Design and Manufacturing of the Boat by Using Laminates from Swedish Wood Reinforcing by Composite Materials for Industry

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Abstract **- This paper presents experimental study about design and manufacturing of the boat. Experimental study was based on (Damen shipyards- Stan Tender 1550: Length o.a. is 16.25m, Beam o.a. is 4.55m, Depth at sides is 2.49m, and Draught aft(approx.) is 1.40m) as module with some slightly changing in the external shape of the boat. Manufacturing technique by method Lay-up of composite material. The composite manufacturing material was fiber glass woven roving (Type E) at $[0^{\circ}/90^{\circ}]_s$ with polyester resin. The boat was made from swedish wood (Type :SS-EN 1611-1/G4-2) with designed dimensions for factor 1: 39.625 which were (length is 400mm, depth at sides is 61.70mm, width is 102.21mm, thickness is 5.678mm, and draught is 27.26mm) and then has warped material inter and around it after wetting it in polyester resin to obtain the required thickness. Solid work program (CATIA V5) was applied to design of the boat as views and prismatic. Also, manufactured materials (wood and fibers). In addition, the boat has been operated by small motor as perfected applying.**

According to studying for scientific useful from information about high good mechanical properties of composite materials as resistance of corrosion and resistance different temperatures in hot and cold specially at sea water, and some another environment such as oceans and seacoasts. Also, stiffness, ideal plastic behavior…etc, can be used of supporting swedish wood in industry as invented methods for low cost rather than metals and another materials which use in boat industry that they have been high cost.

Keywords—Swedish wood; The boat; E-glass fiber;Lay-up; Quasi-isotropic laminate; Composite material.

I. Introduction

The boat designers with experience in steel and aluminium will immediately notice that most fiber glass materials have lower strength and stiffness values than the metal alloys. Because fiber glass materials are much lighter than metals, thicker laminates can be designed so that the stiffness can match that of metal hulls.

There are a number of types of fiber used in reinforced plastics but glass fibers are the most common because they are inexpensive to produce and have relatively good strength to weight characteristics. With the exception of chopped strand mat (CSM), reinforcements used in a marine glass fiber application usually utilize bundles of fibers oriented in distinct directions such as glass cloth and woven roving. Some are aligned in a single direction others multidirectional and the strength of the laminate will vary accordingly.

There is a considerable variety of glass reinforcements but we are mainly interested in what is known as E-Glass or electrical grade glass that was originally developed for insulators, for electrical wiring, and is now used almost exclusively as the reinforcing material commonly known as fiber glass. E-glass is the most common reinforcement used in marine laminates because it is relatively inexpensive, has good strength properties and resistance to water degradation. Another glass fiber known as S-Glass is a structural glass typically used in higher strength applications. It has a greater tensile strength and stiffness than E-Glass and in general, demonstrates better fatigue resistance but at a considerably higher cost which means that it is limited to selected applications.There are other types of fiber such as carbon fiber and graphite fiber, used as reinforcement and known as Multi-axial Engineering Fabrics or just plain Engineered Fabrics which, when knitted stitched or woven into materials, include names such as Double Bias, Biaxial and Tri-axial Fabrics and Woven Fabrics and so on but these are specialised materials which probably won't concern you. There is even an aluminised fiber used primarily for its cosmetic appearance which has a thin coating of aluminium to create a highly reflective surface but, so far, this is not used in boatbuilding.

When you decide to build a fiber glass boat you should, primarily, be guided by the boat's designer and the technical knowledge of your material suppliers. Don't be confused by the vast array of materials on the market, most will never concern you. The majority of readers of this book will be concerned with building a strong, practical boat, so unless you are considering a specialised race boat, lightweight flyer or multihull, you can concentrate on E-glass and use the more traditional fiber glass boat building materials and methods[2].

