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Study and Analysis of 3D Printed FDM Components by Non-Destructive Testing Techniques

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ABSTRACT

In this present work a modest attempt has been made to analyze the quality of the 3D printed components made by fused deposition modeling process. A universal coupling and the impeller is taken for this study. The three different types of non-destructive testing techniques were used in this study. The techniques used in this study are eddy current test, dye penetrating test and ultrasonic test. The main objective of this study is to find the effect of layer by layer printing procedure over the quality of the printed part in 3D printing process. The results of this study shows that no significant defects were found over the quality of the 3D printed parts and the surface is observed good in all the directions without any significant variation. The density of the minute porosity percentage variation is observed significantly in the lateral direction opposite to the printing orientation.

Keywords: Fused Deposition Modeling; Universal Coupling; Impeller; Non – Destructive Testing; Eddy current test; Dye Penetrating test; Ultrasonic Test;

INTRODUCTION

Additive Manufacturing is a layer by layer manufacturing technique which uses the digital CAD file as input for the creation of the required model. [1-3] The complex shaped components can be easily manufactured without the need for any change in setup time. [4-6] The lead time of the product is significantly reduced by using the 3D printing setup. The cycle time of the product which involves the material handling time, part handling time, tool handling time could be reduced significantly. [7-8] The support structures used by the 3D printing process at the time of creating the components could be removed by dissolving the components with the help of salt bath solution. The present work addressed the challenges with the view of transferring additive manufacturing to the industry and qualifying the manufacturing process for applications such as structural components, the quality of the produced parts needs to be assured. [9-11] Thus, the main objective of this project is to analyze additive manufactured FDM components by using the NDT techniques and assess the capability of detecting defects, for inspection either in a monitoring, in-process or post-process scenario. Eddy current testing, dye penetrating inspection and ultrasonic testing were experimentally tested on reference specimens in order to compare the technique capabilities. Experimental outcomes prove that the additive manufactured FDM components can be used as an alternative for small and complex components manufactured by conventional method and can perform well and fulfil its purpose in the industries. Industrial adoption of 3D Printing has been increasing gradually from prototyping to manufacturing of low volume customized parts. [12-14] The need for customized implants like tooth crowns, hearing aids, and orthopedic replacement parts has made the life sciences industry an early adopter of 3D Printing. Demand for low volume spare parts of vintage cars and older models makes 3D printing very useful in the automotive industry. It is possible to 3D print in a wide range of materials that include thermoplastics, thermoplastic composites, pure metals, metal alloys and ceramics.

EXPERIMENTATION

For the purpose of manufacturing and testing the FDM components two specimens were fabricated. The specimens were fabricated by the 3d printing process. The 3d printing processes involved in manufacturing these specimens were fused and microwave sintering process. The specimens had to first go through fused deposition modelling and after a base was created the complex structure microwave sintering was carried out. The specimens fabricated by the 3d printer are universal coupling and an impeller. The specimens were specifically manufactured as they are mostly made from stainless steel and are used by the industries in automotive, turbines, feed water tubes, chemical industries etc. The designs of the specimens are given below in figures 1 to 5.

