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Research paper

A Comparative Study of Investigation of Advanced Materials for Shipbuilding

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Abstract

It is, in fact, a traditional mode of transportation and cargo above the sea that humans have used since ancient times to travel across water bodies. Super carriers, which are used for aircraft carriers weighing more than 70,000 tons, are currently the most prevalent type of navy ship. Planes are transported by aircraft carriers. Battleships are larger than cruisers and destroyers and are equipped with superior armaments. Helicopter carriers are warships that transport aircraft. Cruisers are massive warships designed for long, fast cruises. During assaults, larger warships are accompanied by destroyers. One kind of escort transportation is a frigate. Cor Shipping was regarded as one of the most secure and cost-effective ways to move people and products. Since ancient times, the shipbuilding industry has been a significant and prosperous business. The majority of the activity in the shipbuilding industry were concentrated in the shipbuilding and ship repair sectors amongst them Organizations, including those in the shipbuilding industry, relied heavily on human resource development (HRD). HRD was no longer a support department in today's world; rather, it played a crucial role in businesses. Therefore, recruiting, training, nurturing, and retaining human capital were some of the most important aspects in any organization. The shipbuilding sector in India included ship builders, ship repairers, seafarers, regulators, administrators, insurers, surveyors, equipment manufacturers, port & terminal operators, coast guard, navy, and training establishments. Human resource management, once regarded as one of the most important tools for an organization's growth and development, faced a paradox in this industry today. The industry was at a crossroads between strategies for development and expansion and attracting, training, and retaining human resources for the industry, which has now become quite a challenge.

Keywords: *Shipbuilding; Advanced Materials; Comparative Study.*

1. Introduction

The maritime industry is crucial to a nation's overall development. The sector includes Ports and harbours, Shipping of EXIM cargo, coastal shipping and multi-modal transportation of cargo to and from ports, cargo and passenger movement through inland waterways, shipbuilding and ship repair industries. In the past, the shipbuilding sector has been crucial to the economic growth of maritime nations. Since the 18th century, shipbuilding industries around the world have followed a common economic pattern: they grew, fell, and were eventually replaced by an industry from another country. Indian shipbuilding industry has several advantages such as low labour cost, several deep-water ports, ideal for setting up shipyards, geographical advantages of being close to International Shipping Lanes and large inland navigation network; and moderate facilities. The strengths of ship repair industry in India are geostrategic location of India, abundance of labour, competitive labour rates and quality of work. Shipbuilding is a multifarious manufacturing and assembly industry and involves the fabrication of large and complex welded steel structures. The global shipbuilding business is growing more and more competitive, and increasing efficiency is crucial to staying competitive in the market. Bulkheads and stiffeners are welded to the inside surface of ship hulls, which are normally made up of several steel plates that have been butt-welded together [1]. Ships are built in phases, with the components being created first and then assembled to create subassemblies. Second, subassemblies are assembled to create assemblies, which are subsequently combined to create blocks. The blocks are then joined to create a ship. Maintaining accuracy in overall dimensions of subassemblies and assemblies is critical to the success of shipbuilding [10]. Maintaining the dimensions is made more difficult by the current trend in shipbuilding to optimize designs with thinner plates and lighter stiffening. Outfitting works such as piping, machinery installation are done in block stage as well as on board. In order to maintain the ship's hull, piping systems, various tanks, and machinery, painting is also required. As a result, ship building can be thought of as a complicated assembly job that involves welding, dry survey, painting, and outfitting, among other manufacturing processes [2][4]. Integrated Hull Construction, Outfitting, and Painting (IHOP) and product work breakdown structure are two techniques that modern shipbuilding businesses use to improve their operations through a group technology-based shipbuilding system. Every facet of hull construction is impacted by the IHOP approach. The primary characteristic of this approach to hull construction is that blocks, assemblies, sub-assemblies, and hull parts are produced using group technology principles in structured work processes. In process flow, component or interim product dimensional precision is crucial. Inaccurate interim products have a negative impact on downstream output. Further, fitting and welding of subassemblies, assemblies and blocks consume a major portion of the man-hour requirement in ship building. Due to dimensional inaccuracies, lot of adjustment works is required during fitting and major portion of the fitting man hours is consumed for these adjustment works. Repairing dimensional quality mistakes can sometimes result in a labor consumption increase of up to 30–40% of the total labor required to build a ship's hull. [11] Increased precision can save significant man hours. Therefore, in order to reduce delays and rework during subsequent assemblies, it is necessary to monitor the creation of interim goods and control the accuracy. Quality of the product along with reduction in rework and thereby reduced cycle time for construction are essential for shipyards to stay competitive in the market. When building a hull, there are numerous stages of fabrication, so dimensional variations are expected throughout the process if the processes are not properly managed. These dimensional variations can cause delay due to the requirement of adjustment works. Reworks consume a significant amount of time when the various stages of hull construction are thoroughly examined. It is also identified that due to adjustment work and rework, lot of time is lost in the sub assembly stage of hull fabrication [5]. Further analysis, identified that this is due to the dimensional variation of the plates cut in the preparation stage in the numerical control plasma cutting machine. If these dimensional problems could be managed by accuracy control, based on SPC techniques, lot of savings can be obtained by way of productivity improvement and will enable to stay competitive in the market.

