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Fabrication and Analysis of PLA based Nuts, Bolts and Study

D.B. Naga Muruga[1], R. Samuel Sundar[2], K.R. Mathivani[3]

[1]UG Student, Dept of Mech Engg, Sriram Engineering College, Tiruvallur, Tamil Nadu, India
[2]UG Student, Dept of Mech Engg, Sriram Engineering College, Tiruvallur, Tamil Nadu, India
[3]UG Student, Dept of Computer Science and Engg, Sriram Engineering College, Tiruvallur, Tamil Nadu, India

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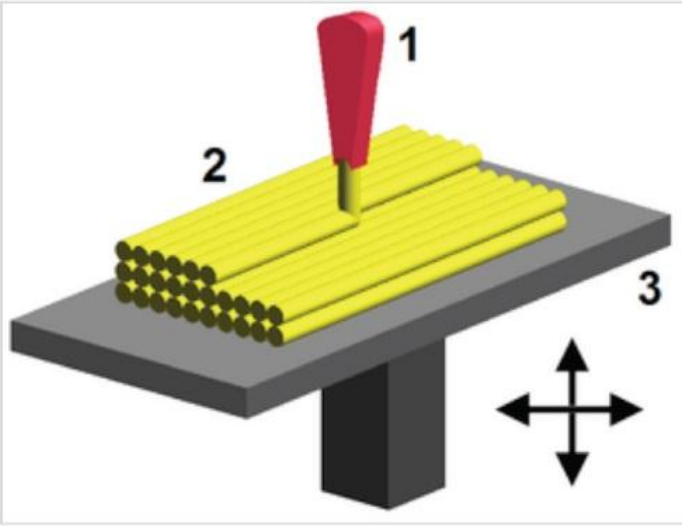
Abstract - *Today manufacturing has become one of the essential necessities for survival of humans. As technologies rise, complex machines and problems in manufacturing also rise. To overcome new methods in manufacturing is used. One such technology is Additive Manufacturing (or) 3D Printing. In this journal, we are going to view about origin and comparison study of Poly Lactic Acid (PLA) in Additive Manufacturing. In further, a product of PLA is Additive Manufactured and implied for tests. The results are cross-checked with standard data of PLA and comparison study of top preferred materials in 3D Printing is also discussed. In further, the advantages, limitations of Additive Manufacturing is also discussed. The upcoming tests to completely verify the PLA material is mentioned clearly. This journal also discusses the current advances of Additive Manufacturing in today's world.*

Key Words: **Additive Manufacturing, 3D Printing, PLA, ABS, PLA vs ABS, Fabrication and Analysis of PLA based materials.**

1. INTRODUCTION

Manufacturing is divided into several categories based on necessities. One such category is Additional Manufacturing (or) 3D Printing and Subtractive Manufacturing. Subtractive Manufacturing is traditional manufacturing which is nothing but the removal of materials and its actions. This includes various operations like Drilling, Boring, Chamfering, Knurling, etc and to be collectively called Machining. But in Additive Manufacturing material an object is initially designed in Three Dimensions using modeling software like Creo, Auto CAD, etc. The obtained CAD file is converted into an STL file. This STL file is nothing but a file of CAD is split into thousands of layers with G-Codes. This language is suitable for reading 3D Printers. The G-Codes explains the movement of an extruder for every layer by layer. The extruder on the top end is connected with the Substrate material. In further it is connected with 3 Stepper Motors that reads the G-Codes and moves the extruder with X, Y, Z axes. The substrate material is melted in an extruder and that filament is applied layer by layer upon the bed, by which our material gets Additively Manufactured.



From this method, any complex or dissimilar or small-sized irregular geometrical object can be manufactured. It is mainly used in prototype Manufacturing were to create the actual material without any Subtractive Manufacturing methods. Because the cost of manufacturing only one or two materials in Subtractive Manufacturing will cost higher than Additive Manufacturing. So this method is preferred for Proto Type manufacturing. The Substrate material for Additive Manufacturing includes (PLA, ABS, Nylon, HIPS, PETG, ASA), etc. But top preferred materials are only chosen to study and one material is Additive Manufactured in form of Nuts and Bolts for further Testings and research purposes.

