"DESIGN AND TESTING OF LIGHTWEIGHT SANDWICH T-JOINT OF COMPOSITE MATERIAL USING FEA AND EXPERIMENTAL TECHNIQUE"

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Abstract

Presently a large amount of research is going on with the objective to strengthen the technological basis for the large scale application of fiber reinforced composite materials for naval vessels and structures. Fiber reinforced composites are widely used in naval ships and aerospace, ground transport, civil infrastructure because of their high strength and stiffness, low mass, excellent durability and ability to be formed into complex shape. Naval superstructure need to be designed with confidence on the basis of modelling and failure prediction. A typical T-joint used in naval ships. It consists of a horizontal base panel, a vertical leg panel and fillet and over laminates. The aim of this work is to investigate the behaviour of composite T-joints used in marine applications due to variation of different parameters.

Keywords: Composite material, Design, FEA, Testing of T-joint.

1. Introduction

Composite materials are used widely in many applications. They are made of two or more homogeneous materials to achieve better properties than the constituent materials. One of the most common advanced composite materials is Fibre Reinforced Plastics (FRP). In marine applications, FRP has been used to build many types of ships, including pleasure craft, ferries and naval mine-hunters or Mine-Counter-Measure-Vessels. The use of composite materials for military applications is desirable, especially because of some of the material characteristics which are absent in metal-hulled ships, such as lighter weight, corrosion resistance and design flexibility due to its anisotropic nature. Moreover, the non metal-hulled ships, such as composite materials have the capability to be a radar proof, which means that it allows the ships to go through the enemy zone undetected. It makes the composite materials even more attractive for military applications. One task is developing improved joint for naval ship super structure can be manufactured from fibre composite. One type of joint in such a super structure is a T-joint between sandwich panel. In the first phase of the project an existing design called base design T-joint has been tested and characterised. The base design T-joint consists of a PVC foam sandwich panels joined by filler forming a smooth transition from the T-panel to base panel, and over laminates with laminates of the fibre glass. This design aiming at T-joint, which is a lighter than the base design but having the same or higher strength.

1.1 Sandwich Panel:

Sandwich panels are a remarkable product because they can act as strong as a solid material, but weigh significantly less. The trend for "stronger-lighter" is becoming increasingly important in the transportation and aerospace industries, and sandwich panels are filling this need. The common composite sandwich structure is made up of two major elements, the skin and the core. Sandwich panel skins are the outer layers and are constructed out of a variety of materials. Wood, aluminium, and plastics are commonly used. More recently though, advanced composite fibers and resins are being used to create skin material.

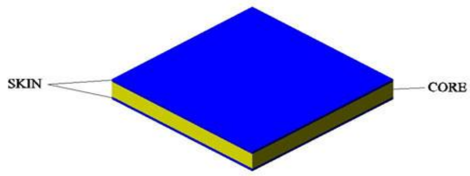


Figure 1.1: Sandwich panel

The core materials provide many of the panels' desirable properties and are often composed of wood, foam, and various types of structural honeycomb. Each core has various advantages; for example, balsa wood is a lightweight core, has high strength, but can rot or mould with exposure to moisture.

2. Design of Lightweight T-Joint

The selected design based on the outcome of the FEA study .The specification for the design, materials and the overall dimensions of the test specimens are summarised in table 1, and the T-joint is illustrated in fig 1. The nominal hull, over laminate and bulkhead thicknesses was 43, 2 and 43 mm respectively, while the nominal over laminate angle is 60° (measured at the base of the fillet triangle as seen in Figure 2.The joint was subjected to static tensile pull-off loading in the plane of the bulkhead. The Hull is considered to be restrained near the two ends of the joint, as indicated in Figure 2, with a 400 mm fixing span and a boundary condition between support-support and support-slide.

