India's First All Composites Road Tanker Wins JEC Asia 2009 Award

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Modern Engineering Plastics Pvt. Ltd. (MEPPL), Mettur Dam, Tamil Nadu has developed a four axis polar winding process for making both cylindrical and non-axi symmetric closed shell structures. The double D shaped all composites road tanker designed, developed and filament wound by the non axisymmetric four axis winding process has won the JEC ASIA 2009 award. Dr. N. G. Nair outlines in this article the innovative work taken up under a TIFAC project by MEEPL and their partners for developing India's first all composites road tanker.

The first prototype fabricated and tested.

Introduction

Road tankers have become part of our life. When we are on the road, we cannot miss them. Whether we are in major cities, smaller towns, highways or even villages, we come across at least one road tanker in every five minutes. Tankers are used for transportation of water, edible oil, milk, acids, alkalis, petroleum products and even waste water. Variations of tankers are used as rail tankers and as bulk powder carriers. Milk is brought from far away villages to the milk diary. Edible oil is transported from oil mills to the consumer centres. Petroleum products are distributed all over the country in tankers. Chemicals are transported from one factory to another. When there is water scarcity, it is the tankers that maintain our life line by bringing water far away places to our door step. It is the tankers plying in Chennai that had helped the city to survive during the severe water shortages in the 1995 to 2003 period. Yes, tankers are part our life today and will remain so in the future.

Tankers come in different shapes; cylindrical, oval or double D, spherical and rectangular. Among them, the double D shaped tankers are popular for transportation of liquids under gravity. Cylindrical tankers with end domes are used mostly for transportation under pressure. Traditionally, such tankers are made of steel.

For transportation of chemicals, metallic tankers are rubber lined. Rubber lining lasts only three or four years and repeated relining becomes necessary. No such lining is used for water tankers and the rusting of the inner surface could contaminate drinking water. One could imagine how this rust can affect our health. Metallic tankers are heavier with 12 to 15 % of the liquid they carry. A few have tried to use stainless steel and aluminium tankers abroad, but they are not yet popular due to high cost.

Fibre reinforced plastics (FRP) are most suitable for all these transportation requirements. FRP tankers are lighter, corrosion resistant and aesthetically appealing. No rubber lining is needed. If lining is needed, thermoplastic lining can be given as an integral part of the FRP tanker. Although FRP tankers are being made and started using in other countries, no attempt has been made in India so far to develop FRP tankers mainly due to the lack of good design, technological capability and manufacturing facility and partly due to the higher cost of FRP compared to that of steel. The recent increase in steel price has narrowed down the price gap.

Seeing the potential of this product and the benefits of using filament winding for making them, Modern Engineering Plastics Private Ltd. (MEPPL), Mettur dam a chemical process equipment manufacturer with over 30 years of experience has decided in 2006 to diversify into the filament winding technology and road tanker manufacture.

MEPPL already had a production unit at Mettur dam about 400 km from Chennai. A second unit was set up nearby exclusively for filament winding process of making pipes, closed pressure vessels and road tankers. This site consists of three acres of land and about 15,000 sq. ft. of built up factory space. The unit has a four axis filament winding machine that can wind closed shells of up to 3 m diameter and 12 m length. The machine can also wind pipes of up to 3 m diameter and 12 m length. Other facilities include a modern materials testing laboratory, facility for pressure testing of pipes and pressure vessels, air conditioned materials storage and hot air oven for curing/ post curing of pipes and tankers. MEPPL is an ISO 9000 certified Company with a total of 50 staff including managers, engineers, supervisors and skilled workers.

The Development Programme

MEEPPL found the idea of making road tanker by filament winding attractive. NGN Composites Chennai, a design consultant and technical service provider in Composites technology has agreed to take up the mechanical and structural design. They also agreed to guide the filament winding manufacturing process. The Advanced Composites Programme of TIFAC, an autonomous council of Department of Science and Technology, Government of India, New Delhi has agreed to be the technology facilitator and they also provided soft loan for development.

The development of the product started in June 2006. TIFAC constituted an assessment and monitoring Committee (AMC) to oversee the technical development and to monitor the progress of the project. This committee had as its members, experts from IIT Madras and ARAI, Pune, representative of Ashok Leyland, the truck manufacturer and MKS Transport, the tanker fleet operator. There was no standard specification available in the country for making road tankers even in steel. A global search was made through web to find whether any standard specifications are available for road tankers in other countries. Since no such standards could be found, NGN Composites prepared the specification which was approved by the AMC as the voluntary standard to be adopted by the company.

It was decided that tankers will be made in both cylindrical and double D shapes. NGN Composites developed the geometric profiles of tankers that are suitable for polar winding. A structural design was also carried out taking into consideration the various static and dynamic load conditions arising during the transportation of liquids and the safety, functional and durability requirements. Considering the design requirements, the geometric pattern of polar winding and layer by layer structure was finalized and approved by the AMC. Based on these profiles, Crescent consultants Pvt. Ltd., England was engaged to develop the software for the non-axisymmetric winding. The machine hitherto used only for symmetric cylinder winding had to be modified to have the polar winding done. These modifications were carried out by CNC Technics, Hyderabad India's only one filament winding machine manufacturer.

Tanker structure

The tanker, as designed, consisted of an inner chemical barrier and baffle plates that are required for reducing the sloshing effect. They were first made and assembled together into a basic structure that served as the mandrel for polar winding. This mandrel thus becomes integral part of the tanker.