Recently, many literature reviews on this point, have presented about high good mechanical properties of composite materials such as. [3] This book presents an experimental study of a composite material for comparative some mechanical properties of types the E-glass. This study was based on two methods. First method based on manufacturing techniques by lay-up of laminate, while second method was develop to evaluate strength stress, hardness, toughness, and stress-strain characteristic for composite material. The composite manufacturing material was fiber E-glass of woven roving at $\left[0^{o}/90^{o}/\pm 45^{o}\right]_S$, $[\pm 30°/\pm 60°]_s$ and chopped mat reinforced with polyester resin. It has been found that a good mechanical properties of experimental results in tests. Also, it has been found that the manufacturing techniques by lay-up apparel to describe the microstructure well. [4] have studied the effect of the fiber volume fraction on mechanical properties of E-glass types with polyester in composite laminate. This requires to carry out experimental studies to exanimate the fiber volume fraction, fiber weight, tensile test, hardness test, impact test. The prepared samples of woven roving at $[0°/90°/\pm 45°]_s$,$[\pm 30°/\pm 60°]_s$ and chopped mat. Experimental results have shown that hardness values increase with the volume fraction of the laminate. $[0°/90°/\pm 45°]_s$revealed ideal behavior in contrast to $[\pm 30°/\pm 60°]_s$ and chopped mat materials. Fiber volume fraction results of $[0°/90°/\pm 45°]_s$, $[\pm 30°/\pm 60°]_s$ and chopped mat were found to be 44%, 41% and 29% at hardness values of 93, 78, and 75, respectively. Toughness values of $[0°/90°/\pm 45°]_s$, $[\pm 30°/\pm 60°]_s$, and chopped mat were obtained to be 25.7 J, 26.14 J, and 25.5 J, respectively. In addition, yield stresses of $[0°/90°/\pm 45°]_s$, $[\pm 30°/\pm 60°]_s$, and chopped mat were obtained to be ideal plastic behavior, 52.5325 MPa, 17.3578 MPa, respectively.[5] have studied Interface between laminates has always been the weakest part of bonded materials which is prone to delamination. This is even more prevalent in bonding of two different materials. The research aims to evaluate delamination of dissimilar materials under a range of temperature. This is a part of the experimental study to investigate the potential of fiber metal laminates (FML) to be used in high temperature environment. The mechanical response of interface of hybrid laminate was characterized at temperatures ranging from 30 to 110 °C. Double cantilevered beam (DCB) and end notched flexure (ENF) tests were conducted on glass fiber laminated aluminum specimens to obtain Mode-I and Mode-II delamination properties with use of data reduction. Mode-I fracture toughness (*GIC*) is significantly degraded by 59.45% at 70 °C and up to 83.65% at 110 °C. Mode-II fracture toughness (*GIIC*) only slightly degrades by 10.91% at 70 °C but drops rapidly by 82.84% at 110 °C.

There are some researches about design and manufacturing the ships and the boats as **[6]** presented propose a simple method to improve productivity for construction and subsequent outfitting of typical hard-chine boats. They discussed the method uses CAD/CAM definition of the structure to manufacture the bottom and sides, decks and bulkheads of the boat as independent panels. they reached to the developable panels which can be outfitted with machinery, foundations, piping, wiring and insulation. Bottom and side panels can be tipped up, joined and more outfit installed in stages optimized for lifting and ready access. The deck is built and outfitted inverted, and then joined to the open hull. The bulkhead details and deck framing are also optimized to allow ready outfitting and subsequent joining of the deck as a unit. The easy access to the panels also allows effective, low-cost surface preparation and painting, so this system has benefits for both steel and aluminum construction.**[7]** studied the Chumash of southern California, the plank canoe (tomol) which played a crucial role in food acquisition, transport, exchange, and social integration,with significant consequences for status building and sociopolitical evolution. They presented new data about plank canoe construction assemblages and new marine faunal data that help to pinpoint the date of the earliest appearance of the tomol , with the ultimate goal of situating this technological development in the broader sociopolitical evolution of coastal Chumash groups and discussed plank canoe manufacturing by-products which including asphaltum and redwood, and the remains of large open-ocean fish species.

