A REVIEW ON ADDITIVE MANUFACTURING PROCESS FOR CLOSE IMPELLER

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Abstract

Additive manufacturing (AM) is a cyclic manufacturing process to create three-dimensional objects layer-by-layer directly from a 3D CAD model. It also enables the construction and manufacturing of a high stable light-weight structure as well as the industrial component that cannot be produced using any conventional system. The system starts by applying a thin layer of the powder material to the building platform. A powerful laser beam then fuses the powder at exactly the points defined by the computer-generated component design data. Once again the material is fused to bond with the layer below at the predefined points. Depending on the material used, components can be manufactured using metal 3D printing. In this work, the study of impeller an industrial component used different convectional processes and materials used.FE Analysis is carried out for enhancing the mechanical properties of close impeller for two different materials. And results of optimized parameters along with mechanical properties are used for the actual development of Impeller. The impeller is manufactured using direct metal laser sintering (DMLS) method an additive manufacturing processes

Keywords: *Additive manufacturing, Finite Element Analysis, Mechanical properties, Materials, Metal 3D printer, DMLS, Close impeller.*

1.0 INTRODUCTION

Now a day's three are different advance manufacturing systems available in markets as well as in industries. Additive Manufacturing refers to a process by which digital 3D design data is used to build up a component in layer by layer depositing material. The term know as "3D printing" is increasingly used as a synonym for Additive Manufacturing. It can create more complex part geometric shape whit accurately. However, the latter is more accurate in that it describes a professional production technique that is clearly distinguished from conventional methods of material removal. Instead of milling a workpiece from the solid block while AM builds up components layer by layer using materials that are available in fine powder form. A range of different metals, plastics as well as composite materials may be used. There are different processes available in additive manufacturing like selective laser melting (SLM), selective laser sintering (SLS) Direct metal laser sintering (DMLS) as well as fused deposition modeling (FDM) for thermoplastic materials.

1.1 Principal Of Additive Manufacturing Process

AM technologies fabricate models by fusing, sintering or polymerization of materials in predetermined layers with no needs of tools. AM makes possible the manufacture of complex geometries including internal part detail that is approximately not possible to manufacture using machining and molding processes, because the process does not require predetermined tool paths, draft angles and undercuts. In AM the layers of a model are formed by slicing CAD data with professional software. All AM system works upon the same principle, however, layer thickness depends upon parameters and machine start used and thickness of layer range from 10µm up to 200µm. Layers are visible on the part surface in AM operation, which

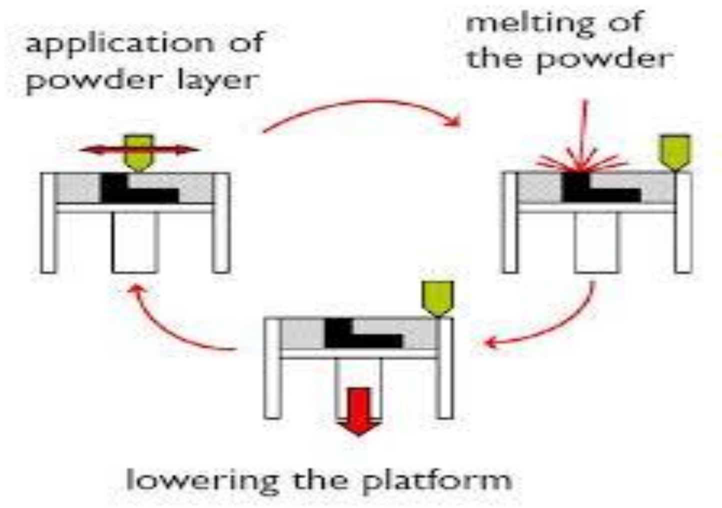

Figure 1.1: Additive Manufacturing Process

controls the quality of the final product. The relation between the thickness of the layer and surface orientation is known as the staircase effect. Although thinner the layer is the longer the processing time and higher the part resolution. Two processes that meet this requirement are Selective Laser Melting (SLM), Direct Metal Laser Sintering (DMLS) for metallic parts and Selective Laser Sintering (SLS) for thermoplastics. Both processes are based on the principle of powder-bed fusion. Figure 1.1 showing the process of the additive manufacturing whit the use of powder application of layers and small fine powder melting as well as bond whit each other through the laser power system.