2.1 T-joint design concept:

In order to construct a new design of composite T- joint based on above theories these conditions and criteria should be consider:

1) Two plates either core A, B or Hull- Bulkhead assembly should be join at 90 degree and some provision should be made to fix them at 90 degree (by groove or guide).
2) It should be a composite structure i.e. use of two or more material.
3) Over laminates or skin is provided for better strength against tension and to protect filler material in main adhesive bonding zone.
4) Minimum use of filler material or resin to make it light weight.
5) Good appearance and simplicity in handling.
6) Dimensions should round off so that manufacturing becomes easy.

From above considerations, a new T-joint can be constructed as shown in fig2.1.

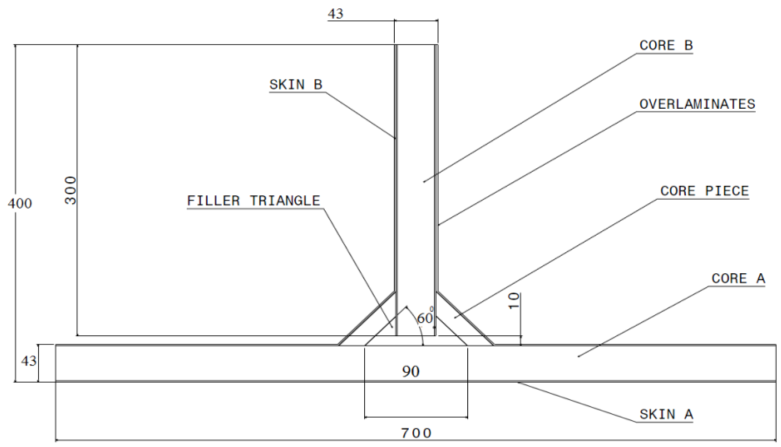


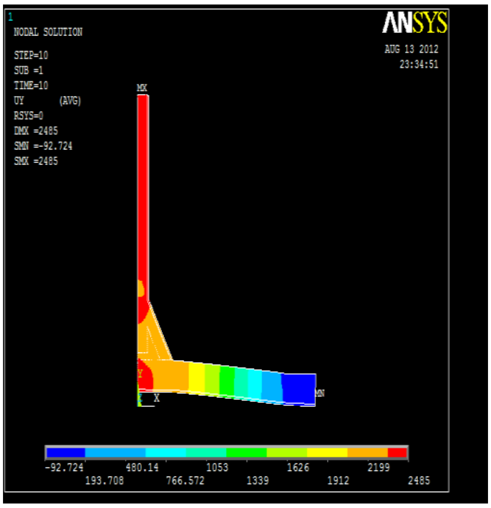
FIG.2.1:- Conceptual composite T- joint outline

3. FE Design Parameter Study

3.1 FE Model

Because of symmetry in geometry and the loading only one half of the T-joint tensile specimen is modelled. The right half of the specimen is shown in fig 3.1.

The commercial FE code ANSYS 12 is used to make a 2D plain strain model of the T-joint tensile specimen. The boundary condition and point of loading as shown in fig.3.1. The material properties and orientation used for each part in various computations are given in table no.2.together with The elastic constant $E_{X,}E_{Y,}G_{XY}$ and v_{xy} in the local co-ordinate system are given with the tensile strength X and Y in the local X-direction and Y-direction,respectively,as well as the shear strength (S).The materials are assumed to be the linear elastic and either isotropic or orthotropic.



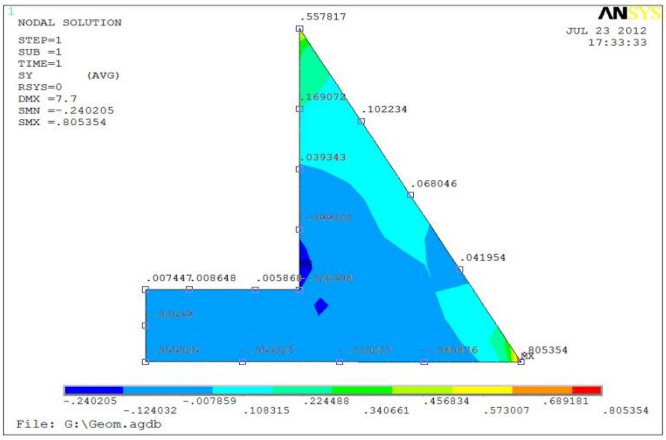


Fig.3.1 contour plot of t-joint Fig.3.2.Nodal solution of Filler triangular

The element (PLANE82) used in the model is a plane 8-Node isoperimetric element with 2x2 gauss integration scheme. It can be used for a mixed (quadrilateral triangular) automatic meshes. The automatic mesh initially used consists of approximately 10000 elements. The element side length is varies from 1mm in the upper skin of panel A and the filler to 3mm in the core.