Fig. 1: Ship Building Industry.

A navy vessel consists of basic components such as the bridge, main deck, forecastle, rudder, funnel, hull, port side, starboard, bulwark, bow thrusters, waterline, and bottom. Made from steel pieces, bars, strips, and plates, these vessels float on the surface because air-filled interior voids reduce their relative density. The large capacity of the steel industry allows construction of enormous vessels with hundreds of millions of tons [6]. Materials also experience steel castings and forgings of wrought copper alloys, and have to meet standards such as compression tests, notch impact energy, mechanical and chemical content. Tests are performed with tensile testing, notched-bar impact bending, corrosion resistance, and surface polish and size test. Specifically, seagoing ships and structures are impacted by the salt and corrosive seawater.

2. Literature review

In essence, shipbuilding is an assembly industry. The steel gradually expands to the size of the ship as it passes through various workstations. Through the many stages of assembly, the structural elements are put together. The hull block construction method based on the product-oriented work breakdown structure require a coordinated work flow. The accuracy of each process shall be well controlled to achieve the quality of final assembly and productivity. Dimensional accuracy of prefabricated parts is very crucial in ship building process since rework is a time-consuming process and correcting the errors due to the previous process accounts for the greatest part of the total hull construction work. Improving the accuracy of the hull parts will reduce adjusting works, minimize the work needing skill sets, promotes mechanization and improves product quality and productivity [3]. This is very important on the context that cost of man-hour for hull fabrication constitute half the cost of the hull of the vessel. Use of capability charts combined with logical problem-solving techniques can be used for controlling the variations in a manufacturing process. In addition to its advantages in terms of productivity and quality, process capability analysis needs to be carried out on an ongoing basis for the purpose of continuous improvement. One of the critical issues related to ship production is production of hull blocks of required accuracy. Accuracy control of prefabrication stage of ship production is vital since it forms the basis for the hull production. In a manufacturing process, variation from specified dimensions is expected since it is not possible to perform the process repeatedly without any variation. Variation can arise from different sources and the aim of process control is to limit the variation. The process's accuracy is the difference between the specified dimension and the obtained mean dimension. The degree of process capability is indicated by the fluctuation of the distribution around its mean. Working with a variety of variants is crucial for maintaining production control and ensuring that the finished product is accurate. Accuracy control aims in improving the manufacturing processes in shipbuilding with the help of statistical techniques. This system uses statistical techniques to monitor and control work processes and to improve the same. Recent studies have also shown that SPC techniques can be used for improving the process performance by reducing variability in process and increasing efficiency in production process by reducing re-work and scrap. It was also pointed out by researchers that quality of ship can be improved by accuracy control since defects such as crack and buckling of hull structure are largely contributed by residual stresses due to forced joining of inaccurate structural components.