1.2 Design for Additive Manufacturing

Additive manufacturing (AM) gives us huge freedom to design parts differently, but we do need to be aware of some of the characteristics and limitations of the process, so that we create parts that can be built successfully. Modern design and build preparation software helps enormously to find an optimum design, orientation and support strategy so that we can produce consistent parts economically.

The feature article details dfAM essentials:

- How to print parts efficiently and effectively including feature size, surface finish, overhangs, lateral holes and minimizing supports.
- Residual stress and distortion.
- Multi-scale structure design.
- Multi-material design.

2.0 LITERATURE REVIEW

Timothy C. Allison*, J. Jeffrey Moore*, Aaron M. Rimpel*, Jason C. Wilkes*, Robert Pelton*, Karl Wygant*, [1] "Manufacturing and testing experience with direct metal laser sintering for close centrifugal compressor impeller.", Here this paper survey on DMLS is an attractive option for test rig articles due to its design flexibility and reasonable turnaround times, and maybe attractive for production machinery since the process allows for one-piece parts with reduced stresses and potentially higher operating speeds. They have manufactured closed impeller designs constructed from Inconel 718, 17-4 PH Stainless Steel, and Titanium 6Al-4V and testing also . *Pumpturbo.tamu.edu, September 23-25, 2014 , Houston, TX*

E. Hosseinia*, V.A. Popovich*, [2] "A review of mechanical properties of additively manufactured Inconel 718.", Numerous studies have investigated different aspects of the mechanical behavior of additively manufactured (AM) Inconel 718. It has a wide range of applications in aircraft, gas turbines, turbocharger rotors. This paper has main observations are summarized as follows on Fatigue , Creep and Microstructure of Inconal 718.

S. Tammas-Williams*, I. Todd*, [3] "Design for additive manufacturing with site-specific properties in metals and alloys.", The transition from one set of material properties to another is of crucial importance in determining not only the manufacturability of the component, Also Having a smooth transition from one set of properties to another can avoid the problems associated with a discrete interface. Looking for minimise these variations. Department of Materials Science and Engineering, *University of Sheffield, Sheffield, S1 3JD, UK, Published by Elsevier Ltd.*

J.T. Geating*, M.C. Wiese*, and M.F. Osborn*, [4] "Design, fabrication, and qualification of a 3d printed metal quadruped body: combination hydraulic manifold, structure and mechanical interface." They have performed Fatigue Analysis to estimate the fatigue life of the manifold pipe with defects relative to the nominal wall thickness. After fabrication, they did a rigorous program involving post-processing, inspection, and destructive and non-destructive testing was performed to validate the design and manufacturing methods. Constructed using powder-bed direct laser metal sintering (DLMS). *Naval Research Laboratory, DC 20375, Solid Freeform Fabrication 2017.*

Christoph Klahna*, Bastian Laurencekirk*, Mirko Meboldtb*, [5] "Design Strategies for the Process of Additive Manufacturing." They have used Fused Deposition Modelling (FDM) in which a thermoplastic filament is extruded through a heated nozzle and placed on the previously build portion of the part. The mechanical properties of FDM parts are highly anisotropic and this should be respected in design. They have also mentioned about manufacturing-driven design strategy, it allows a substitution of manufacturing processes at a later stage of the product life cycle, while a function-driven design strategy increases the performance of a product. *Procedia CIRP 36 (2015) 230 – 235, Zurich, Switzerland*.

L. Zhu, N. LI, P.R.N. Childs*, [6] "Light-weighting in aerospace component and system design." Light weighting represents an effective way to achieve energy consumption reduction and performance enhancement. *Elsevier, Imperial College London, SW7 2AZ, United Kingdom. - 6 June 2018.*

A.W. Gebisa*, H.G. Lemu, [7] "Design for manufacturing to design for additive manufacturing: Analysis of implications for design optimality and product sustainability." Concerning the sustainability of products, the analysis shows that the technology is on a promising progress with better achievements than conventional manufacturing techniques. *ELSEVIER B.V., Procedia manufacturing 13 (2017), faculty of science and technology, Stavanger, Norway.*

Melissa Orme 1, *, Ivan Madera 1, Michael Gschweitl 2 and Michael Ferrari. [8] "Topology Optimization for Additive Manufacturing as an Enabler for Light Weight Flight Hardware." topology optimization exercise must be coupled to the Additive Manufacturing build direction, and steps are incorporated to integrate the AM constraints. *MDPI, Ruag Space, 8052 Zürich, Switzerland. 25 November 2018.*