4. Evolution strategy

The aim is to compare different choices of T-joint geometry and materials to select promising (strong) configurations. This is done by considering the calculated stress levels of each part (skin, core, filler etc) relative to the part for a total load. The stress variation in each part is illustrated in fig.3.1 by contour plots of the shear stresses. A contour plot is made of each part, and the different colours plots were assembled.

5. Manufacturing of Test Specimens

The sandwich panels for the T-joints are manufactured by a hand lay-up technique. Resins are impregnated by hand into fibres which are in the form of woven, knitted, stitched or bonded fabrics.

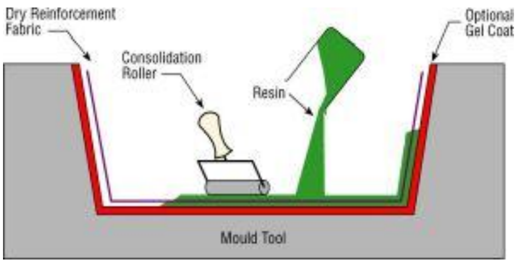


Figure 5.1: Wet/Hand Lay-up

This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin.

Laminates are left to cure under standard atmospheric conditions. The edges of the infused panels are trimmed to the desire geometry, and the T-panel, the filler and the triangular fillets are applied and mounted manually. Small pieces of PVC foam are used as spacers to ensure correct gap for the filler. The T-joints are manufactured and completed.

5.1 Hull and Bulkhead

Hull and bulkhead are made of core laminated with skin. PVC foam is used as core whereas skin is made from fibreglass. PVC foam is soft and pores material can be cut easily on machine saw. It is cut according to following dimensions and quantity.

Table 1:-Dimension and quantity of PVC foam to cut.

Sr.No.	Length(mm)	Width(mm)	Thickness(mm)	Quantity
1	700	150	18	2
2	347	150	18	2

A surface preparation is carried out on above four plates by scratching on surfaces by blade. Uniform layer of epoxy is applied on them and attached them like a sandwich. A 700 mm and 347 mm length pieces are joined separately with epoxy and kept for solidifying. It requires 30-45 min for solidifying. Then fibreglass is cut according to above dimensions and glued to PVC foam and kept to solidify.

5.2 Core pieces:

Core pieces were cut according to dimensions at 60 degree angle with the help of hex blade.

5.3 Filler Triangle:

Filler Triangle is made from resin Epoxy 520 mixed with Hardener Epoxy PAM. It's in liquid form hence great care is taken for its use to avoid leakage. This resin is suitable for pouring and capable to cover small spaces or gaps. Hence we've decided to make a mould containing hull and bulkhead and resin is poured in it. So on a flat table, covered with thick paper or card sheet, these two plates were kept at 90 degree and gap of 10 mm. Core pieces are placed at its measured position. Outer portion is covered with card sheet and plastic paper to avoid leakage while pouring. Whole mould is fixed on table with nails to ensure positional accuracy and to avoid movements while working.