Contemporary shipyards use the Integrated Hull Outfitting and Painting (IHOP) system that uses a product work breakdown structure. The system in most cases encompasses three major methods: Hull block construction, Zone outfitting, and Zone painting, since different kinds of work are naturally involved in shipbuilding. The work breakdown structure should also include area-oriented part family manufacturing because of the need for numerous pipe pieces in large quantities [12]. It is widely accepted that a product breaks down structure based on group technology concepts and lean manufacturing leads to improvement in productivity. Solid solution strengthening is an alloying technique used to increase the strength of a single metal by introducing atoms of another element into the crystalline structure. It forms a solid solution, but once the concentration of the alloying element goes beyond a threshold value, a second phase is produced in the majority of binary systems, concerning the area of intermetallic alloys. Precipitation hardening, also referred to as age hardening, is a heat treatment method that enhances the yield strength of ductile materials, such as structural alloys consisting of magnesium, nickel, titanium, aluminum, and some steels and stainless steels. The process results in small particles of an impurity phase that impede the movement of dislocations, creating increased high-temperature strength in superalloys. Precipitation hardening takes advantage of variations in solid solubility with temperature in order to form these particles. The presence of impurities in particle-reinforced composite materials, similar to particle material, restricts dislocation movement and hardens the material. Solid precipitation can generate particle sizes of varying features, just as ice formation in the air forms clouds, snow, or hail based on thermal history. In naval architecture, the dimensions used must make the displacement of the ship equal the combined deadweight (cargo, fuel, and provisions) and lightweight (machinery, hull, and fittings). The fineness of the hull should correspond to the target speed, whereas the depth is estimated by calculating the draft with freeboard regulation rules. Designers need to achieve weight balance, choose a moment balance for longitudinal and vertical orientations, and calculate the shaft horsepower required for the given speed. The hull needs to satisfy the requirements of the classification society in terms of strength and stability, such as scantlings for plate thicknesses and frame sizes. The ship also needs to satisfy several international requirements, such as minimum net registration tonnage for harbor and docking charges, and beauty. Passenger vessels also need to meet bulkhead subdivision regulations to provide stability in case of accidental hull puncture.

3. Methodology

The section on materials, techniques, and experiments is organized into several subsections, including process parameters, testing procedures, equipment and experimental setup, base material selection, tool design, and tool selection. There are three main categories into which the selection of base materials can be divided: The dissimilar aluminum alloy system, the dissimilar steel-alcohol system, and the dissimilar aluminum-magnesium system are the first three.

A different Steel-Al system Alloys of the 6xxx family are heat treatable because they contain silicon and magnesium in roughly the right amounts to generate magnesium silicide (Mg2Si). Alloys in the 6xxx series are medium strong and have good formability, weldability, machinability, and corrosion resistance. [13] After being created in the T4 temper, these heat-treatable alloys can be strengthened to full T6 characteristics by precipitation heat treatment (but not by solution heat treatment). uses include bridge railings, bicycle frames, transportation equipment, welded constructions, and architectural uses. The aluminum alloy AA6082-T6 was commercially available at the time of the current study. A similar Al alloy system was used to conduct Friction Stir Welding (FSW) between T6 and AA6082 aluminum alloy materials. Other Al-Mg systems were also studied in the research. In particular, commercially available 220×75×6mm plates of AA6082-T6 aluminum alloy and AZ91 magnesium alloy plates were used as the base metals (BM).

Tools and experimental configuration: The materials were friction stir welded in a butt joint configuration for every testing. To create joints, a typical milling machine was employed. Before welding, the plates' surface was washed with acetone and physically polished with 300 grit emery paper [8].

In system design, engineers combine their engineering and scientific knowledge to create a working prototype that incorporates both process and product design phases. The product design phase includes the selection of materials, components, and the estimation of product parameters. The process design phase includes the analysis of processing sequences, the selection of manufacturing equipment, and the estimation of process parameters. As a first-cut functional design, the system design will not necessarily be optimal cost-wise and quality-wise but is a starting point for subsequent refinement and optimization [15].

The goals of parameter design are to determine the best product parameter values that match process parameter values, and to maximize process parameter settings to improve quality characteristics. Taguchi does this by employing an orthogonal array in parameter design, which allows the investigation of the whole parameter space using a small number of experiments [14].

3.1. Testing methods

Tensile testing: One of the most significant and often performed material tests, the tensile test yields information about the fundamental mechanical characteristics of materials, including their strength. This test shows how materials behave elastically and plastically under various loading scenarios. Tensile strength, yield strength, and elongation % were assessed using the computerized universal testing machine. The ratio of the manufactured junction's tensile strength to that of the weaker base metal is known as joint efficiency for dissimilar joints. The test specimen is placed between the flat grippers and held at the proper gripping pressure; if the pressure is too high, it will slip out of the gripper instead of enduring tensile load, and if it is too low, it will shatter and crush before the experiment begins [7]. The experiment started when the run knob was turned on, and a uniaxial stress was applied until fracture happened. The pace at which the load increases is determined by the strain rate. In order to gather and display the material's response as a stress-strain curve, the data collecting system is also turned on concurrently. Three samples were processed for each separately produced joint, and its reproducibility was assessed.