Sebastian Hällgrena, b*, Lars Pejrydb*, Jens Ekengrenb*, [9] "(Re)Design for Additive Manufacturing". It is shown that redesigning for AM can reduce mass but depending on part size and print speed, the part can become more expensive than the original design, creating a need to know the customer value of what the redesigned part provides, in this case, the value of reduced mass. *ELSEVIERa Saab Dynamics, Development, 69180 Karlskrona, Örebro, Sweden.*

Hamed Seifia, AnoosheRezaeeJavana, ShanqingXua, Yang Zhaob, Yi Min Xiea,c*, [10] "Design optimization and additive manufacturing of nodes in grid shell structures" It is represented about the improved structural performance and design efficiency by using the transitional section method and the bi-directional evolutionary structural optimization (BESO) method. Laplacian smoothing algorithm is elective in reducing the stress concentration of structural nodes .*ELSEVIER, Melbourne, Victoria 3001, Australia, Shanghai 200092, China, Hangzhou 310027, China*

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VeronicaLivescu, CameronM.Knapp, GeorgeT. GrayIII, RamonM.Martinez, BenjaminM.Morrow, BinehG.Ndefru*, [11] "Additively Manufactured tantalum microstructures" Deposition speed and laser powder were important parameters to consider for obtaining porosity- freematerial. Stripe Widthhad themostsignificante ectongrain growth. ELSEVIER, material science and technology division, LosAlamos,NM 87545,

2.1 Summary of the Entire Research survey

- To study the close impeller in DMLS process and Additive materials gives the best performance.
- In this study paper to perform the Inconel 718 materials property analyzed on fatigues, creep in additive manufacturing.
- It has to carry out the additive manufacturing materials like Inconel 718, 17-4 PH Stainless Steel, and Titanium 6Al-4V for close impeller with used DMLS process.
- To study about the different factors of Additive manufacturing process such as bottom-up manufacturing factor, computer-aided manufacturing factor, distributed manufacturing factor, and eliminated manufacturing factor.
- Some research paper indicated different types of additive manufacturing process explained in brief like, SLM, SLS, DMLS, FDM, etc

2.2 OBJECTIVES

- To analyze the close impeller using a finite element method.
- To change the design parameters of the impeller to increase the efficiency. also find suitable materials for impeller.
- To manufacture of close impeller using AM Validate the results

3.0 Process and Methods for Impeller Production

Now a day's manufacturing point of view, a pump impeller classify into two categories like close and open. for that, it would be better for manufacturing according to the different shapes or types. There are most easiest pump impeller manufacturing process can be presented as follow.

- Sand casting method
- Machining
- Welding or some other joining

Figure 3.0.1 : Impeller manufacturing via sand casting method

The sand casting method is the most popular and applicable methods among the impeller manufacture. Low cost and convenient in technological terms made this technology pervasive compare to other methods. Besides, it has some limitations which compel a manufacturer to select other methods as well. Afterword this technology will be investigated completely in case of direct and reverse engineering of impeller manufacturing