Winding was carried out on the basic profile made as per the designed fibre orientations and layer structure. A quality control scheme was formulated by NGN Composites for assessing the quality of incoming materials, checking the manufacturing process etc. Fig.1 demonstrates the mould that will become part of the tanker and the dry winding of fibres on the mandrel creating the winding pattern. Fig.2 shows the wet winding of the fibre on the mandrel. On completion of winding, the manholes, nozzles, saddles etc. were fitted and the tanker was finished for mounting on the trucks. The FRP saddles were bolted on to the longitudinal beams of the chassis using U bolts.

The tanker was finally post cured mainly to see that the cross linking of polyester resin is complete and that the free styrene if any is removed. The tanker was then subjected to various static tests formulated by NGN Composites. On completion of ground tests, the tanker was filled with water and mounted on truck for field trials. Field trials were carried out with full and partial load conditions. About 20,000 km of road trials were carried out taking the truck to various road conditions and hilly regions.

The success of the project was mainly due to the meticulous planning, coordinated effort by all partners and the systematic execution of work by the dedicated workers of MEPPL. The technical director of MEPPL, Air Vice Marshall (Retd.) R. Krishnan ensured to make every

Wet winding of road tanker

suggestion made in the design into the production process. The planning of the production shop and the implementation of the quality control programme was meticulously directed by Air Vice Marshall Krishnan. The AMC approved, in September 2008, the launching of the tanker for field application making India's FRP road tanker a reality.

Design features

Fig. 3 is the photo of the prototype developed, made and tested. It has an oval or double D shaped straight shell mounted longitudinally on the truck with domed ends at the front and rear. The capacity of the tanker is 15 kilolitre (KL). The horizontal width was limited to 2.10 m and height to 1.6 m. This has helped to keep the centre of gravity of tanker with contents low giving better vehicle stability during driving. The chosen dimensions permit a cage or outer frame to be added if necessary without violating the dimension limits specified by road traffic requirements. The cylindrical tankers can be of 2.1 m diameter with dished or hemispherical ends. Tanker capacity can be changed by keeping the cross section profile same and varying the length. The length can be fixed based on the length of the vehicle chassis and the load carrying capacity of the truck. Tankers of up to 34 KL capacity can be made on the existing four axis winding machine.

The shell wall was made by polar and hoop winding. The special purpose software ensured the correct fibre laying at the required winding angle and layer sequence. The tanker is a mobile structure and, unlike in a static pressure vessel, is subjected to severe dynamic loads. They include forces on baffles and end domes due to sudden acceleration and breaking, high force on bottom part of shell due to the acceleration when the vehicle falls into a gutter, upward force on top of shell due to upward acceleration of liquid and the centripetal force on sides while the vehicle negotiating curves at high speed. Thus, both the tanker profile and loads on the tanker are not symmetric. The design has to allow for these load variations. The tanker is designed for 15 years life with a factor of safety of 6. The allowable strain at design loads is taken as 0.002 to prevent possible resin cracking due to strain magnification. Factor of safety of four is used for interlaminar shear stress and peel stress. Panel deflections are limited to less than thickness of panels. Vibration effect is nullified by proper design and mounting.

Key Benefits

The benefits of this innovation results from the design and process developed and from the use of composites for the tanker.

a. Benefits due to the innovative development

The main benefit is the weight savings achieved. A weight saving of 1000 kg over steel tanker was achieved in a tanker of 15 kilolitre (KL) capacity which is only 7 % of the liquid it carries (compared to the 12 to 15 % for steel tanker indicated earlier). This is a 45 % saving in weight over steel tanker. The tanker capacity will be increased by one KL taking this saving into consideration. The tanker user is able to get one KL extra capacity by using the composites tanker. The second major benefit is the production advantage it offers. The main shell is made in one piece without any jointing. The joint less winding of shell in an automated machine makes the production faster and the product stronger. Two tankers can be made in a day. The steel fabrication will run into days to make and finish one tanker using the same number of manpower. The filament winding process developed makes it possible to commercially produce double 'D" shaped tankers using the four axis winding machine in one integral piece without any joints in the shell. The shell due to its non symmetry and gravity loading is subjected to membrane forces and bending. The design uses local thickening to take the bending and it helps to resist these two forms of load effectively. The tanker is designed taking the longitudinal transverse, downward and upward accelerations as adopted for transport vehicles in rough terrain. By a pressure test, it was found that the tanker can have a factor of safety of 6 or above without any resin leakage.

b. Benefits due to the use of composites

Composites are resistant to water and many chemicals and the required resistance to chemicals can be created in the composite tanker by selecting the right fibre and resins. The high strength to weight ratio and stiffness to weight ratio make tankers lifght and long lasting. Composites offer the capability to make the tanker in one piece without joints in main shell which helps to speed up production.

Conclusions

Road tankers are being used in all countries for transportation of liquids and there is a ready market for this product. India alone needs more than 600,000 tankers for getting over the drinking water shortage and for the transportation of chemicals and oils. Assuming 10 years life for one tanker, about 60,000 tankers have to be produced every year. Even a fraction of this market is sufficient to take the FRP tanker a major outlet for composites. One machine can wind about 500 tankers only in a year which means a large number of production units are required. A city like Chennai uses more than 5000 tankers for transportation of water. Similar number is required in other cities and also in villages. This market is currently dominated by steel tankers. The all composites tankers developed here have to enter this market competing with steel on its superior properties, better durability and production advantages. FRP tankers will certainly win the race.

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