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Marine Propeller Manufacturing – A New Approach

Yonas Mitiku Degu[1], K. Sridhar[2]
[1, 2] *School of Mechanical and Industrial Engineering, IoT, Bahir Dar University, Bahir Dar, Ethiopia*

Abstract: - Laser Engineered Net Shaping (LENS) is one of the rapid prototyping manufacturing process for producing metal parts directly from Computer Aided Design (CAD) files, In this approach to fabricate the ship propeller by layer additive methods. The LENS technology is unique in that fully dense metal components with material properties that are similar to that of wrought materials can be fabricated. The LENS process has the potential to dramatically reduce the time and cost required realizing functional metal parts. In addition, the process can fabricate complex internal features not possible using existing manufacturing processes.

Keywords: *– LENS, Propeller manufacturing, RPT*

I. INTRODUCTION

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. [1] A propeller is the most common propulsion inducer on marine vessel; imparting momentum to a fluid which causes a force to act on the ship there by the ship will start sailing. Till now RPT technique is usually used to prototyping of new products, this paper proposes the LENS technology for the manufacturing of marine propellers.

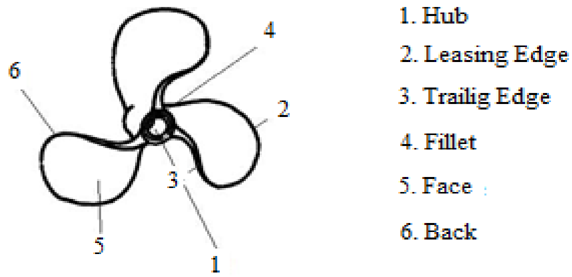

Figure1. Marine propeller parts

II. MANUFACTURING OF PROPELLER

The manufacturing process of marine propellers has remained virtually unchanged in the last 50 years. As the boat designs evolve, the shape and style of the propellers have changed, but they are still made the same way they were in the 1950′s [2].

The propeller is manufactured by sand casting technology. Sand casting is the common process to manufacture many components. In that pattern making, forming the mold cavity, metal pouring and finishing are the main steps. But particularly in propeller manufacturing the pattern making technique is different and tedious. Advantages in that, many metals can be molded in different sizes, shapes and cheaper in cost. But it has poor finish and tolerance. Engine blocks, cylinder heads are some example part to be made. The major steps involved in manufacturing marine propellers by sand casting method.

2.1 Layout

The layout is done first and most important part of the job. It shows cross sections of the blades at chosen points. This includes the angle, rake, thickness machining allowance; length and shrinkage allowance for the metal casting process. After the general layout is complete, material requirement calculation made for the construction of the propeller. It is important that the wood be clear of knots, as a lot of carving is involved in the shaping process. For these propellers, nineteen layers were used for each. A separate layout is then generated off the original layout to determine shape of the individual cants. Once both layouts have been completed and checked, then checked again, construction can begin.

2.2 Pattern

The wood is planed down and shaped according to the layout. The layers are cut on a band saw. In order to guarantee the layers line up properly, a center hole is drilled in each layer. This center hole represents the center of the hub.


Figure 2. Center hole drilling and stack of offset wood layers

Using the layout, an offset is determined enabling the correct pitch of the blade. The layers are then marked and prepared for gluing. The layers are glued together using the offset. We use screws to hold the layers together because it is very difficult to use clamps. It is now starting to look like a propeller blade.

2.3 Shaping

The steps in the shaping the wood need to be taken down to make a smooth surface. Tools are used in order of precision; it can typically go as follows:
Axe – Draw Knife – Power Plane – Angle Grinder – Spoke Shave – Block Plane – Sand Paper. According to thickness the back is taken down in the same fashion as the face. Once the blade is finished, the hub can be built up.

The off cuts from the cants are already kept to build up the hub. Hubs can be different depending on the foundry's needs, and the specifications of the vessel the support will use for. Typically a machining allowance is added on the diameter, as well as an addition in length on the forward end. The extra length allows for the work holding a lathe's chuck for machining. Once the hub takes shape, and the blade is near completion, the fillet is made. The fillet is the radius where the hub meets the blade. The fillet is created using composite filler. It can also be carved into the wood.

2.4 Finishing

All the small holes, scratches and minor defect are filled with wood filler. The entire blade is sanded down with at least 80 grit sand papers. The scratches left by the 80 grit paper will be filled with paint. Special pattern paint is used to finish the propeller. It can be sprayed, rolled, or brushed on. The paint will fill small scratches and become extremely hard once dry. After painting, the pattern is now ready for molding in the foundry.