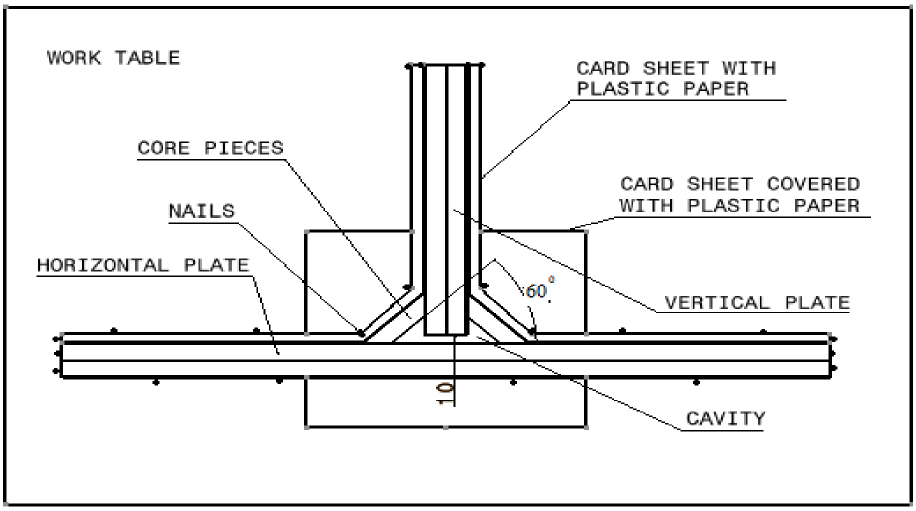


Figure 5.2: Typical mould arrangement for filler triangle

5.4 Over laminates:

Over laminates were made from fibreglass. It was cut by size with the help of scissor. It is also joined by HLU method. With the help of painting brush resin is spread on the surface of horizontal as well as vertical plates and on core pieces and fibreglass was glued on it. A small layer of resin was applied on the outer surface of over laminates to cover strings of fibre and glass particles Extra part of it cut down by scissor and hex blade and kept it to solidify for 10 days to ensure full solidification at the room temperature.

6. TESTING

The machine operator filled necessary Information in computer attached to UTM. This machine operated and Controlled by software and results were displayed on computer screen. Initially Preload was kept zero and displacement also brought to zero. There were two possibilities, one that the material of T-joint might fail and second was, failure might occurred in fixture. Because there was no way to predict the failure. Fixture could be replaced if it was Failed, but if T-joint would fail then results directly belonged to its strength. Hence we have decided to take test as trials. They were as follows:

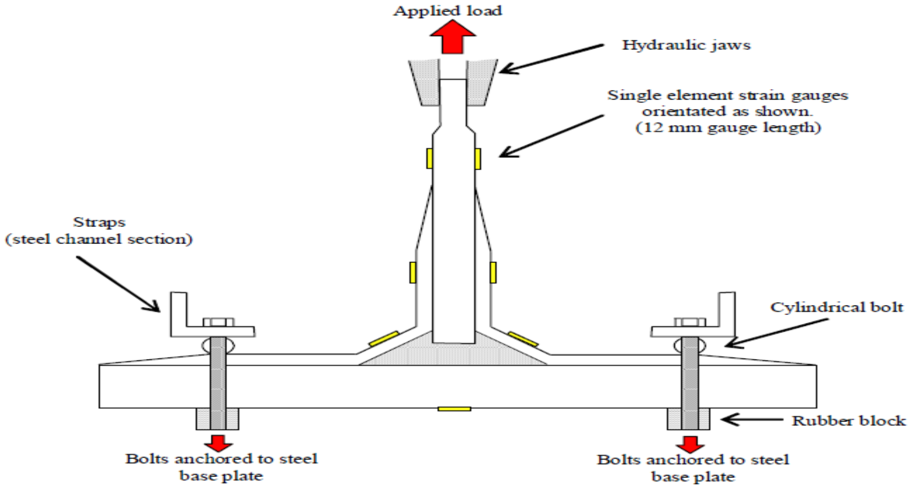


Fig.6-Joint Schematic Experimental Set-up

6.1 TRIAL NO. 1:

FEA work was carried out at 2 kN, hence for first trial the limiting load was kept 3 kN, but it was free for further loading. Load was gradually applied on T-joint with speed of 5 mm/min. Load Vs Displacement curve displayed on computer screen shows progress of gradual loading. At 5938.8 N load, the upper bolt was failed i.e. fixture was failed in trial no.1. But there was no damage to T-joint. That means it might take more load.