3.1 Comparison Between Casting And Additive Design of Closed Impeller.

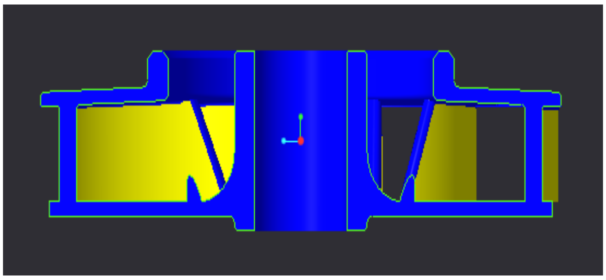


Figure 3.1.1 Design for Casting Process

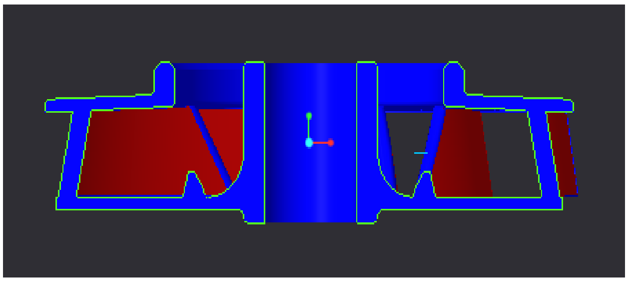


Figure 3.1.2 : Design for AM Process

Generally closed impeller manufactured by different casting processes because of the inherent feature of this method which makes it possible to molding shapes, also as beneficial way with low cost and no need to very professional labor. figure 3.1.1 showing a vane angle of 90" which can easily be manufactured through casting process while it can change angle instated of 90" there some limitation of the casting process. although, figure 3.1.2 shows a vane angle of 80" it can be manufactured by additive manufacturing process because of its more flexible to build also it can make very complex shapes through the AM. Compare to other methods, the cost of changing and improvement of the segment is too low and moreover over it saves more time and accelerates the speed of manufacturing procedure.

4.0 Analysis of Close Impelle

1) CAD model :
First Step to create a model in CAD software(Creo Parametric).

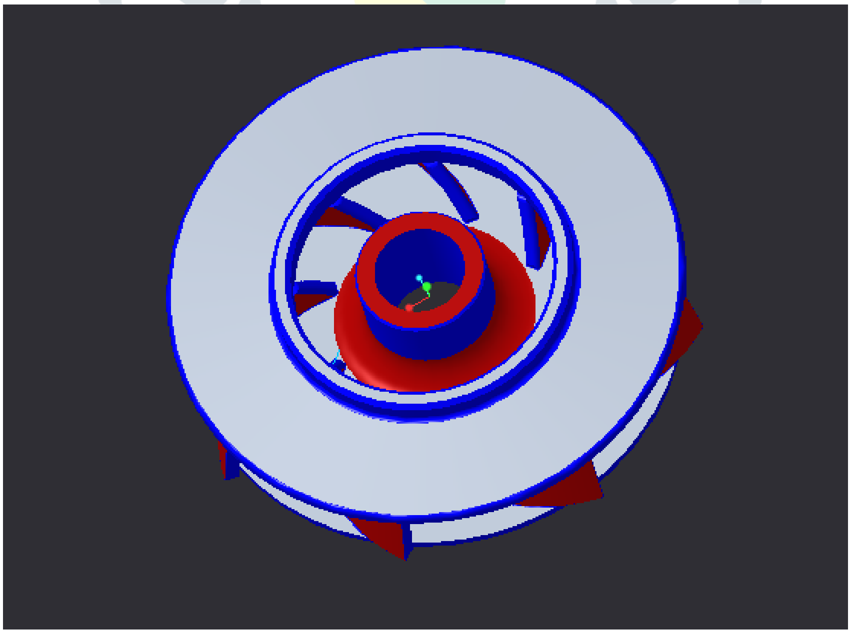


Figure 4.1.1 : 3D CAD model of close impeller

2) Meshing model :
Solid mesh (Method Tetrahedron, Algorithm-Patch Independent) which is programmed generated.
Fine Meshing is applied.
Element Size: 1mm

No. of Nodes: - 458001
No. of Elements: - 267610

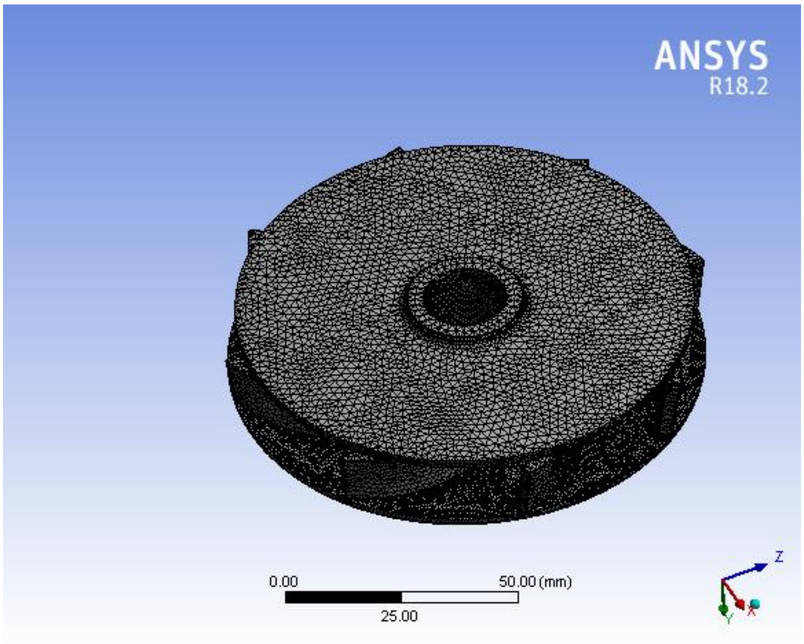


Figure 4.1.2 : Mesh of pump impeller

3) Material Properties Of Stainless Steel 316L

Material used	Young Modulus (Gpa)	Yield Strength (Mpa)	Poisions Ratio	Density (Kg/m3)	Tensil ultimate strength (Mpa)
SS 316 L	200	250	0.30	8000	460