Visual and Macroscopic Examination: To perform in-depth examinations, high-resolution cameras are employed to take pictures of welded samples and macro samples. The visual and macro exams are used to identify and analyze visual flaws including surface lines, surface tunnels, voids, macro-cracks, oxide formation, etc. Following a metallographic method, macro exams are carried out to facilitate the easy interpretation of flaws and macrostructure.

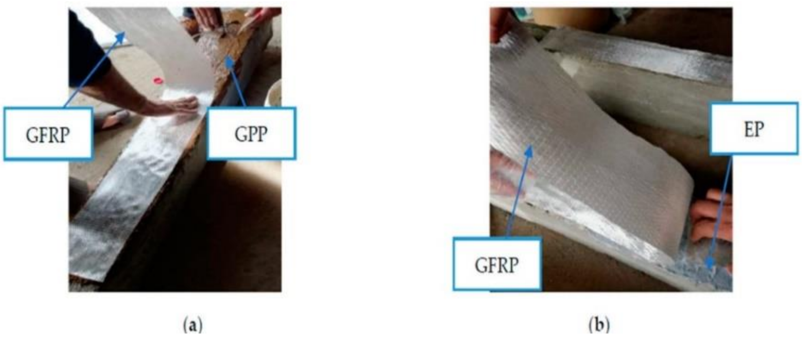

Fig. 2: Advanced Composite Material.

3.2. Advanced materials for shipbuilding

The metal nickel has a silvery-white sheen with a touch of gold. Nickel is a ductile, hard transition metal with excellent chemical reactivity, especially in the powdered state. Big pieces react very slowly with air, though, because of an oxide protective layer. Nickel is sparingly found in native form on the surface of Earth because of its great reactivity with oxygen, but it occurs in nickel-iron meteorites and with iron in the Earth's core. Nickel occurs in ultramafic rocks as well. A super alloy, or high-performance alloy, possesses higher mechanical strength, oxidation resistance, corrosion resistance, and thermal creep deformation resistance, along with superior surface stability. Hastelloy, Inconel, and Rene alloys are some examples. Super alloys tend to have a face-centered cubic austenitic crystal structure. Super alloys are a result of the advancement in chemistry and processing, and attain high thermal strength by solid solution strengthening. [9] Precipitation strengthening, which generates secondary phase precipitates like carbides and gamma prime, is an important strengthening mechanism. Elements like aluminum and chromium provide resistance to oxidation or corrosion. These alloys are mostly used in aircraft and marine turbine engines.

A modified form of directional solidification produces single-crystal superalloys, which are single crystals devoid of grain boundaries. In contrast to the majority of alloys, which utilize grain boundaries to achieve mechanical properties, high-temperature alloys must use different methods to avoid creep. A disordered phase matrix with ordered intermetallic phase islands, simulating grain boundary behavior without amorphous solid introduction, characterizes many of these alloys. Single crystal superalloys, applied to gas turbine engines, have a distinctive microstructure with cuboidal γ' precipitates in a γ matrix. Efforts to increase temperature capacity have been emphasized since the single crystal casting development. New alloying constituents such as ruthenium and rhenium have greatly enhanced performance. Knowing the physical mechanisms of creep deformation in single crystal superalloys is important, particularly under harsh conditions of high temperature and stress. Creep response in such alloys is heavily dictated by factors including alloy composition, orientation, temperature, and stress.

