International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-08, Special Issue, MAY 2022

Modeling and 3D Printing Simulation of Jet Engine Propeller with Minimum Printing Time Orientation Optimisation

Mr. P. Varaprasad*, Mr. B. Venkata Abhinav*, Mr. M.Sanjay kumar*, Mr. S. Vamsi*, Mr. U.Tarun*, Mr. A Yeswanth, Mr. GVN Santosh****

***UG students, **Faculty, Department of Mechanical Engineering College, Pragati Engineering College (A)**

ABSTRACT: Turboprop motors are the class of motors that drives the air ship propeller. Turboprop comprises of propeller, blower, burning chambers, turbine, and a spout. It works with less speed, less cost, better eco-friendliness, low climbing pace, less ozone depleting substance discharge and less vibration. The propeller cutting edge and shaft are viewed as the basic pieces of a turboprop motor as they turn at high speeds. To manufacture these propellers by using conventional manufacturing is very difficult. To manufacture these propeller, Additive manufacturing will be the best suitable option. But due to very less thickness manufacturing of propeller is also difficult. Before 3D printing the part, we have simulated the propeller for best optimized orientation for minimum displacement and strains. In this study horizontal printing orientation is the best orientation for LPBF process.

Key words: 3DP, AM, LPBF, Propeller, Simulation

I. INTRODUCTION

Air ship motors are the real piece of the drive framework in a flying machine and it will create the mechanical power. They are significantly arranged into three sorts. They are turbine motors, cylinder motors and electric engines. The greater part of the air ship motors utilizing today is open rotors/turbofans. These motors will be appropriate for long courses and eco-friendliness of these motors is less contrast with turboprop motors. Turboprop motors are the sorts of air ship motors which drives the propeller. Propeller sharp edge is a critical piece of the motor. Propeller cutting edge will have the airfoil shape which will pivot at fast. As the sharp edge will pivot it will push the air. In the event that the airfoil is of the deviated shape, there will be weight distinction over the cross segment. There will be lift and drag drive following up superficially on account of the weight distinction, Along with these powers there will be streamlined pushed compel acting because of air mass stream and radiating power packaging because of turn. For the plan of the cutting edge we have to consider all the above said powers and furthermore need to locate the regular recurrence of the sharp edge so as to maintain a strategic distance from the reverberation marvels.

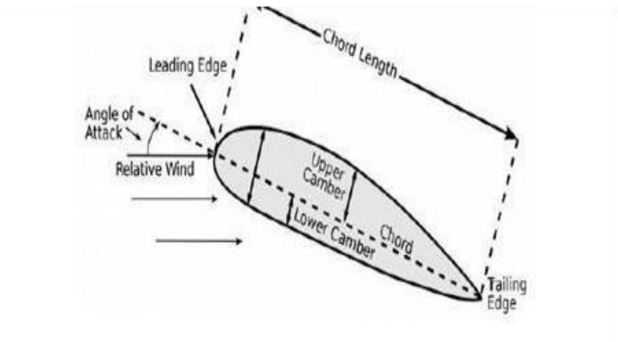


Figure 1.1 : Basic nomenclature of an air foil

1.1.1 INTRODUCTION TO THE PROPELLER

- Propeller changes over rotational power from the motor into push.
- The pivoting sharp edge of a propeller has comparative qualities to a wing going through the air
- A propeller sharp edge produces push F through a streamlined lift compel segment, requests a motor torque Q to conquer streamlined drag, and will slow down if the neighborhood resultant approach of the edge surpasses max
- Additional factors: trailing vortex age, tip misfortunes, compressibility

1.1.2 General Information

Push is the power that moves the air ship through the air. There are distinctive sorts of drive frameworks create push in various ways, in spite of the fact that it ordinarily produced through some utilization of Newton's Third Law. Propeller is one of the impetus framework. The motivation behind the propeller is to move the flying machine through the air. The propeller comprises of at least two edges associated together by a centre point. The centre serves to append the edges to the motor shaft.

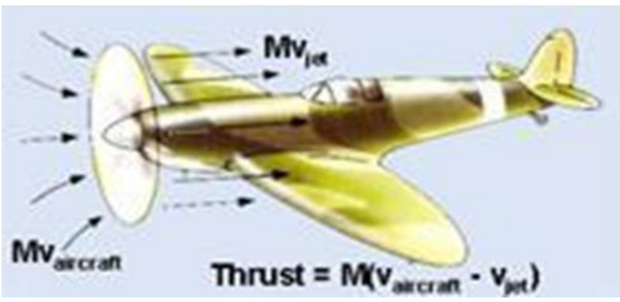


Fig:1.2 air flow through propeller

 DOI : 10.35291/2454-9150.2022.0261

At the point when the motor turns the propeller cutting edges, the edges produce lift. This lift is called thrust and pushes the air ship ahead. most flying machine have propellers that pull the air ship through the air. These are called tractor propellers. Some air ship have propellers that push the airplane. These are called pusher propellers.