2. ORIGIN OF 3D PRINTING

Initially, this 3D Printing has different names. Stereolithography was the name coined by Charles Hull in 1984. Later in 1989 S. Scott Crump patented and coined the term Fused Deposition Modelling. Later in 1993 Massachusetts Institute of Technology further commercialized Additive Manufacturing. After several kinds of research taken place in Additive Manufacturing. As a result in 2004, Adrian Bowyer introduced a new type of 3D Printer called RepRap Project. It is nothing but 3D Printers print their own parts and it has made to open source available for all people to use. It is also accepted in terms of the General Public License. The main motto of RepRap is to make the printer mobile for people. Especially for people who live in less-civilized areas, to create a new survival opportunity for them.

As by its motto, it was very easy to use the printer for all. Even compared to past printers in that period, this Self Reciprocating Printers was very easier for people to operate and Additively Manufacture the materials. So it entirely revolutionized the Additive Manufacturing. Later new sub variance in Additive Manufacturing came to rise with new methodologies based on the requirements. Further, the Additive Manufacturing start to use Substrate materials as Steel and Composite. Even today several types of research undergoes in these topics to create effective 3D Printed objects.

3. CURRENT ADVANCES IN 3D PRINTING

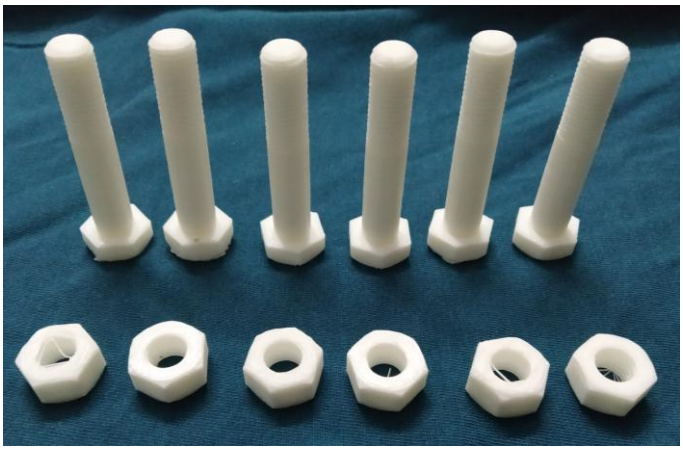
Additive Manufacturing today has revolutionized the traditional manufacturing methods. When designing a new or complex component, Initially the component is designed in 3D Modelling software as a CAD file. Now the CAD file is sliced as STL file and implied for the Additive Manufacturing process. For identifying and analyzing Geometrical Tolerances, actual shape, view, and some more minute perfections, this Additive Manufacturing methodology is utilized. In other words, it has become a great boon for Manufacturing. Because the cost of manufacturing a Prototype is very high when compared to additive manufacturing. The cost of a prototype includes all metal removing processes like drilling, machining, surface finishing, etc. As the costs of taking all these actions for a single material is higher and they cost each process individual changes in machines. This also proves that it is a time taking and costlier process of manufacturing a prototype in the normal manufacturing process. In Additive Manufacturing, no machines are needed for any actions, once the STL file is given the 3d Printer will take the care.

Additive Manufacturing has also revolutionized the Medical Industry and Medical Education. PLA Composite based screws are being replaced for Titanium screws which have been used long term ago since now. During Surgical Operations, this achievement was made successfully in foreign countries. It is also observed that for Knee Surgical Implant, Screws from the material of Poly Lactic Acid given greater efficiency and strength when compared to Titanium Bolts. Not only that Additive Manufactured organs are used to train Medical students for surgical operations. As the organs are similar to human body parts and they match the properties of shapes, sizes, appearance, feelings, etc. Additive Manufactured tissues are planning to arise and it is going to keep the astronauts healthy during space missions. Several leading Space organizations started their work experiments in this.