Fig 1. Lateral view of Specimen 1

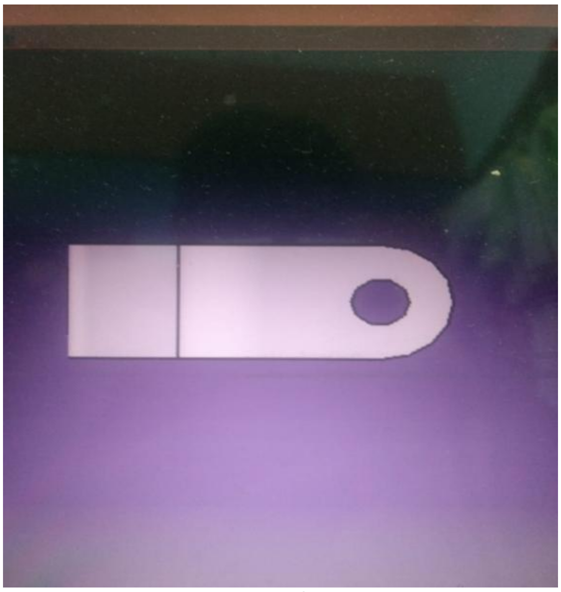

Fig 2.Top view of Specimen 1

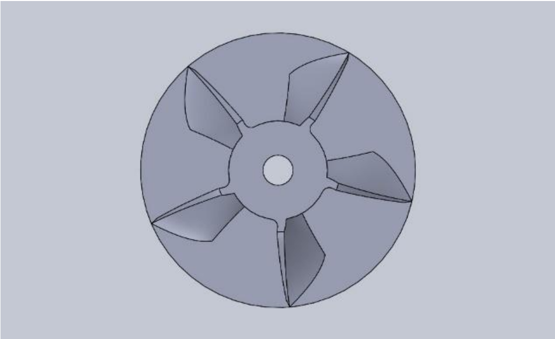

Fig 3. Top view of Specimen 2

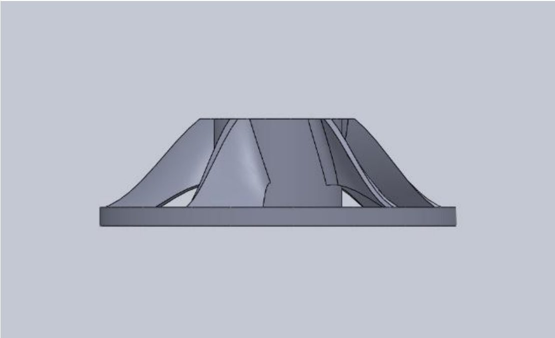

Fig 4. Front view Specimen 2

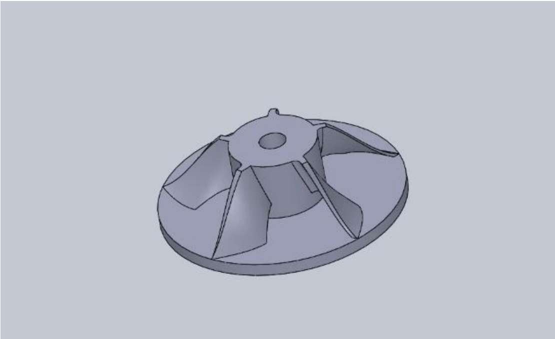

Fig 5. Lateral Specimen 2

NON DESTRUCTIVE TESTING

Non-destructive testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms non-destructive examination (NDE), non-destructive inspection (NDI), and non-destructive evaluation (NDE) are also commonly used to describe this technology. Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. The six most frequently used NDT methods are eddy-current, magnetic-particle, liquid penetrant, radiographic, ultrasonic, and visual testing. NDT is commonly used in forensic engineering, mechanical engineering, petroleum engineering, electrical engineering, civil engineering, systems engineering, aeronautical engineering, medicine, and art. Innovations in the field of non-destructive testing have had a profound impact on medical imaging, including on echocardiography, medical ultrasonography, and digital radiography.

The material used for manufacturing the component is ABS and the component produced is feed water tube. In order to detect the defects present in the blocks, Eddy current testing, Liquid Penetrant Inspection (LPI) and Ultrasonic Testing were applied. For penetrant liquids, the fluorescent or color contrast (dye) penetrant was applied followed by a developer, applying the recommended exposure times for each material, and then the respective appropriate method of cleaning. In case of ultrasonic testing, the equipment used consisted of different transmitting probes, coupling gel and a conventional UT equipment OLYMPUS, OMNISCAN MX.Dye penetrant inspection (DP), also called liquid penetrate inspection (LPI) or penetrant testing (PT), is a widely applied and low-cost inspection method used to check surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). The penetrant may be applied to all non-ferrous materials and ferrous materials, although for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components. The steps involved in dye penetrant testing is shown in figure 6.

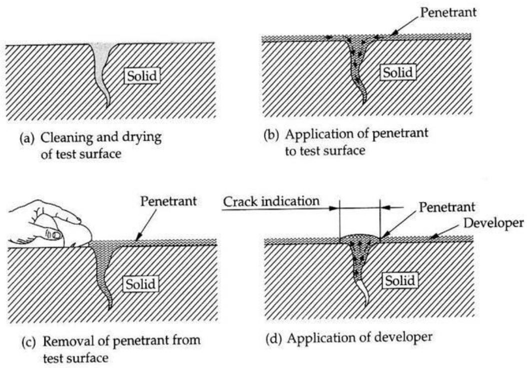

Fig 6. Dye Penetrant Testing

Eddy-current testing (also commonly seen as eddy current testing and ECT) is one of many electromagnetic testing methods used in non-destructive testing (NDT) making use of electromagnetic induction to detect and characterize surface and sub-surface flaws in conductive materials. In its most basic form the single-element ECT probe a coil of conductive wire is excited with an alternating electrical current. This wire coil produces an alternating magnetic field around itself. The magnetic field oscillates at the same frequency as the current running through the coil. When the coil approaches a conductive material, currents opposed to the ones in the coil are induced in the material eddy currents. Eddy current testing has gained worldwide acceptance over the past 50 years in the automotive, petrochemical, aviation, nuclear, and aerospace industries, including a diverse array of manufacturing, quality, and integrity assurance applications. The eddy current testing setup is shown in figure 7 and 8 as follows.