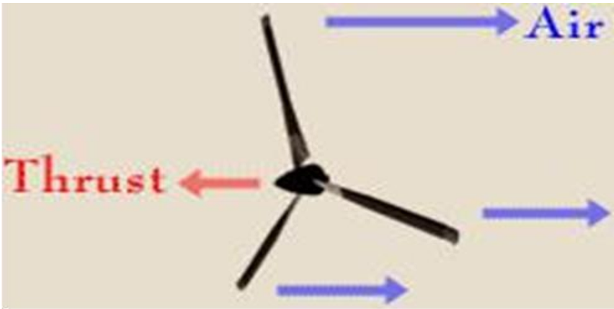


Fig1.3 flow direction of air & thrust

1.1.3 Description

Driving Edge of the airfoil is the bleeding edge that cuts into the air.

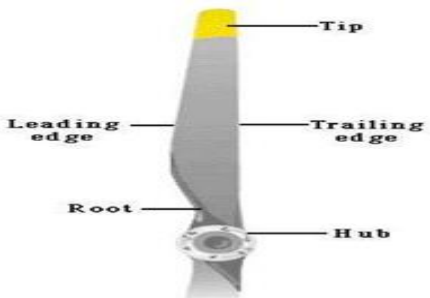


Fig:1.3 propeller parts

Blade Face is the surface of the propeller blade that corresponds to the lower surface of an airfoil or flat side, we called Blade Face.

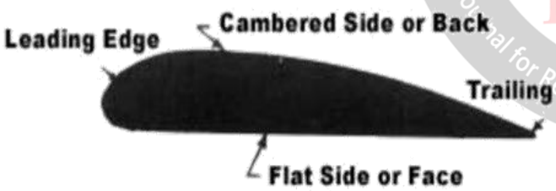


Fig:1.4 cross section of propeller blade

Blade Back / Thrust Face is the curved surface of the airfoil

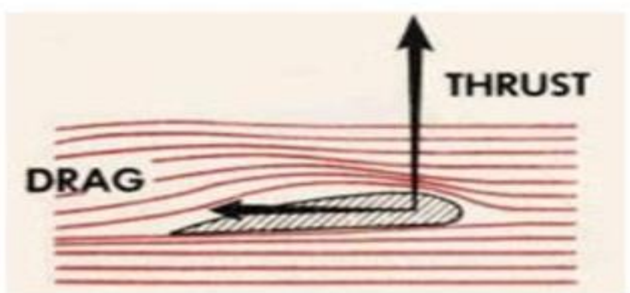


Fig: 1.5 Thrust Face is the curved surface of the airfoil

Sharp edge Shank (Root) is the segment of the cutting edge closest the centre point. Sharp edge Tip is the external end of the cutting edge fastest from the centre point. Plane of Rotation is a non-existent plane opposite to the pole. The plane contains the hover in which the edges turn.

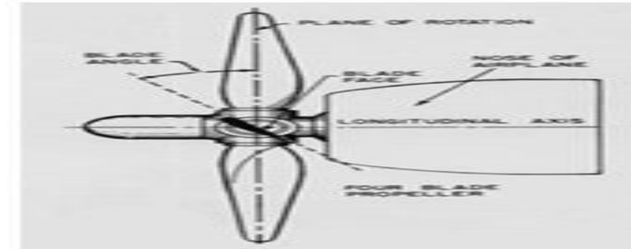


Fig: 1.6 blade axis

Cutting edge Angle is shaped between the substance of a component and the plane of revolution. The cutting edge all through the length of the edge isn't the equivalent. The purpose behind setting the sharp edge component areas at various edges is on the grounds that the different segments of the edge travel at various speed. Every component must be planned as a feature of the sharp edge to work getting it done approach to make push while rotating taking care of business configuration speed