4) Boundary Condition Application On Close Impeller

a) Fixed the Close Impeller on the main shaft of the motor.
b) Pressure is applied at the internal vane side 0.13MPa.
c) The impeller is rotating counter-clockwise at 2900 RPM speed.

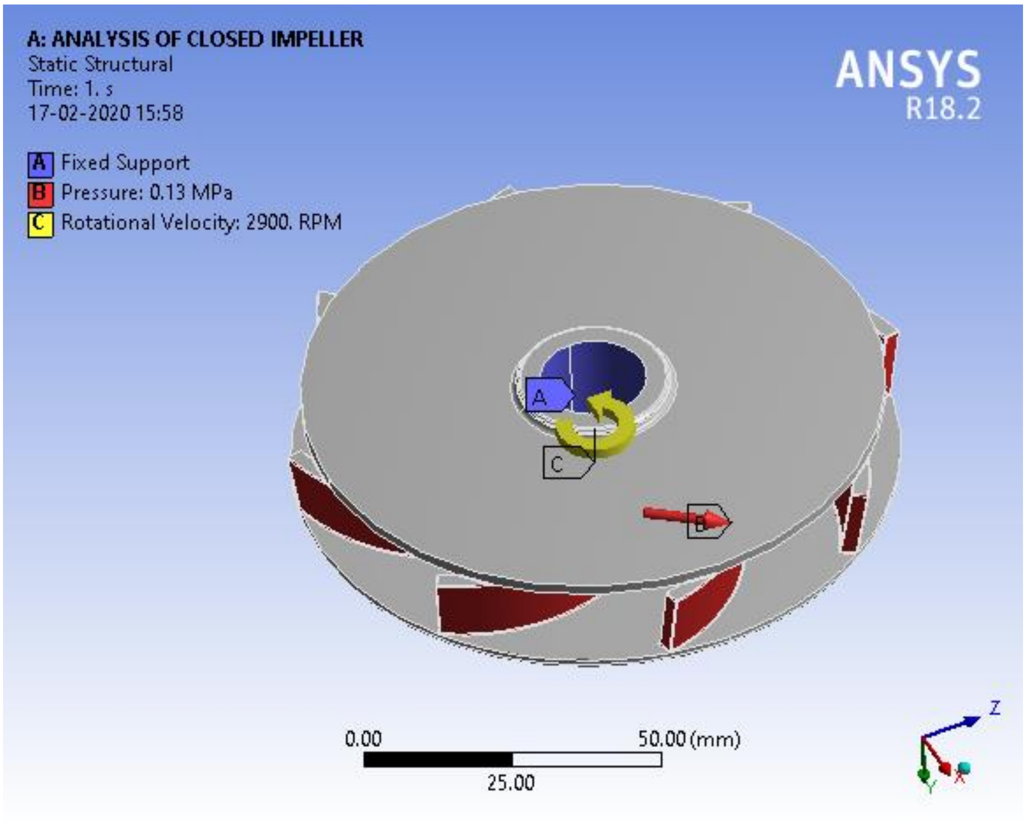


Figure 4.1.3 : Boundry Condition

Results of Analysis

Equivalent Stress for static analysis

Name	Type	Min	Max
Stress1	VON: von Mises Stress (Equivalent Stress)	0.0027337Mpa Nodes: - 458001	22.359Mpa Nodes: - 458001