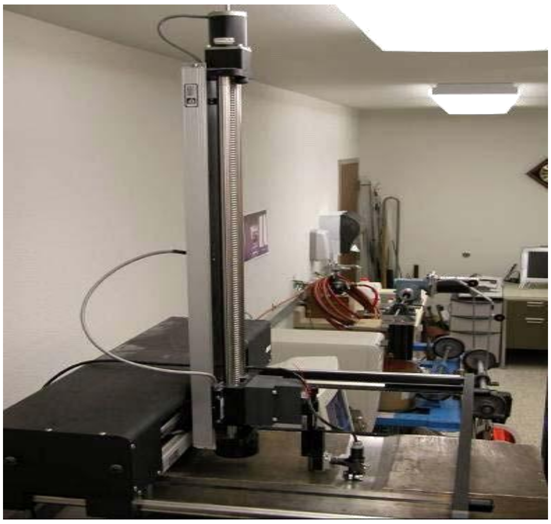

Fig 7. Eddy current testing setup

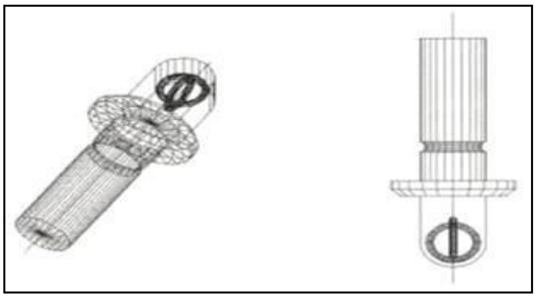

Fig 8. Probe design used in this study.

Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more. To illustrate the general inspection principle, a typical pulse/echo inspection configuration as illustrated below will be used. A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. In the applet below, the reflected signal strength is displayed versus the time from signal generation to when a echo was received. Signal travel time can be directly related to the distance that the signal travelled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

RESULTS AND DISCUSSION

The ultrasonic tests were conducted on specimen 1.specimen was specifically chosen because of its flat and thick surface compared to that of specimen 2. The following ultrasonic tests were conducted Grain structure analysis and Velocity and attenuation test. Grain structure analysis gives a microscopic view of the grain structure of the specimen by passing ultrasonic waves through the specimen. Velocity and attenuation test gives the velocity of the ultrasonic waves that propagates through the specimen giving us a clear view of the packing of grains of the specimen. For eddy current testing specimen 2 was chosen because of its rough and complex structure as it is very difficult to detect cracks by other conventional methods. Eddy current testing is done to show the cracks inside the specimen at different depths of the specimen. The Figure 9 shows the responses observed from this study.

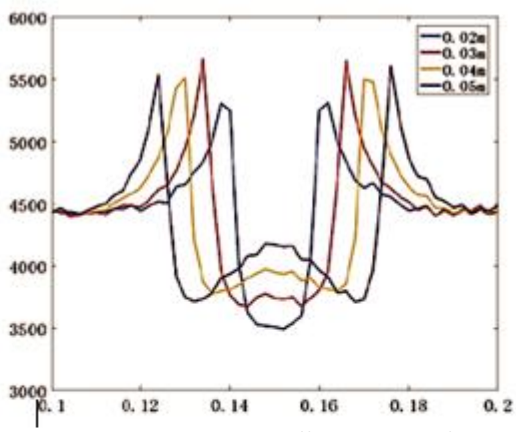

Fig 9 Magnetic responses to different lengths of cracks

The dye penetrating tests were conducted on both the specimens as both the specimens have flat surfaces. The die was applied on the top surface of the specimen 1 and the bottom surface of the specimen 2. The dye penetration tests indicate the presence of cracks through the depths of the specimen and also show the porosity as it penetrates through the specimens. Based on table 1, according to the standard ASME Section VIII Division 4 mandatory appendix 8 on the liquid penetrant testing method states that the standard criteria for discontinuity contained in the welding results shall be independent of linear indication, rounded indication greater than 5 mm and there are 4 or more Rounded indication with a distance of 1.5 mm. Based on table 2, according to the standard ASME Section VIII Division 4 mandatory appendix 8, then based on the available data then in specimen 3 this indication is still within the permitted tolerance limits so that the specimen 3 is declared accepted.

Table 1. Indication discontinuity of specimen 1

S.NO	SIZE OF DISCONTINUITY(mm)	DISTANCE (mm)	INDICATION	REMARK
1	8	57	porosity	Rejected
2	6	73	porosity	Rejected
3	4	77	porosity	Accepted
4	6	171	porosity	Rejected
5	3	182	porosity	Accepted
6	2	185	porosity	Accepted
7	3	188	porosity	Accepted

Table 2. Indication discontinuity of specimen 2

No	Size of discontinuity (mm)	Distance (mm)	Indication	Remark
1	2	23	porosity	Accepted
2	7	102	porosity	Rejected
3	2	111	porosity	Accepted
4	3	195	porosity	Accepted
5	1	201	porosity	Accepted
6	3	234	porosity	Accepted

CONCLUSION

Based on the results and discussion the following points are concluded as

- After analyzing the test results and comparing it with the standard results of original material we can agree that the specimens can be approved for usage even though they have some minor defects which does not affect the properties of the components.
- The additively manufactured component can be a replacement for conventionally manufactured components but only up to a certain limit as it cannot be used for manufacturing components of larger size as it is a very costly process.
- The 3d printing can also be used as an alternative to produce small complex structures and some medium sized components up to a certain extent and also the component can perform well enough to compete with conventionally manufactured component.