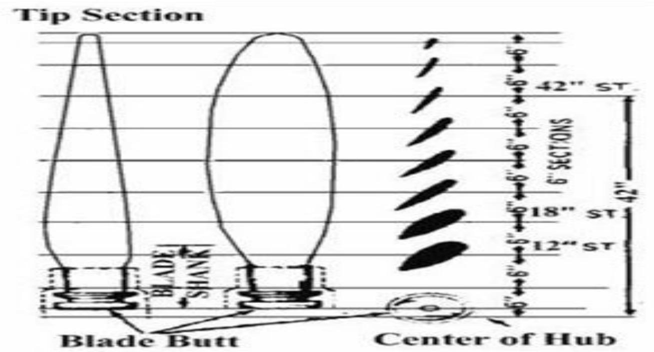


Fig: 1.7 cross section of propeller blade at different area

Sharp edge Element is the airfoil segments joined one next to the other to shape the edge airfoil. These components are set at various points in pivot of the plane of revolution. The explanation behind putting the edge component segments at various points is on the grounds that the different areas of the cutting edge travel at various paces. The inward piece of the sharp edge area voyages slower than the external part close to the tip of the cutting edge. On the off chance that every one of the components along a cutting edge is at a similar sharp edge, the relative breeze won't strike the components at a similar approach. This is a direct result of the diverse in speed of the sharp edge component because of separation from the focal point of pivot. The cutting edge has a little turn (because of various edge in each area) in it for an essential reason. At the point when the propeller is turning round, each segment of the sharp edge travel at various speed, The contort in the propeller cutting edge implies that each area advance forward at a similar rate so preventing the propeller from twisting. Push is created by the propeller appended to the motor driveshaft. While the propeller is turning in flight, each area of the cutting edge has a movement that consolidates the forward movement of the flying machine with round development of the propeller. The slower the speed, the more extreme the approach must be to create lift. In this manner, the state of the propeller's aerofoil (cross segment) must change from the middle to the tips. The changing state of the aerofoil (cross area) over the cutting-edge results in the bending state of the propeller.

 DOI : 10.35291/2454-9150.2022.0261

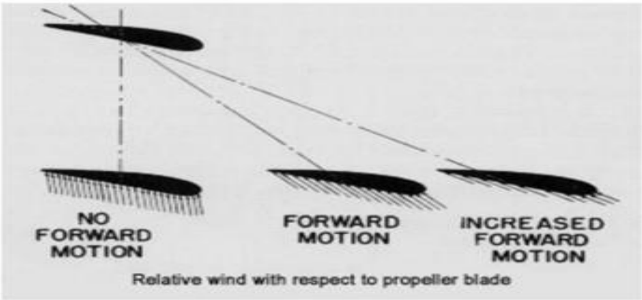


Fig: 1.8 motion of blade

Approach is the point between the harmony of the component and the relative breeze.

The best productivity of the propeller is acquired at an approach around 2 to 4 degrees.

Edge Path is the way of the bearing of the edge component moves.

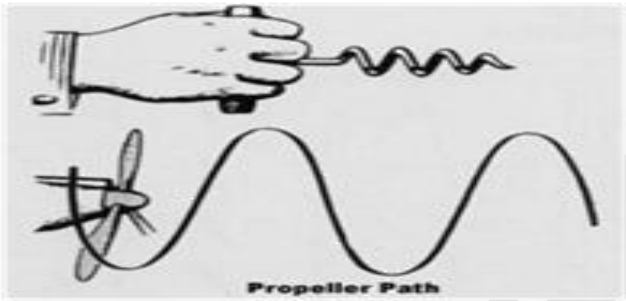


Fig:1.9 propeller path

Pitch alludes to the separation a winding strung item pushes ahead in one unrest. As a wood fasten pushes ahead when turned wood, same with the propeller push ahead when turn noticeable all around. Geometric Pitch is the hypothetical separation a propeller would progress in one upset.

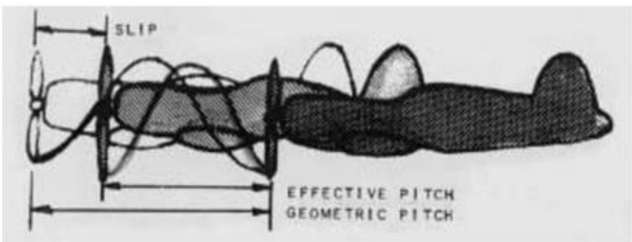


Fig: 1.10 geometric and effective pitch

Compelling Pitch is the genuine separation a propeller progresses in a single upset noticeable all around. The successful pitch is constantly shorter than geometric pitch because of the air is a liquid and dependably slips. Powers and stresses following up on a propeller in flight

The powers following up on a propeller in flight are:

1. Thrust is the flying corps on the propeller which is parallel to the direction of advance and prompts twisting worry in the propeller.
2. Centrifugal power is brought about by turn of the propeller and will in general toss the sharp edge out from the inside.
3. Torsion or Twisting powers in the sharp edge itself, brought about by the resultant of aviation based armed forces which will in general curve the cutting edges toward a lower edge.

