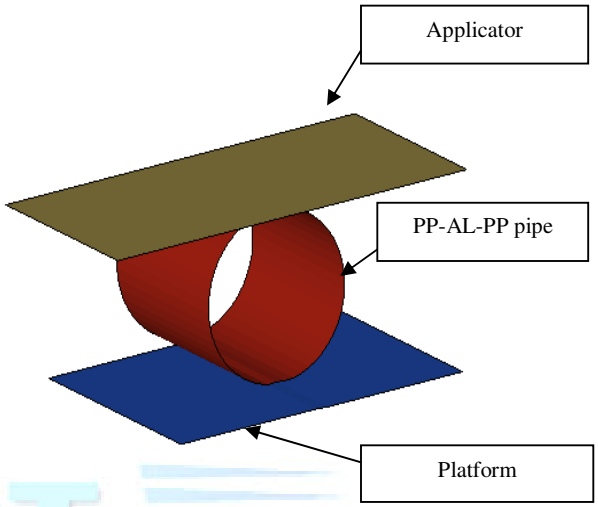
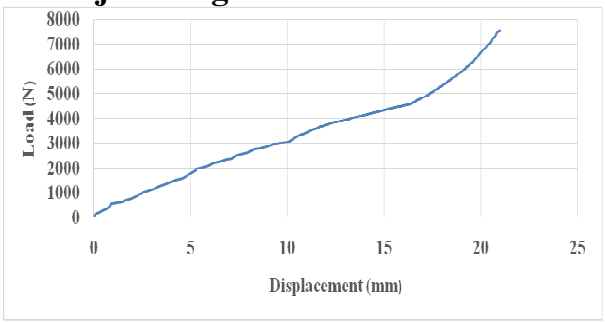


Fig-Test set up

Table 7:Results of Load Vs displacement from CAE

Load(N)	Displacement (mm)
1000	2.69
1950	5.4
2619	8.13
3047	10.90
4016	13.70
4514	16.75
5707	18.69
7590	22.75



4.1Load Vs displacement for PP-AL-PP from CAE

5.Result and discussion:

5.1 The software and analytical results for first three alternatives :

The software and analytical results for first three variants shows the deviation upto 10% only.The von mises stress for the PP-EG-PP material exceeds the yield strength of the materials so this design is not safe and is elliminated.Between two remaining variants both the variants i.e. PP-AL-PP and PVC-EG-PVC both shows minimum values of plastic strain and the displacement and the von mises stress is below the yield strength for these variants.But by applying the weight crieteria the PP-Al-PP weighs less than PVC-EG-PVC.So PP-AL-PP variant is selected as the best alternative and for further experimentation.

5.2 Weight and cost comparison for alternatives

The weight reduction of piping system is the important safety aspect. The materials ability to be handled more easily minimizes worker injury and facilities lower cost installation and transportation. A person can easily carry the composite pipes.

Table 8: Comparison of weight and cost table

	Existing steel pipe		Modified pipe (PP-Al-PP)	
Sr.No.	Weight (kg/meter)	Cost (Rs/meter	Weight (Kg/meter)	Cost (Rs/meter
1	4.04	278	0.2413	200

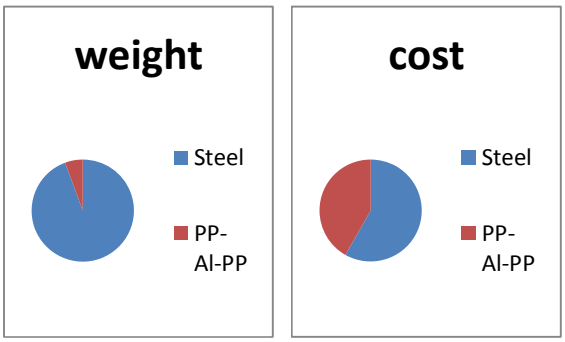


Fig5.1 Pie chart

The above chart shows the weight and cost comparison of existing steel pipe and the modified pipe of PP-Al-PP. The weight of existing steel pipe is found to be 4.04 Kg per meter. Amongst all alternatives the PP-Al-PP weighs less and is of 0.2413kg per meter. By considering the weight advantage of the mentioned pipe the specimen is prepared and it is tested for the load vs deflection.