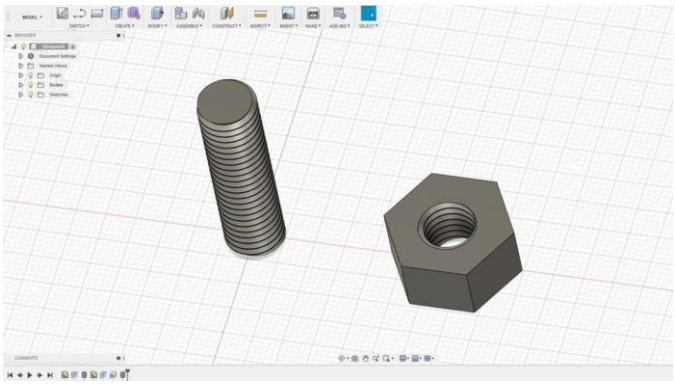
In the Food Industry, it made its giant leap. If a kid wishes to celebrate its Birthday Party, the face of the child same can be 3D Printed. And the most important thing is the kid and the most important thing to be noticed here is the kid can eat that cake and nothing will happen to it. This shows the evolution of Additive Manufacturing in the Food Processing Industry.

4. OUR PROJECT

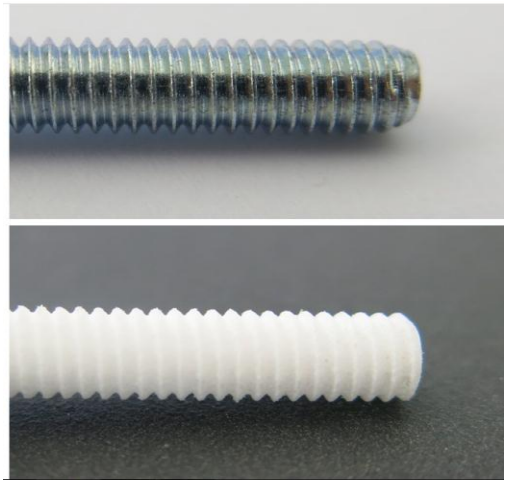
We wish to study and compare the hardness of PLA and Steel manufactured. So, we designed to Additive Manufacture some pairs of nuts and bolts.



The above image is Additively Manufactured PLA based nuts and bolts. The make charges are Rupees One Thousand Five Hundred. It took nearly 6 days to complete manufacturing from scrap and the printer we used to print is a MAKERBOT type printer. We observed that the nut and bolt physically have good strength and a good hardness surface on nut and bolt. This shows that it will have a good resistance in Tear and Wear. The weight of our nut and bolt is 6gms. We instead of 3D Designing the object downloaded an STL file on the Thingiverse website. (i.e) an open-source website that has thousands of STL files for DIY printers and projects.



This is the 3D STL file that we chose for Additive Manufacturing. The color of PLA material we chose is White so that we can easily detect any grease or oil leakages. We also tested its melting temperature to be 205^0 C approximately. We planned to take some comparisons from PLA to Stainless Steel material.



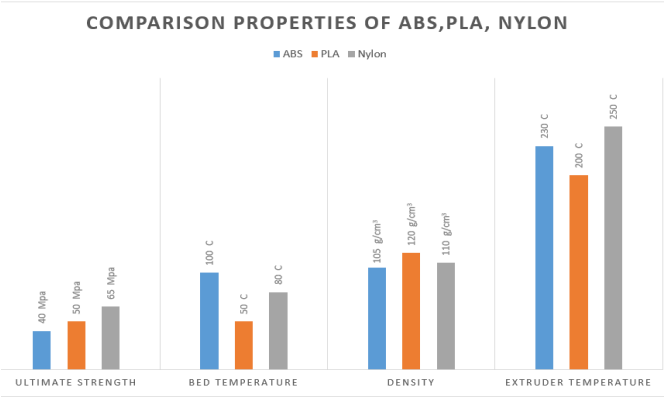
Although PLA could not be used instead of even Mild Steel in industries, as it is degradable. We tried to compare the Hardness values of both PLA and Stainless Steel material.