The AM is not a new technology. It emerged with the invention of the first system, the stereolithography or SLA. It is a method that involves the use of a pool of a photopolymer resin where the successive layers are solidified and bonded to the previous ones by a UV laser that cures the liquid resin according to the required part geometry to produce 3D parts and it was developed by Charles Hull in 1984. The idea was patented in 1986. Then the invention of Selective Laser Sintering or SLS followed in 1987, a process that involves the melting powder substances to create an object via laser (again, find a more concise way of explaining SLS please). Later, the invention of "Three Dimensional Printing" (3DP) came out in 1993 by the Massachusetts Institute of Technology and the Z402 printer was introduced by Z Corp in 1996. During the next years several systems launched and the term “3D printing” was popularized. Today the AM has gained and earned its momentum. It can replace the traditional ways of manufacturing to meet the actual requirements of the industries. In addition, AM is available, nowadays, even for the households with the prosumer (producer-consumer) AM machines. Just in 2012, the AM has become more affordable and available for office, residential and academic purposes due to MakerBot together with RepRap that stormed the market. [2], [3] Moreover, AM can be applied in numerous fields. One of the applications of the AM products is the creation of molds for sand casting made by SLS technology, that they can be used for casting patterns in the lost wax method or even as medical models for the visualization process to plan a surgery. Therefore, some other most current and interesting applications in medical and dental fields can be the hearing aid shells, the dental aligners, or the orthopedical and craniomaxillofacial implants. Furthermore, there are more applications in the aeronautical industry, the artistic and design field or in the academic level and research. Hot topics on AM are the biomaterials (tissue and organ printing), the new design principles and software, the adaptation of available materials and the addition of new materials for AM, the new, faster and less costly processes and the fact that bigger and metallic machines are about to be launched. [2] Some can be wondering if there is a demand for AM from the industry. The AM technology has already been tried back in the 90s and RP is still used when it is needed. The materials are not so good compared to conventional manufacturing but in some cases the rough surfaces and pores in metallic AM are actually very beneficial for prostheses. AM is slow for real manufacturing, more expensive and the technologies are not that precise with the production of poor surfaces, but if one needs a product that requires customization then the AM is the only way to produce it with an affordable cost comparing to conventional machining. On the other hand, AM today offers the freedom to create new geometries, materials with excellent properties and a variable composition, as well as the recycling of the material. As a result, a lot of research is being focused on AM since all the above characteristics, including the intense customer demands, force the companies to look for better responsiveness through better methods and improvements. AM is advantageous for customer-based production which is the key for a company in this competitive market. [2]

1.2 AM technologies:

1. Stereolithography Apparatus (SLA)
2. Fused Deposition Modeling (FDM)
3. Binder Jetting
4. PolyJet Printing
5. Selective Laser Sintering (SLS)

 DOI : 10.35291/2454-9150.2022.0261

6. Digital Light Processing (DLP)

1.3 Metallic technologies:

1. Direct metal laser sintering (DMLS)
2. SELECTIVE LASER MELTING (SLM)
3. ELECTRON BEAM MELTING (EBM)
4. ELECTRON BEAM DIRECT MANUFACTURING (EBDM)