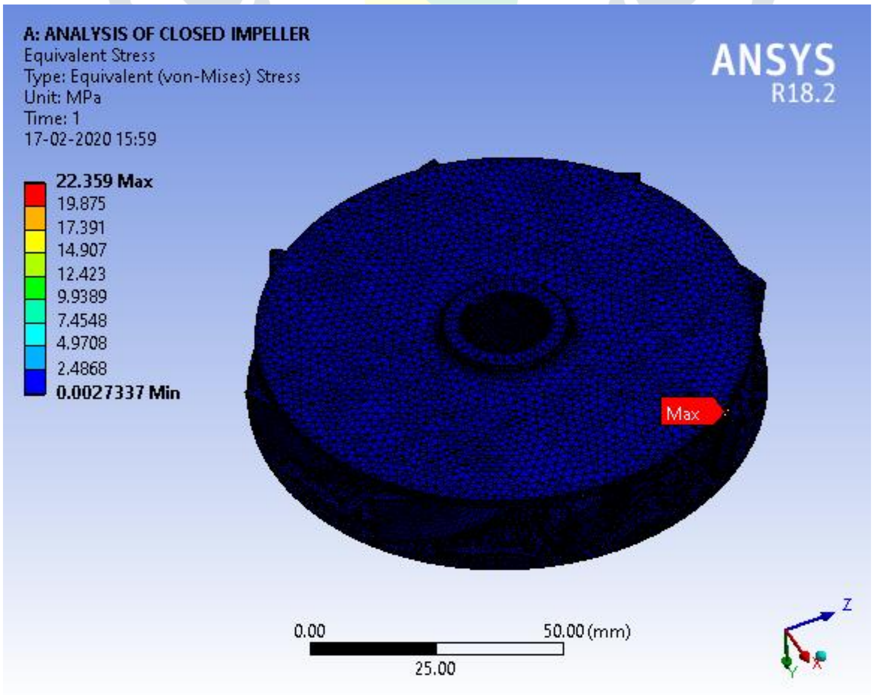


Figure 4.1.3 Equivalent Von-Misses Stress

Deformation

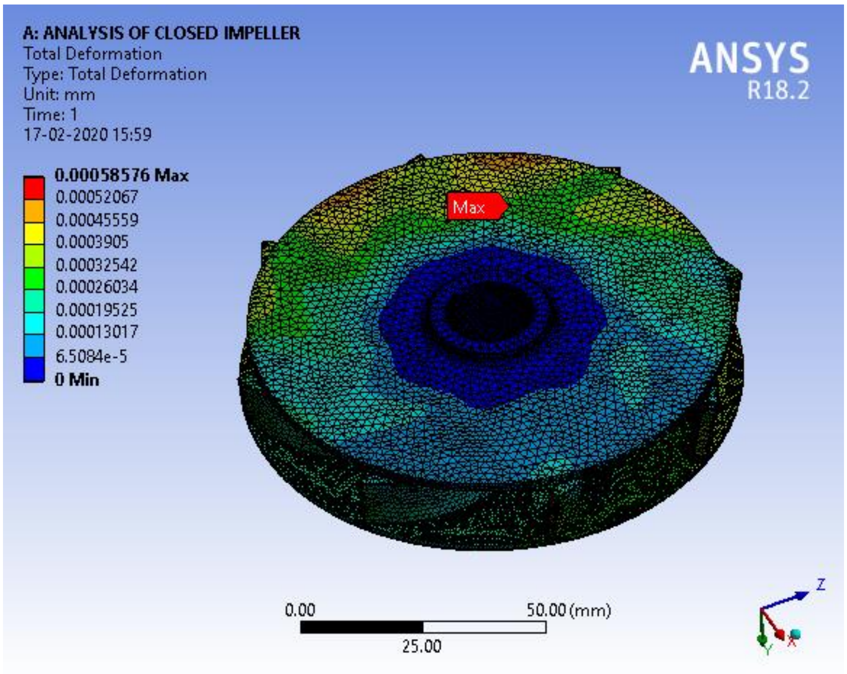
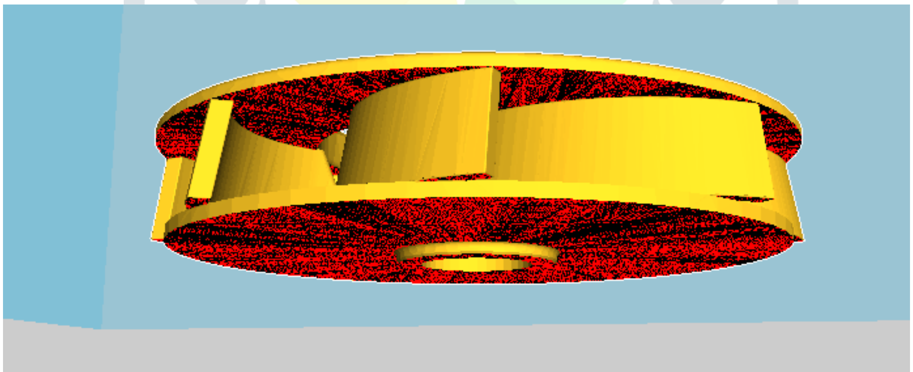