Many applications and researches in recent years about design and manufacturing ships and boats.[8] studied an innovative 3D acquisition method for digital recording of floating objects. They discussed digital photogrammetry both underwater and terrestrial. They presented two surveys of the boat in floating conditions are carried out and then joined by means of special rigid orientation devices built ad hoc.[9] presented method for design and machining of the cylindrical cam with boat-shape follower which based on the differential geometry and the conjugate theory. They discussed the notion of the interference-free toolpath generating method and the machining process. Also, reached to the cutting simulations with solid model to verify the proposed toolpath generation method. It was also verified through the real cut with medium-carbon steel on a four-axis turn-mill machine tool.[10] presented to study about application LVL (Laminated-Veneer Lumber) as many advantages and economic values for wooden boat construction. He discussed wooden boat processing and LVL material for deck and hull planking in the wooden boat constructions. He reached to result of experiment indicated that at the position 0o (β), the flexibility and strength of LVL up to proportional limit increased with increasing number of layer and spacing of butt-joint (d/t). LVL at the position 45o and 90o (β), all types of LVL had lower flexibility and strength than the standard value for deck and hull planking. While in bending experiment tested speciment at position 45° with direction of grain, maximum width of LVL equal to the spacing of frame and at position 90° equal to the width of hull planking in wooden boat.**[11]** studied renowned leisure boat-building sector in the Marche Region (Italy) as a case-study. They discussed the characterization of (1) the industrial waste generation from the building of composite material-based boats and (2) some chemical-physical properties of representative types of boat-building residues (plastic foam, hardened resin, fibre-reinforced composite residues, and sanding dust). They presented three case-study for their research about companies provided values of 1.56, 3.07, and 1.12 $tons_{waste}$ $employee^{-1}$ $year^{-1}$ as representative for a mass-produced motor boat builder (case-study company '1'), a customized sailing boat builder (case-study company '2'), and a mould and structural component builder (case-study company '3'), respectively. They observed the unit generation rate per boat area (UGRpA) and per boat weight (UGRpW), confirmed the higher waste generation for the sailing boat builder (representative UGRpA and UGRpW values of 0.35 $tons_{waste}$ $year^{-1}$ and 2.71 $tons_{waste}$ $year^{-1}$, respectively) that compared with the motor boat builder (representative UGRpA and UGRpW values of 0.06 $tons_{waste}$ $year^{-1}$ and 0.49 $tons_{waste}$ $year^{-1}$, respectively). While the chemical-physical property characterization of the selected residues revealed the following aspects: a general condition of low moisture contents; significant ash contents in the glass- and carbon-fibre composite residues and the correlated sanding dust; and relatively high energy content values in the overall range 14,144–32,479 kJ kg^{-1}, expressed as the lower heating value.**[12]** introduced to study about 'new' material and corresponding manufacturing technique, referred to as 'Vacuumatic Concrete', of which its potential was demonstrated by producing a small boat (or rather canoe) and also focussed on architectural applications. They discussed Vacuumatics 3D Formwork Systems by the first author put forward the idea of effectively using vacuum pressure to draw a concrete mortar with low viscosity through a porous material, analogue to the resin-infusion process that was used for producing light-weight composite structures (not-surprisingly also boat hulls) and the reinforcement of the concrete object when fully cured. They reached to the vacuum-infusion process facilitates the casting process of the concrete mortar as it does not require the use of (potentially) complex, double-faced, rigid formworks.**[13]** depended on two previous papers of the author which presented at a conference (see Muscia, 2015a,b) about Study of a vibrating propulsion system for marine vessels: Evaluation of the efficiency for a boat 13 m long. He discussed the resultant of the centrifugal forces applies an alternate thrust to the hull that oscillates forward and backward along the longitudinal axis of the boat. He reached to the vibration that causes the motion can be suitably defined to maximize the forward displacement and the efficiency propulsion of the system. Also, Correlations between numerical experiments on models and possible full scale application. [14] studied Using Big Area Additive Manufacturing (BAAM) to directly manufacture a boat hull mould. They discussed the application of a BAAM system to fabricate a 10.36 m (34 ft) catamaran boat hull mould to explore the feasibility of using BAAM to directly manufacture a mould without the need for thick coatings. They succeeded of this project which illustrated the time and cost savings of BAAM in the fabrication of large moulds.

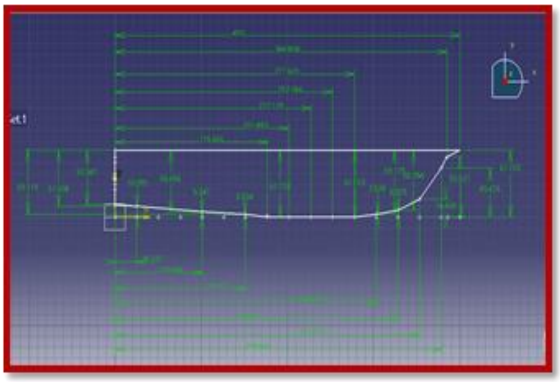
In this paper, design and manufacturing techniques of boat using Swedish wood with composite material(E-glass and polyester) will be presented including experimental investigation as module of (Damen shipyards- Stan Tender 1550 [1]). In addition, solid work program (type CATIA V5) for design the boat.

II. Experimental set-up

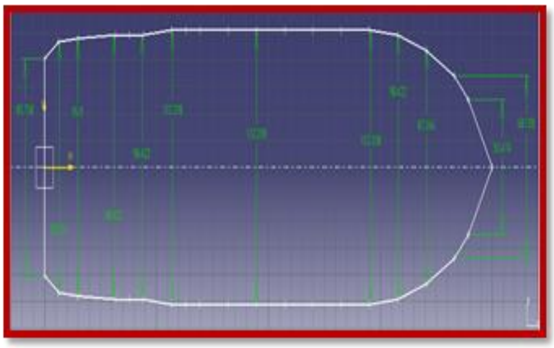
A. Design of the boat.