1.4 Overview of metallic materials of AM

1. Pure metals powder
2. Ti- based alloys
3. Ni- based alloys
4. Fe- based alloys
5. Al-based alloys
6. Cu-based alloys

1.5 METAL MATRIX COMPOSITES (MMC):

Leonardo Da Vinci (1452-1519) was most likely the first to coin lifting water by diffusive powers. He has portrayed crude models of turbomachines by making a few representations. From his unique portrays, a French physicist Denis Papin was first to depict the outward siphon logically in 1687. He manufactured first siphon in 1705, which had impeller with sharp edges and a volute. Consequently, divergent siphons and blowers of today are made after over 300 years' of upheaval. The hypothetical treatment of turbo machines requires the learning of liquid elements, stream material science and thermodynamics. Spannhake has made spearheading work here and has characterized stream material science and related wording in his book entitled "Outward siphons, turbines and propellers" in 1934. His successor Wislieenus expanded his work and recorded in "Liquid Mechanics of Turbo apparatus" in 1947. Amid this period, W. J. Kearton watched breaks in trademark bends via conveying precise tests. His estimations demonstrated that the stream is a long way from uniform, and that on the trailing face of the vane there is a territory of "idle stream". This region increments as the limit is decreased. The impact of this dormant stream is proportionate to expanding the vane thickness and decreasing the section territory. He had seen that number of impeller sharp edges has huge impact on fan execution bends. W. J. Kearton examined these conditions and has displayed his discoveries in an intriguing paper, "Impact of the Number of Impeller Blades on the Pressure Generated in a diffusive blower and on its General execution." He additionally discovered that beneath the basic stream the speed dispersion was genuinely symmetrical and taken after the speed conveyance got with violent stream in a pipe. Over the basic stream the speed circulation was not symmetrical, yet a lot more noteworthy in favor of the impeller far. A. J. Stepanoff considers pressure driven misfortunes as the most essential and however least known misfortunes in turbo-machines. He includes that the water driven misfortunes are brought about by skin erosion and swirls. Division misfortunes happen because of alters in course and size of the speed of stream. The last gathering incorporates stun misfortune and dispersion misfortune. D. J. Myles accounts impeller and volute misfortunes as a small amount of the dynamic leave weight in respect to impeller and volute, separately. They are related with a dispersion factor over a wide volume stream go. The outcomes are connected to different impellers and volutes. The low volume stream scope of activity is likewise considered. Dr. Bruno Eck [14] first managed impeller erosion or plate grating misfortune tentatively. He separated impeller misfortune in to two segments as impeller passage misfortune and erosion misfortune in impeller. The grinding misfortune in impeller comprise hindrance and resultant weight misfortune. William C. Osborne states that the real execution of a diffusive fan (at the plan direct) contrasts to the perfect fan control which can be anticipated by Euler's condition. This distinction can be represented bury sharp edge course which results in a decrease of the work done by the impeller. Different elements which add to decrease in yield are inner volumetric spillage and weight misfortunes inside fan get together. Mechanical misfortunes likewise influence fan input influence.

MODELING OF PROPELLER

The Modern universe of plan, advancement, producing so on, in which we have ventured can't be envisioned without obstruction of PC. The utilization of PC is with the end goal that, they have turned into a necessary piece of these fields. On the planet showcase now the challenge in cost factor as well as quality, consistency, accessibility, pressing, stocking, conveyance and so on. So are the necessities driving businesses to receive present day strategy as opposed to neighbourhood compelling the enterprises to adjust better procedures like CAD/CAM/CAE, and so on.

The Possible essential approach to enterprises is to have brilliant items at low expenses is by utilizing the PC Aided Engineering (CAE), Computer Aided Design (CAD) And Computer Aided Manufacturing (CAM) set up. Further numerous devices is been acquainted with streamline and serve the necessity Solidworks, PRO-E, UG are some among many.

3.1.1 Parametric

The measurements and relations used to make a component are put away in the model. This empowers you to catch structure goal, and to effectively make changes to the model through these parameters. Driving measurements are the measurements utilized while making a component. They incorporate the measurements related with the sketch geometry, just as those related with the component itself. Consider, for instance, a round and hollow cushion. The measurement of the cushion is constrained by the breadth of the portrayed circle, and the tallness of the cushion is constrained by the profundity to which the circle is expelled. concentricity. This sort of data is regularly imparted on illustrations utilizing highlight control images. By catching this data in the sketch, Solidworks empowers you to completely catch your structure expectation in advance.

3.1.2 Solid Modeling:-

A strong model is the most total sort of geometric model utilized in CAD

frameworks. It contains all the wireframe and surface geometry important to completely depict the edges and faces of the model. Notwithstanding geometric data, strong models likewise pass on their ―topology‖, which relates the geometry together. For instance, topology may incorporate recognizing which faces (surfaces) meet at which edges (bends). This knowledge makes including highlights simpler. For instance, if a model requires a filet, you essentially select an edge and determine a range to make it.

3.1.3 Fully Associative:-

A Solidworks show is completely affiliated with the illustrations and parts or congregations that reference it. Changes to the model are naturally reflected in the related illustrations, parts, as well as

 DOI : 10.35291/2454-9150.2022.0261

congregations. In like manner, changes with regards to the illustration or get together are reflected back in the model.

3.1.4 Constraints

Geometric imperatives, (for example, parallel, opposite, flat, vertical, concentric, and incidental) build up connections between highlights in your model by fixing their situations regarding each other. What's more, conditions can be utilized to build up scientific connections between parameters. By utilizing limitations and conditions, you can ensure that structure ideas, for example, through gaps and equivalent radii are caught and kept up.