Figure 4.1.4 Total Deformation

Name	Type	Min	Max
Deformation	Total Deformation	0 mm Nodes: - 458001	0.00058576mm Nodes: - 458001

5.0 Post Processing After The AM process



- Removed all supports after the AM process because of better surface finishing and quality of close impeller.
- supports only have to apply on the red color portion which is overhanging part shown in the figure.
- Machining on the outer body of close impeller.

Benefits of Additive Manufactured Close Impeller :

- Utilizing AM technology caused to enormous time reduction in initial pattern manufacturing procedure compare to both traditional and machining way.
- Surface quality and dimensional accuracy in both machining and AM method is much better than conventional manufacturing methods.
- presents the AM method utilizing is dependable and applicable method in reverse engineering case of complicated blade shapes

6.0 SCOPE FOR FUTURE

The following are recommended for future work elaborations of this research.

- Measure the efficiency of the impeller by using CFD / CFX tool.
- Impeller analysis in this study consist of a hydraulic test.

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REFERENCES

[1] Scot Laney*,Akiyoshi Ando*, Derrick Bauer**,**Turbo machinery Laboratory, Texas A&M Engineering Experiment Station, Higgs, F, 2015, Mechanics of Additive Manufacturing Powder Spreading, Additive Manufacturing for Small Manufacturers, Canonsburg, Pa, Lecture

[2] Tan, X., Kok, Y., Tor, S. B., & Chua, C. K. (2014).Application of Electron Beam Melting (EBM) in Additive Manufacturing of an Impeller. Proceedings of the 1stnternational Conference on Progress in Additive Manufacturing (Pro-AM 2014), 327-332, http://hdl.handle.net/10220/41691

[3] *B. Dutta**, *Francis H. (Sam) Froes*** *DM3D Technology, Auburn Hills, MI, USA **Consultant to the Titanium Industry, Tacoma, WA, USA The additive manufacturing (AM) of titanium alloys.

[4] J. *Campbell*, *Complete casting handbook: metal casting processes, techniques and design: Butterworth-Heinemann, 2011.*

[5] J. G. Bralla, *Handbook of manufacturing processes*: Industrial Press, 2006.

[6] Fudos, "CAD/CAM Methods for Reverse Engineering: A Case Study of ReengineeringJewelry," Computer-Aided Design and Applications, vol. 3, pp. 683-700, 2006.

[7] H.-T. Young, L.-C. Chuang, K. Gerschwiler, and S. Kamps, "A five-axis roughmachining approach for a centrifugal impeller," The International Journal of Advanced Manufacturing Technology, vol. 23, pp. 233-239, 2004

[8] Shitong Peng,1 Tao Li,1 Xinlin Wang,1 Mengmeng Dong,1 Zhichao Liu,2 Junli Shi,1and Hongchao Zhang1,21School of Mechanical Engineering, Dalian University of Technology, Dalian, China 2.Department of Industrial Engineering, Texas Tech University, Lubbock, TX, USA

[9] Ju-Jie Yana,b, Man-Tai Chenc,e,, Wai-Meng Quacha, Ming Yanb, Ben Youngd,f a Department of Civil and Environmental Engineering, The University of Macau, Macau, China b Department of Materials Science and Engineering, and Shenzhen Key Laboratory for Additive Manufacturing of High-performance Materials, Southern University of Science and Technology, Shenzhen, 518055, China

[10] Timothy C. Allison*, J. Jeffrey Moore*, Aaron M. Rimpel*, Jason C. Wilkes*,Robert Pelton*, Karl Wygant*, 43rd Turbo machinery & 30th Pump Users Symposia (Pump & Turbo 2014)September 23-25, 2014 | Houston, TX | pumpturbo.tamu.edu

[11] S. Tammas-Williams*, I. Todd*, Design for additive manufacturing with site-specific properties in metals and alloys. Department of Materials Science and Engineering, University of Sheffield, Sheffield, S1 3JD, UK,Published by Elsevier Ltd.