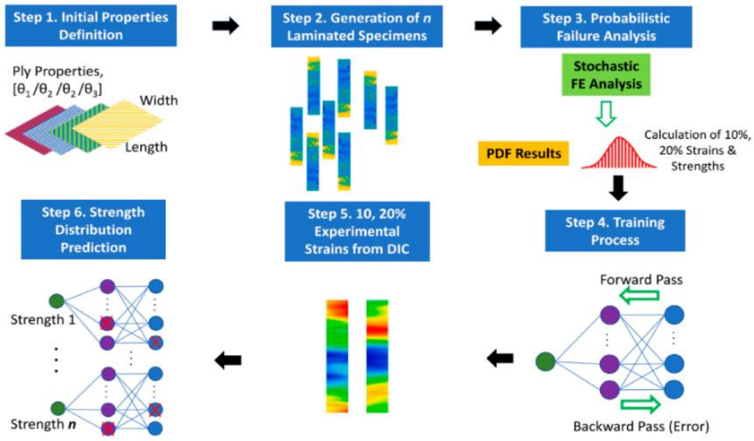

Fig. 3: Advanced Structures.

Chromium metal and ferrochromium alloy are both made from commercial chromite using different processes, such as roasting, leaching, and silicothermic or aluminothermic reactions. Chromium metal is very much prized for its superior hardness and corrosion-resistant nature. An important development was the realization that adding metallic chromium to steel might make it incredibly resistant to corrosion and discoloration, a process known as stainless steel. Currently, 85 percent of the element's commercial use is in applications for chromium compounds. CFRP and GFRP: Fiber reinforced plastic (FRP) composites and aluminum alloys are the primary lightweight materials utilized in ships. FRP is utilized in sandwich and single-skin forms. In single-skin applications, a stiffener system is typically used, but unstiffened monocoque solutions are also available. (Here, the specific case of glass-reinforced polymers, or GRP, is called "FRP.") Although sandwich arrangements are also an option, aluminum alloys are typically found in welded, stiffened plate shapes and as extruded pieces, both open and closed.

Although they are not usually thought of as lightweight materials, high-strength steels can be employed to save weight in stiffened plate and, more recently, some sandwich forms. The utilization of mixed solutions, which incorporate several materials into a single ship or superstructure, is growing. The main uses for lightweight materials are in patrol and rescue boats, sailing yachts, pleasure craft, small naval ships (such mine countermeasure vessels), high-speed passenger and automobile ferries, and possible future applications. Nonetheless, they are also utilized in the superstructures of bigger naval vessels (such as frigates) and cruise ships. They are also widely used in secondary constructions and parts for various ship types, such as decks, masts, casings, and ramps for movable vehicles.

Composite substance: The manufacturing of naval ships has advanced significantly with the development of innovative composite materials. The unique benefits of using eco-friendly composite materials reinforced with silk fabric in the construction of civil infrastructure have been researched. One such quality is its exceptional resistance to corrosion, which has resulted in successful applications all around the world. Its extension is the space or platform that a boat can operate from. While a boat is underway, the scaffold is monitored by a watch official, who is mostly assisted by a competent sailor acting as a post. The skipper will be on the extension during basic maneuvers, usually supported by a watch official, a competent sailor on the deck, or a pilot as necessary.

4. Conclusion

The modern industries in advance engineering applications constantly demand a material of superior mechanical and tribological properties to fulfil the high needs at a low cost. Combining two or more different materials with different physical and chemical properties creates a composite material, which has special qualities of its own. One of its parts is matrix in which the second one known as reinforcement is embedded, may be as an individual or in hybrid form. At both the macro and microscopic levels, the newly formed composite material maintains its distinct matrix and reinforcement. The various components that are used will overcome each other's shortcomings in the composite material to create improved properties that are suitable for advanced engineering applications. The composite material can be preliminary divided based on the parts used. Aluminums, titanium, copper, magnesium, etc. and their alloys are commonly adopted as the matrix material. Modern technology breakthroughs have fueled numerous recent innovations across a range of areas. Technological developments have allowed man to progress in all facets of existence. As technology has advanced, shipbuilding and related technologies have also advanced swiftly. The maritime and shipbuilding sectors are poised for revolution with recent technological advancements facilitated by research and development. Improvements in 3D printing, robotics, artificial intelligence, and virtual reality are making construction methods better, while more environmentally friendly and sustainable ships are being developed through prioritizing regulation compliance and minimizing ecological footprint. Materials that can boost performance and carry more weaponry while lowering fuel expenses, maintenance costs, and environmental impact are becoming more and more popular among shipbuilders. About 80% of a ship's fuel is used to keep it moving forward and get past hydrodynamic drag. Utilizing cutting-edge materials can enhance the variety of military tasks carried out by naval vessels.

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