REFERENCES

1. Sathishkumar, N., M. Sugavaneswaran, and G. Arumaikkannu. "Investigation of sparse mode build style on material consumption, build time and compressive behaviour of additive manufactured cellular structures." 6th International & 27th All India Manufacturing Technology, Design and Research Conference (AIMTDR-2016). 2016.
2. Balamurugan, L., et al. "Investigation of mechanical behaviour and surface roughness properties on electroplated FDM ABS parts." Int. J. Eng. Res. Mech. Civ. Eng 2 (2017): 60-67.
3. Prithvirajan, R., et al. "Metal bellow hydroforming using additive manufactured die: a case study." Rapid Prototyping Journal (2019). https://doi.org/10.1108/RPJ-07-2018-0182
4. Sugavaneswaran, M., N. Rajesh, and N. Sathishkumar. "Design of Robot Gripper with Topology Optimization and Its Fabrication Using Additive Manufacturing." Advances in Additive Manufacturing and Joining. Springer, Singapore, 2020. 75-85. https://doi.org/10.1007/978-981-32-9433-2_6
5. Sathishkumar, N., et al. "Investigation of Mechanical Behaviour and Surface Roughness Properties on Copper Electroplated FDM High Impact Polystyrene Parts." Advances in Additive Manufacturing and Joining. Springer, Singapore, 2020. 287-300. https://doi.org/10.1007/978-981-32-9433-2_25

6. N Sathishkumar, Naren Vivekanandan, L Balamurugan, N Arunkumar, Ijaz Ahamed. "Mechanical Properties of Triply Periodic Minimal Surface based lattices made by Polyjet Printing." Materials Today: Proceedings, 2020. 2934-2940. DOI:doi.org/10.1016/j.matpr.2020.03.427
7. Sathishkumar N, Kumar VA, Gokulnath M et.al. Performance analysis of palmitic acid coated PCM storage container. International Journal of Research and Review. 2020; 7(3): 495-500. DOI: inrein.com/10.4444/ijrr.1002/1857
8. Sathishkumar N, Premkumar P, Bruce AR et.al. Design and analysis of an impeller of a turbocharger. International Journal of Research and Review. 2020; 7(4): 45-51. DOI: inrein.com/10.4444/ijrr.1002/1871
9. Vincent B, Sathishkumar N, Anand G. Synthesis and investigation of peek based hybrid composite reinforced with zinc oxide and aluminium oxide nanoparticles. International Journal of Research and Review. 2020; 7(4): 189-193. DOI: inrein.com/10.4444/ijrr.1002/1889
10. B Vincent, N Sathishkumar, G Anand. Investigation on Thermo-Mechanical Behaviour of E Glass Fibre and Iron Oxide Filler Particles Reinforced Epoxy Composite. International Journal for Research in Applied Science and Engineering Technology.2020; 8(4): 1522-1526. http://doi.org/10.22214/ijraset.2020.4245
11. N Sathishkumar, K Pravinkumar, G Ashwin Prabhu, M Siva, PL Sudharsan. Investigation of mechanical properties in Al359 hybrid metal matrix composite reinforced with SiC and fly ash. Materials Today: Proceedings.2020. https://doi.org/10.1016/j.matpr.2020.04.024
12. M Arun, N Sathishkumar, K Nithesh Kumar, SS Ajai, S Aswin. Development of patient specific bio-polymer incisor teeth by 3D printing process: A case study. Materials Today: Proceedings. 2020. https://doi.org/10.1016/j.matpr.2020.04.367
13. R. Prithvirajan, M. Sugavaneswaran, N. Sathishkumar, G. Arumaikkannu. Study on feasibility of FDM made ABS die for metal bellow hydroforming. International Conference on Manufacturing Technology and Simulation. 2017; 105-108. ISBN 978-93-80689-26-5
14. V Ashok Kumar, N Sathishkumar. Effect of fin geometry for various tubes shape using CFD simulation on multi-channel heat exchanger in mobile air conditioning (MAC). International Journal of Mechanical and Production Engineering Research and Development (IJMPERD). 2018; Vol.8 (special issue 8);26-32. ISSN (P): 2249-6890; ISSN(E): 2249-8001.

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