5.3 Load Vs Deflection comparison of PP-Al-PP pipe by CAE and experimental analysis

The application demands a load bearing capacity of 500kg before critical damage or visible cracked exterior. The PP-Al-PP pipe is tested for the application of 500 kg load on the universal testing machine**.** Specimen is loaded onto the UTM and the load is applied onto the specimen gradually corresponding deflections are noted down. The test is conducted for failure. The corresponding load at failure is found to be 759

Kg. This offers a safe design with factor of safety in excess of 1.5 for load bearing capacity of 500kg.

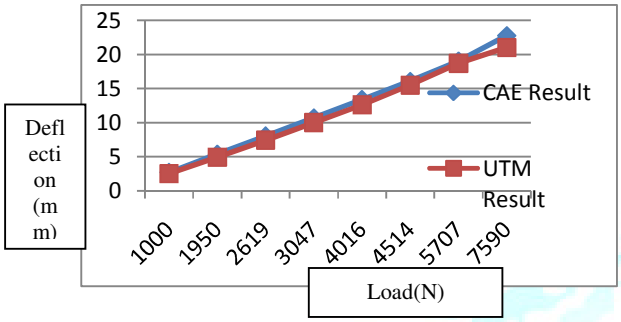


Fig 5.2:Graph of CAE Vs UTM for PP-Al-PP

The red colour graph shows the load vs deflection results from experimental analysis and blue graph for software analysis. The verification by the software results and the experimental investigation is studied and compared..The CAE results show a good agreement with the experimental trend. The deviation for the deflection obtained against the load applied is obtained upto 10% as shown in graph8.1.

On experimentation it is observed that the material failure occurs at 759 Kg load. The analysis (FEA) is conducted for 759 kg load. The corresponding deflections are also noted down and these matches well with the physical experimentation.

6.Conclusion:

1.The weight of PP-AL-PP is 0.2413Kg and corresponding weight of steel pipe is 4.04Kg. Weight saving upto 16 to 17 times vis-a-vis steel is achieved by using composite in piping.

2.Conventional materials displayed higher stresses(Von mises) with the same loads.Amongst all variants the PP-AL-PP gives best results in terms of stress,plastic strain and displacement. This variant is therefore selected for physcial experimentation. The test specimen of PP-AL-PP is procured and tested as per the standard test plan.

3.The Crushing test is carried out on the test specimen and it is found that the results obtained from the crushing test are below the yield values which is the requirement from the sponsoring company.

4.The specimen PP-AL-PP sustains the load upto 500Kg without visible damage or crack.For the applications below 500Kg crushing loads this pipe can withstand without visible crack.

5.One meter PP-AL-PP pipe costs around Rs.200 and that of steel is around Rs278 per meter So the cost saving of around Rs78 can be achieved .

6.The difference between the Experimental values and the CAE values shows the error of only 10%.

7.From all these points it is seen that the PP-AL-PP is the best alternative for the steel from amongst all alternatives which we have selected in this work for the applcation demands of lower weight and lower cost.

Future scope:

1.The different variants like PVC-AL-PVC,HDPE-AL-HDPE,NYLON-AL-NYLON can be tested for other industrial applications.

2.PP-AL-PP variant can be tested for corrosion type application.

3.For application in the chemical industries the PP-AL-PP pipe can be tested for inertness over the chemicals in the industry.

4.For further weight reduction the perforated AL(rectangular/circular) can be used and tested for required application.

5.By changing the thickness of plies one can test the behavior of the PP-AL-PP pipe.

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