Figure 3. Shaping stack of offset wood layers and the final shape

- The pattern is made with one blade for a number of reasons. The first being strength. If the pattern were to be made (in wood) with more than one blade, the hub would actually only be connected to one blade and the others would have to be attached after the fact. The second reason is continuity. The pattern is made with one blade to ensure that when molded, all the blades are the same. The third reason is price. Most of the price of the pattern is in the blade shaping. If a 5 blade pattern is needed, it would cost 5 times what a normal pattern would.

- Because of the way the pattern is molded, less than half the hub surface is used at a time. So a full hub is not necessary. A flat back on the hub also allows for easier pattern storage.
- The color of the pattern usually indicates the type of metal being used. However a foundry may have their own reason for color
- It's actually quite common to re-pitch old patterns, update the blade shape, or build up the hub diameter. As we said earlier, propeller patterns are always built per vessel. They have to take into account the boat size, engine specs, region, etc. So if an old pattern was built for an engine with less horse power than a new one, the pattern may have to be modified to allow for a stronger propeller [2].

III. MATERIAL

Over the years there has been advancements made in steel materials and alloys used for marine propeller. Long gone are the days of using stainless steel and others the most commonly used material is stainless steel [3], to avoid all the above manufacturing difficulties said in section I and II, increase the productivity and material compatibility the authors propose the following latest, waste eliminating technology called RPT [Rapid Prototyping].

IV. RAPID PROTOTYPING

Rapid Prototyping (RP) is a term most commonly used to describe a variety of processes, which are aimed at quickly creating three-dimensional physical parts from virtual 3D computer models using automated machines. The parts are "built" directly from the 3D CAD model and can match that model very closely (within the precision limits of the chosen process). Rapid prototyping is different from traditional fabrication in that it is only possible through the use of computers, both to generate the 3D CAD model data, as well as to control the mechanical systems of the machines that build the parts. Virtually all RP processes are "additive". Parts are built up by adding, depositing, or solidifying one or more materials in a horizontal layer-wise process. The part is built up layer by layer until done. This is similar to the result one would get if one made a topographical map of the object, with the contour lines representing the layer thickness of the process.

A virtually geometry model is cut into slices for layer wise production. RP technologies are able to create one-piece part geometries which would be difficult if not create by machining, including overhangs, undercuts and enclosed spaces. To create these types of structures, RP technologies often really on a support material, this is used alongside the model material. These automatically generated supports must be removed after the part is finished. Other processes rely on the unused model material to support the part being built.

The materials which are available for RP use will depend on the process chosen and are still relatively limited, but the variety is growing. There are a number of plastics and resins commonly used, as well as some process that can use things like starch, plaster, wax and metal. The word "Rapid" in RP is a relative term, as most of these processes are actually quite slow. The rapid actually refers to the reduced time from initial design to the production of the final part. This is due to the elimination of extensive amounts of hand and machine work involved in making prototypes with traditional methods, as well as the ability to quickly iterate and test a design through various stages. Also, as contrasted with more complicated CAM programming and CNC machining, RP software and machines are generally simple and quick to use, resulting in significantly reduced "human time" needed to produce prototype parts.

RP processes are generally quiet, non dangerous processes which can run in an office environment all over the year.

This contrasts with machining, which generally needs a workshop or factory environment (noise, dust, liquids) and has a number of safety issues (including personal injury or the possible destruction of the machine if things are not done properly) [4].

V. SEQUENCE OF RPT

- CAD solid model
- '.STL' file
- Slicing the file
- Final build file
- Fabrication of part
- Post processing

- **STL format**
- All commercial CAD systems can convert 3D models → STL
- User specifies accuracy: Higher accuracy → many, small triangles → large files

VI. RAPID PROTOTYPING TECHNOLOGIES

- Stereo lithography (SL)
- Laminated Object Manufacturing (LOM)

- Selective Laser Sintering (SLS)
- Fused Deposition Modeling (FDM)
- Solid Ground Curing (SGC)
- 3D Printing (3DP)
- Laser Engineered Net Shaping (LENS)

The authors' approaches LENS technology is most appropriate to manufacture of propeller for marine vessel; because it has ability to create parts with different material compositions.

VII. LASER ENGINEERED NET SHAPING (LENS)

A technology that is gaining in importance and in early stages of commercialization and it is designed for aerospace industry especially to produce titanium parts. A high power laser (1400W) is used to melt metal powder supplied coaxially to the focus of the laser beam through a deposition head that is deposited onto the table. The head is moved up vertically as each layer is completed. Metal powders are delivered and distributed around the circumference of the head either by gravity, or by using a pressurized carrier gas. Inert gas is used to shield the metal from atmospheric gases and repeat process till build is complete. Objects fabricated are near net shape, but generally will require finish machining. Normally the material using for the propeller manufacturing are kinds of stainless steel. The LENS technology also most suitable for producing complicated shape parts with stainless steel.