6.2 TRIAL NO. 2:

The failed bolt in trial no.1 was replaced by high tension bolt of class 8.8. It's a special bolt used for heavy duty application. The size of bolt was same as that of previous one i.e. M10 X 150. Again same conditions were applied as in case of trial no.1 and results were recorded. At 13965.0 N load, the high tension bolt was failed i.e. failure was occurred again in fixture but there were no harm to T-joint.

6.3 TRIAL NO. 3:

For trial no. 3 whole fixture was replaced by new one. New fixture contained MS plates with thickness more than previous one. Drilled size was increased from 12mm to 16mm. Distance between plates as well as upper surface of vertical plate to jaw is reduced. High tension bolts of size M15 X 150 was used in fixing plates as well as to clamp with upper jaw. In this case, at 19815.6 N T-joint was failed.

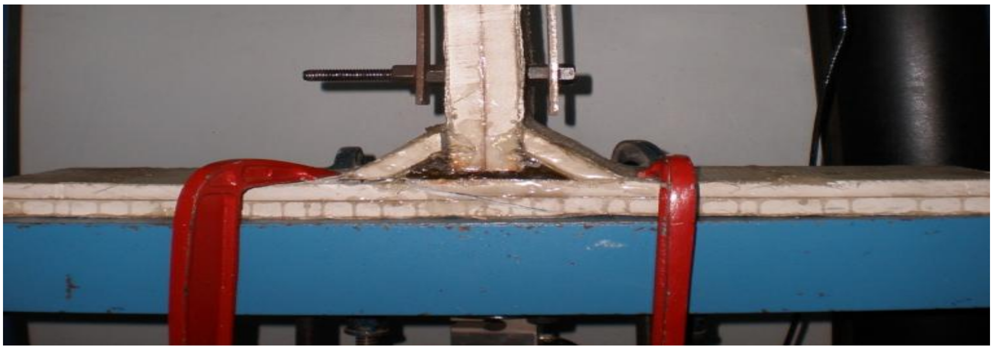


Fig.6.3 A failed T-joint with crack to the bottom plate

7. RESULT AND DISCUSSION

The crack initiated from the interface between the over laminate and bottom skin through core A (see Figure 6.3) at about 19.8 kN after 8.4 mm displacement. The load versus displacement curve is shown in fig 7.1.

Table 2:-Comparison of Results

LOAD (N)	ANSYS RESULTS IN (mm)	EXPERIMENTAL RESULTS IN(mm)
1982	0.809423	1.2
3964	1.619	1.9
5946	2.428	2.6
7828	3.238	3.1
9910	4.047	3.6
11892	4.857	4.3
13874	5.666	5.1
15856	6.475	5.6
17838	7.285	6.7
19820	8.094	8.4