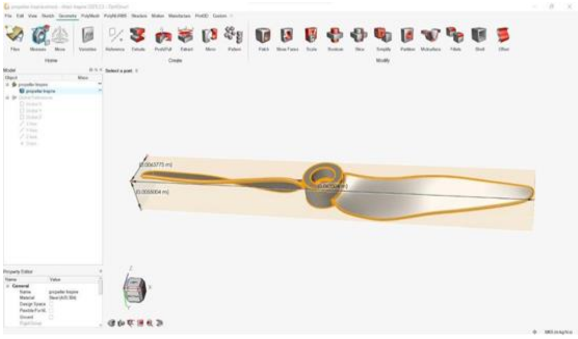


Fig:3.1 front view of propelle

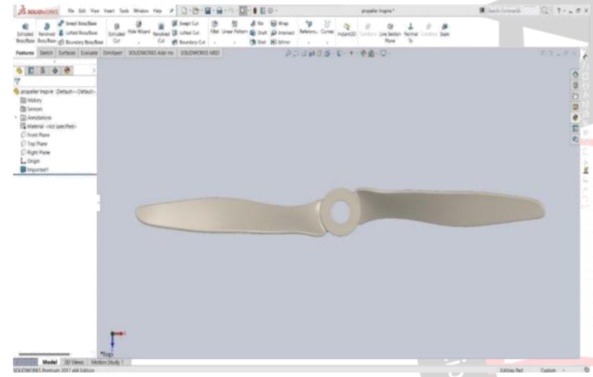


Fig:3.2 top view of propeller

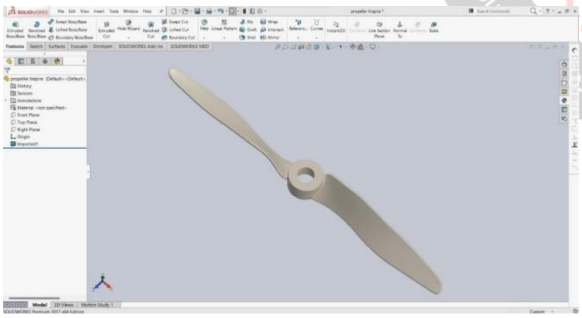


Fig:3.3 isometric view of propeller

Temperature distribution

The gradient of temperature is the root cause of all the mechanical phenomena occurring during a build.

The temperature gradient can sometimes be computed alone, without any mechanical deformation. It is usually quicker than a full simulation and solving the heat accumulation issues might at the same time solve the mechanical deformation problems.

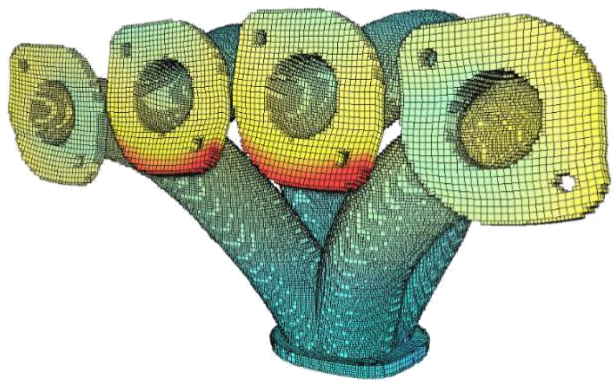


Fig 3.4 simulation of engine manifold

Temperature gradient distribution of a discretised model (SLM/DMLS) in Netfabb. Courtesy Poly-Shape

3.3.2 Deformation

Assuming that the true mechanical properties of the material are known, the deformation of the part during manufacture can be calculated. The direction of the deformation are usually correct no matter what simulation parameters are used, but the amplitude of the deformation is closely dependent on the size of the simulation mesh: using a finer mesh will yield more precise results, but requires more time to run.

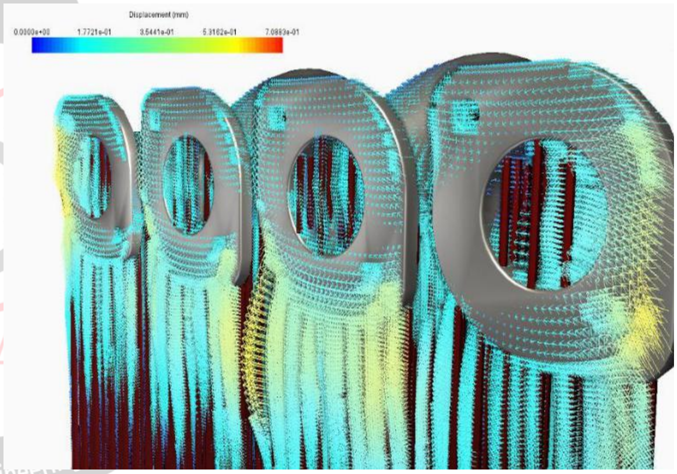


Fig 3.5 deformation

Deformation vectors of a model (SLM/DMLS) in Netfabb. Courtesy Poly-Shape

3.3.3 Recoater interference

In powder bed technologies (such as SLS and SLM/DMLS), if the deformation along the z-axis is larger than the layer thickness, the recoater can come in contact with the part, sweeping it away and causing a failure. In some simulation packages, you can define the height of the recoater tolerance, and the software will warn you in case a deformation along the z-axis exceeds that threshold.