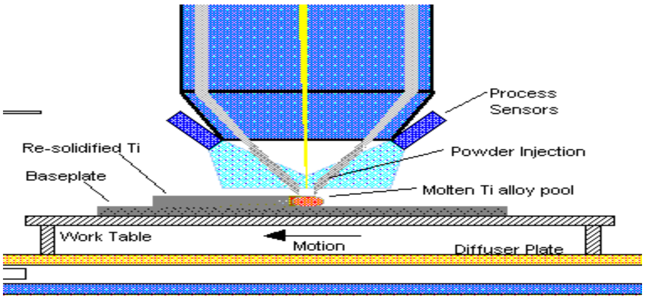

Figure 4. LENS Technology

Materials composition can be changed dynamically and continuously, leading to objects with properties that might be mutually exclusive using classical fabrication methods. Has the ability to fabricate fully-dense metal parts with good metallurgical properties at reasonable speeds; so it is suitable for alloying to add the properties for parts producing by this technology.[5]

1. Advantages of LENS

- Can be used to repair parts as well as fabricate new ones
- Has a very good granular structure
- Powder forming methods have few material limitations
- The properties of the material are similar or better than the properties of the natural materials
- Comparatively good surface finish than sand casting because not require secondary finishing operations

2. Disadvantages of LENS

- Some post processing involved
- The part must be cut from the build substrate
- Has a rough surface finish, may required polishing

3. LENS Initial Applications

- Fabrication and repair of injection molding tools
- Fabrication of large titanium and other exotic metal parts for aerospace applications

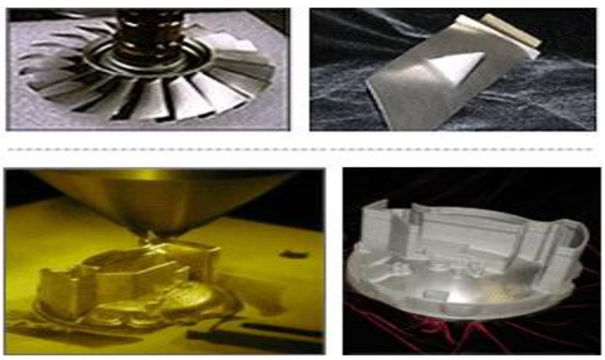

Figure 5. Parts manufactured by LENS [Source:-www.optomec.com]

4. LENS Capabilities

- Ability to build fully dense shapes
- Closed loop control of process for accurate part fabrication
- Ability to tailored deposition parameters to feature size for speed, accuracy, and property control
- Composite and functionally graded material deposition
- Three- and four-axis systems for complex part fabrication [6]

5. Limitations of RP methods

a. Accuracy

Precision: tolerances are still not quite at the level of CNC, Because of intervening energy exchanges and/or complex chemistry one cannot say with any certainty that one method of RP is always more accurate than another, or that a particular method always produces a certain tolerance.

b. Fınısh

The finish and appearance of a part are related to accuracy, Technologies based on powders have a sandy or diffuse appearance, sheet-based methods might be considered poorer in finish because the stairstepping is more pronounced.

c. Secondary operations

Metal parts will almost certainly require final machining and must usually undergo a thermal baking cycle to sinter and infiltrate them with a material to make them fully-dense. Other than powder-based methods all other methods require a support structure to be removed in a secondary operation which may require considerable effort and time.

VIII. CONCLUSİON

The authours conclded that, in propeller manufacturing the LENS technology can be adopted to produce the propeller to reduce the time, cost and increse the mechanical property, quality and productivity. LENS will be the apropriate production technology in future to produce marine propellers because it has own flexiblity in sizes and materials.

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AUTHORS' BIBLIOGRAPHY

Yonas Mitiku Degu received his B.Sc. in Mechanical Engineering from Bahir Dar University, Bahir Dar, Ethiopia in 2005; pursued M.Sc. in Applied Mechanics (Mechanical Design) Addis Ababa University, Addis Ababa, Ethiopia graduated in 2008; From 2008 to 2012 as a lecture and currently working as an Assistant Professor in the School of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia.

K. Sridhar-received his B.E., Degree in Mechanical Engineering from Anna University, Chennai. He received M.E. Degree from ANNA University, Coimbatore. Since Oct '2011, he is working as a lecturer in the School of Mechanical and Industrial Engineering, Institute of Technology, Bahir Dar, University, Bahir Dar, Ethiopia.