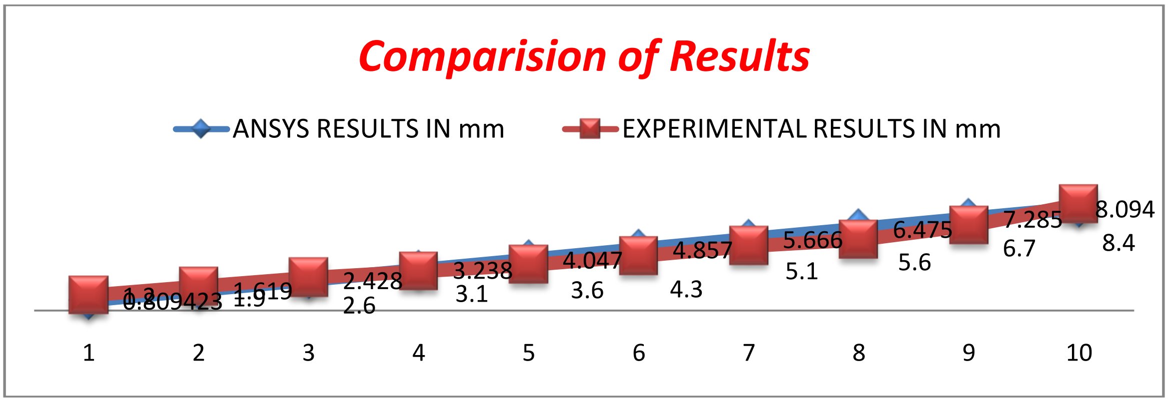


FIG.7.1 Comparison of Results graph

The failure mechanism of this undamaged T-Joint verifies the experiment done by St. John et al. (2000) that the failure will be always along the over laminate bond line. However, the initial location where the crack begins to grow may be either at the hull- over laminate interface or the bulkhead-over laminate interface. No matter where the crack initiates, the crack will grow along the filler region to cause fracture along the over laminate bond line. It is suggested that the initial crack growth is due to the manufacturing imperfections, such as poor bonding.

According to Finite Element Analysis result, maximum stress was developed on over laminate and bottom skin. Hence it was obviously failed at high stress region i.e. from over laminate.

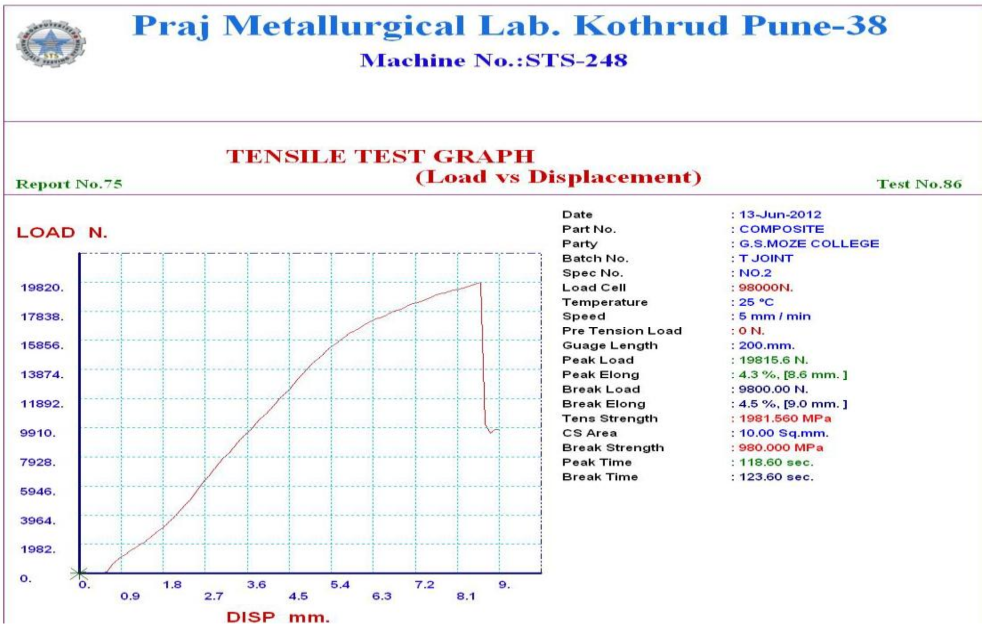


FIG.7.2. Tensile Test Result

7. CONCLUSION

- Geometry and materials for a lightweight sandwich T-joint have been optimized for tensile loading by a new developed FE strategy.
- The lightweight T-joint is designed for sandwich panels with two sheets of 18 mm thick PVC foam core and 1.5 mm thick fibreglass skin laminates. The panels are joined by use of filler and two supporting core pieces of PVC foam.
- CATIA V5 R17 was used for Finite Element study of T-joint with static loading condition.
- The different joint configurations have been compared on the basis of relative stresses in the different parts of the joint. They were compared on the basis of Von Misses stress distribution.
- 2 kN load was used to stimulate the finite element model.
- The selected sandwich T-joint has been tested in static tension in special design fixture.
- The failure load of new T-joint is nearly 20% higher than that of the reference Base Design T- joint.
- Both the failure load and deformation matched very well the predictions from the FE parameter study.
- The failure mode is initiated from over laminate to foam core A by shear failure.
  The release of energy from the shear failure of the core A causes the T-joint itself to fail as well. The load Vs deflection curve is almost linear until a load of 19.8kN.

8. REFERANCES

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