3.3.4 Post processing steps

The primary focus of the 3D printing simulation packages is the computation of thermo-mechanical phenomena occurring during the fabrication of a part. However, other problems can also appear in later steps of the manufacturing process. During the detachment of the part from the build platform or the removal of the support structures, the residual stress from the manufacturing process can cause the part to deform. Heat treatments can help relieve the

 DOI : 10.35291/2454-9150.2022.0261

ISSN : 2454-9150 Vol-08, Special Issue, MAY 2022

internal stress. Some simulation packages allow you to simulate these post-processing steps and help evaluate whether a heat treatment is necessary (or even effective).

3.3.5 Discretization

The first step of a good simulation is the correct discretization of the part volume. Unlike regular mechanical simulation, which uses conformal meshing with tetrahedrons, most 3D printing simulation software use voxelization. the 3D volume of the part is represented by small cubes (or voxels), in a similar way that a 2D image in a PC monitor is represented by square pixels. Using more meshing elements produce more precise results, but also increases significantly the simulation time. Finding the right balance is key. For an initial simulation, it can be interesting to launch a first coarse simulation, with large voxels, in order to obtain "quick and dirty" results. Such a simulation should enable you to obtain in a matter of seconds or minutes the main deformation areas of your print. It will not cost you much and can help you decide if a more precise simulation (with smaller voxels) is necessary.

3.3.6 Material & print parameters

Once the part is discretized, you need to select the material properties. Defining the material properties is probably the most crucial step in the simulation process, as inaccurate data will produce wrong simulations results. Most editors provide their own material library, which can be really helpful to get you started. In both cases, they are probably not perfectly adapted for simulations. Every simulation software allows you to modify or create your own materials to generate the most accurate simulations. This requires expert material science knowledge to be done correctly and it is not recommended for inexperienced users.

3.3.7 Calibration

Some simulation software allows you to calibrate the material properties based on test specimens printed in a specific material and on a specific machine. This way, more precise material properties are identified, resulting in more accurate simulation results.

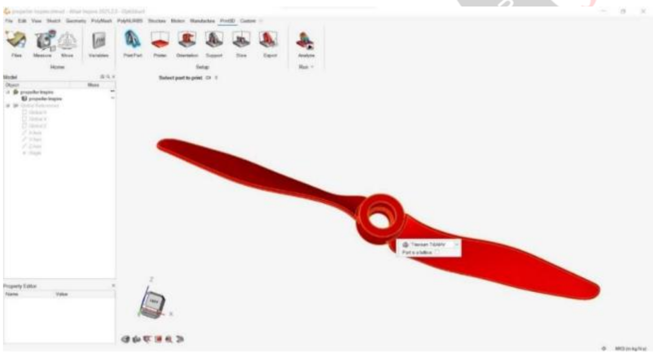


Fig3.6: assigning material to propeller

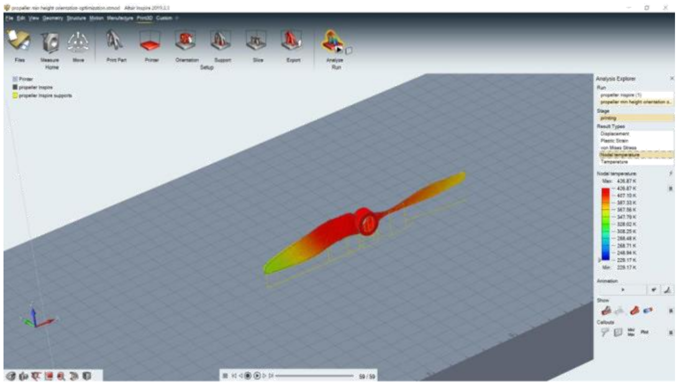
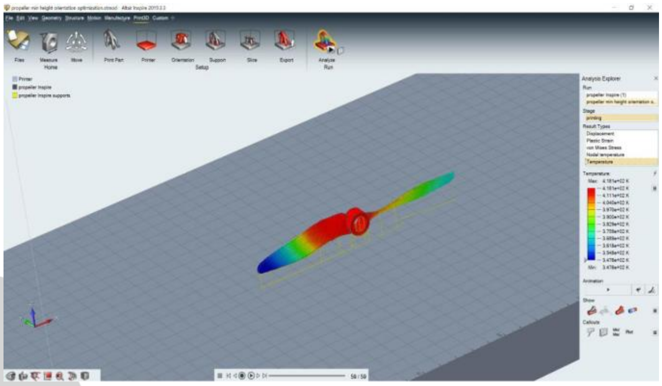