Firstly, the boat has designed as module from (Damen shipyards- Stan Tender 1550) [1]. Secondly, views and dimensions the boat shown as Fig.1. These has calculated by using factor 1:39.625. thirdly, they have drawn by solid work program (type: CATIA V5) that useful to draw shell the boat as prismatic shown as Fig.2.

(a)



(b)



(c)

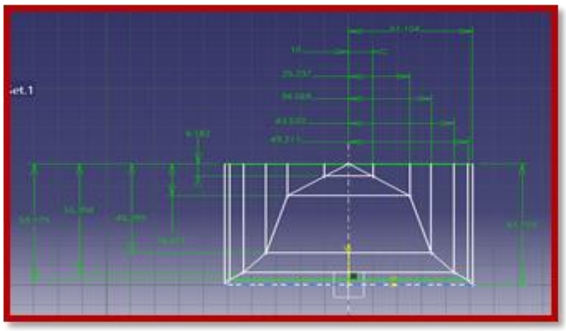


Fig.1 **a** photo of front view with dimensions the boat, **b** photo of top view with dimensions the boat , **c** photo of side view with dimensions the boat.

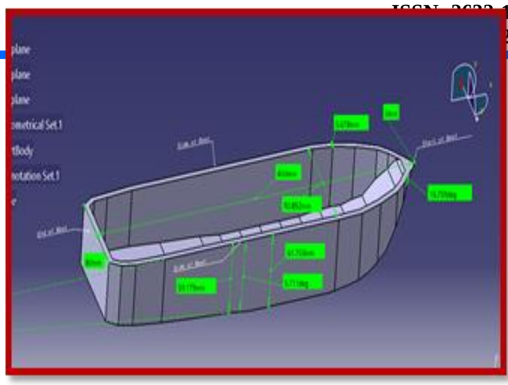


Fig.2 photo of prismatic with dimensions the boat.

III. Manufacturing Technique the Boat.

A. Manufacturing Technique by using Swedish wood.

The scenario of manufacturing is started by preparation block from swedish wood (type SS-EN 1611-1/G4-2) then limited all dimensions on it by hand and pensile for cut using electrical-saw at each steps using polishing machine for smooth surface of the boat shown as Fig.3. secondly, manufacturing of beam at thickness is 5.678mm that demanded using thin milling machine and some another tools to reach to the required internal depth of the boat shown as Fig.4.

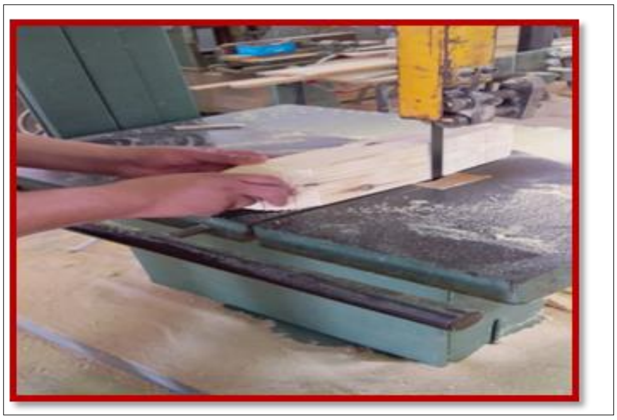
(a)

(b)

(c)

(d)

(e)



(f)

(g)

Fig.3 **a** cut block from swedish wood**,** **b** smooth the swedish wood surface, **c** limitation the dimension on block in side, **d** limitation the dimension on block in top, **e** electrical saw for cut limitation dimension of the boat on sides , **f** electrical saw for cut limitation dimension top of the boat, **g** graining machine for smooth the boat surface.

(a)

(e)

(b)

(f)

(c)

Fig.4 **a** thin milling machine for limitation thickness around the boat, **b** remove reich of the wood around the boat, **c** electrical machine to remove remaining part from depth, **d** tool for completing internal depth of boat, **e** finishing with smooth internal surface of the boat, **f** using tools in manufacturing the boat.