Fig 3.19: nodal temperature for second orientation



II. RESULTS AND DISCUSSIONS

In the first orientation large area of propeller exposed to laser which is result in thermal stress. In the first orientation has very large displacement value when compare to second orientation. Plastic strain is more in the second orientation due to this there will permanent deformation in the component very large after removing the part from the build plate.

The stresses developed in the both orientations are almost very nearer. Stresses are depended on the surface area exposed to laser power. in both orientation area of exposer very close.

In both orientation nodal temperature and temperature distribution also very close

Table 4.1: comparison of maximum values of mechanical properties

Max values	1st orientation	2nd orientation
Displacement	5.260e-04m	1.306e+03m
Max. of plastic strain	0.35	0.52
von mises stresses	3.170e+08pa	3.221e+08pa
nodal temperature	403.88K	426.87K
Temperature	3.877e+02K	4.181e+02K

DOI : 10.35291/2454-9150.2022.0261

III. CONCLUSION

3D printing technology is advanced manufacturing process in the field of production and rapid prototyping. The quality and dimensional accuracy of the 3D printed depends on the so many factors depend on the geometrical conditions of the component. To study that we have simulate the analysis for jet engine propeller. Propeller is in aerodynamic shape and due to less thickness the printing process would become difficult and there is more chance to lift off from the build which can damage the recoater lip. From the simulation results we can conclude that

In the first orientation large area of propeller exposed to laser which is result in thermal stress. In the first orientation has very large displacement value when compare to second orientation. Plastic strain is more in the second orientation due to this there will permanent deformation in the component very large after removing the part from the build plate.

The stresses developed in the both orientations are almost very nearer. Stresses are depended on the surface area exposed to laser power. in both orientation area of exposer very close.

In both orientation nodal temperature and temperature distribution also very close.

From the above results we can conclude that first orientation would give us better dimensional accuracy.

IV. REFERENCES

[1]EXOne. (2013). ExOne-Rapid Growth of Additive Manufacturing (AM) Disrupts Traditional Manufacturing Process. Available: http://additivemanufacturing.com/2013/06/06/exone-rapid-growth-of-additive-manufacturing-am-disrupts-traditional-manufacturing-process/. Last accessed 14th Feb 2014.

[2]Klas Boivie, Additive Manufacturing: A brief overview by SINTEF Raufoss Manufacturing AS, lecture notes distributed in Not Just CAD at KTH Royal Institute of Technology, Stockholm on 19th November 2012.

[3]Robots and Androids. (2013). History of 3D Printing. Available: http://www.robots-and- androids.com/history-of-3d-printing.html. Last accessed 14th Feb 2014.

[4]Laser Prototypes Europe Ltd. (2012). Stereolithography – The Materials. Available: http://www.laserproto.com/services/stereolithography-2/stereolithography-sla-materials- used. Last accessed 3rd Feb 2014.

[5]3D Systems Inc. (2014). Stereolithography (SLA) Material Selection Guide. Available: http://www.3dsystems.com/files/downloads/3D-Systems-SLA-material-selection-guide- 0813-USEN.pdf. Last accessed 3rd Feb 2014.

[6]Materialize NV. (2014). FDM: Materials & datasheets. Available: http://manufacturing.materialise.com/fdm-materials-datasheets-0. Last accessed 3rd Feb 2014.

[7]RedEye Copyright©. (2013). FDM Thermoplastics. Available:

http://www.redeyeondemand.com/PPSF.aspx. Last accessed 3rd Feb 2014.

[8]Thre3D. (2013). HOW BINDER JETTING WORKS. Available: https://thre3d.com/how-it-works/binder-jetting. Last accessed 11th Mar 2014.

[9]Stratasys Ltd. (2014). PolyJet Technology. Available: http://www.stratasys.com/3d-printers/technology/polyjet-technology. Last accessed 11th Mar 2014.

 DOI : 10.35291/2454-9150.2022.0261