(d)

B. Manufacturing Technique by using Composite Materials.

The scenario of reinforcing method is started by cutting the E-glass fiber woven roving to limited dimension with fiber orientation of $[0^\circ/90^\circ]$ and putting a first layer on a surfaces the boat then wetting it by a polyester resin using a small brush. Cut the second layer with $[0^\circ/90^\circ]$ fiber orientation and put it on the first layer and wet it again by polyester resin with small brush until all the resin impregnate in to the fiber. Repeat this procedure with orientation $[0^\circ/90^\circ]_s$until reach the required thickness , this scenario continuous at inter and outer surface of the boat shown as in Fig.5. Finally, the boat is lifted to cure at room temperature for 24 hours and post curing at 120°C for two hours. After the curing, the reinforced boat that was ground to flatten the surface and remove rough edges using silicon carbide paper. When the surface of the boat became flat, it was polished using an oil based cloth until all scratches disappear, then painting by color suitably shown as Fig.6.

(c)

(d)

(a)

(e)

(b)

(f)

(g)

(h)

Fig.5 a Manufacturing tools: resin, hardener pot, gloves, scale,**b** E-glass fiber preparing, **c** clean the work-table,**d** cut fiber for limitation the boat dimension, **e** paint surface the boat by polyester resin,**f** putting a first layer from E-glass fiber on a surfaces the boat, **g** continuous wetting the fiber with polyester by small brush, **h** continuous putting layers and wetting by resin.

(a)

(b)

(c)

Fig.6 a the boat is lifted to cure at room temperature for 24 hours, **b** using silicon carbide paper to flatten the surface and remove rough edges, **c** color the boat by blue paint and white for draught level at 27.26mm.

IV. Testing method.

Fig.7 shows a photograph of an assembly two small motors with the boat for control the driver by remote control . first motor to drive the boat direction forward and backward by propeller, while second motor to drive the boat direction right and lift by impeller. The test was started by its putting in seawater then directing shown as Fig.8.

Fig.7 assembly the two small motor by brackets behind the boat.

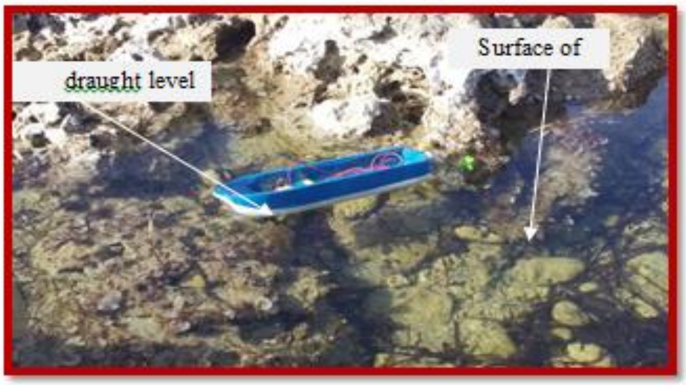


Fig.8 the boat put on surface seawater.

V. Results and Discussion.

There was steadying state of the boat when put in the seawater shown as Fig. 9. This can be indicated to excellent design and manufacturing of the boat by solid work program and E-glass fiber and polyester resin respectively. In addition, mechanism of control at directing the boat in seawater that showed easy using small motors to power. This can be obtained at driving the boat and its facing for more than directions in seawater shown as Fig. 10. This work depended on model (Damen Stan Tender 1550) shown as Fig.11.

Fig.9 the boat moves by remote control to forward.

Fig.10 the boat rounds by remote control to more directions.

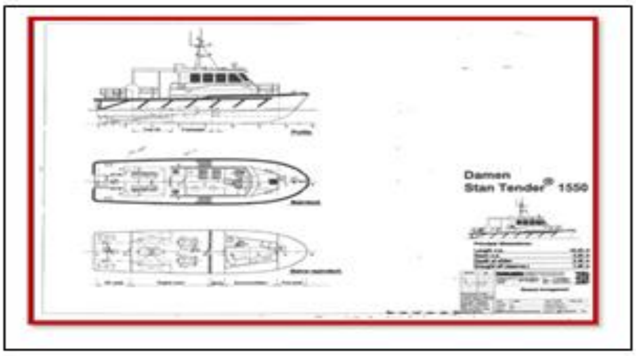


Fig.11 schematic of shipyards Damen Stan Tender 1550.

VI. conclusion

- The work conclusions showed that it is possible to employ composite material rather than metals materials in industry for manufacturing and reinforcing of ships or boats.
- Useful from good mechanical properties of composite materials for manufacturing and reinforcing of boats or ships in industry.
- Can be use some models of ships or boats for design and manufacturing as them.
- Mechanical properties of composite materials are almost the same some mechanical properties of metals materials. However, they are lowest cost in materials.

- Can be support the wooded boats by using fibers and resin (composite materials).
- Can be design any ship with designed dimensions by using solid work program type: (CATIA V5).
- Uniform steadying of the boat in seawater and good control driving at small power.

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