5. TEST REPORT AND COMPARISON

We plan to make the Shore Hardness test to our sample and identifies the hardness value of both nuts and bolts. As they gave a good strength output, even still they are biodegradable. So they cannot be replaced instead of Stainless Steel or Mild Steel. We found that our PLA based nut and bolt's properties matched with the standard PLA based Hardness value during Hardness experiments we performed.

Sample obtained to test	Observed Values
PLA Nut	76 – 78
PLA Bolt	76 - 78

From the Shore Hardness test, we can identify that in terms of Durometer our PLA comes under the category of SOFT typed. It has given an impact load of 0.822 kg with a resulting force of 8.064 N. Commonly the foot for indentation used will be made from Hardened Steel Rod with a diameter of 1.1 mm to 1.4 mm. Similarly, it also has a truncated cone of 35^0. The diameter of this ball ranges from 0.79 mm.

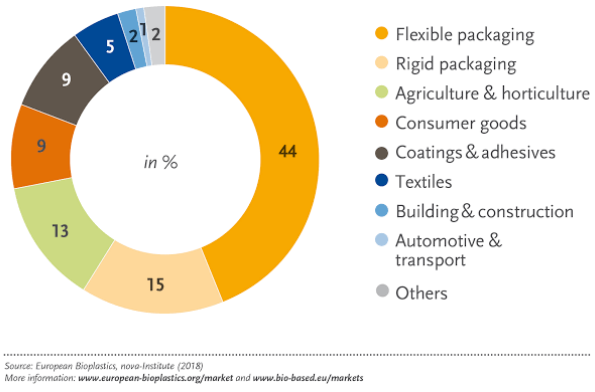


When we observe its degradable properties, we can identify that PLA can be easily decomposed with a time period of 50 days in Industrial Composters and 48 months in water. Where ABS is non-biodegradable, were it can only be recycled. So PLA is preferred in 3D Printing applications that include food, medical industries, etc.

Parametres	PLA	ABS	Nylon
Ultimate Strength	65 Mpa	40 Mpa	40 – 85 Mpa
Stiffness	7.5 / 10	5 / 10	5 / 10
Density	1.24 g/cm³	1.04 g/cm³	1.10 g/cm³
Extruder Temperature	190 – 220^0 C	220 – 250^0 C	220 – 270^0C
Durability	4 / 10	8 / 10	10 / 10

6. APPLICATIONS

The application of Additive Manufacturing based PLA covers huge sectors. Because of its properties, it is preferred for most and used by many. Engineers have confirmed that Food made from PLA is safe to eat and it won't cause any health issues even to children. So, this has made a major move in the incubation of several different ideas holding startups along with the world. Also, PLA is used in medical and Pharma industries. Today several biomedical components are being manufactured in PLA and given for medical students to study. Especially Additive Manufactured organs of humans look like the same in appearances and operating. So these PLA organs are used to train Surgery Students to give a clear education with practical learning. Other than that PLA is also used in wardrobes, fashion jewel, mobile spare parts, automobile components, containers, bottles, table wears, cups, etc.



When making a comparative study with the top materials of Additive Manufacturing, we can identify that PLA is stronger than the ABS and Nylon. But because of its low melting point, it loses all its stiffness and it has a higher brittle property and lower impact resistance. So, it is weaker when compared to both ABS and Nylon.

7. LIMITATIONS

This Additive Manufacturing can easily solve several problems in Traditional Manufacturing methods. Still, it has some disadvantages. It is a little longer time taking process than some processes. The major Disadvantage in Additive Manufacturing is Illegal 3D Printing of Explosives and Fire Arms. Because whatever the 3D Scanned file we give will be printed and by the way it is misused in some parts of the world.

The above-given Picture is a fully Additive Manufactured gun with similar mechanisms of a normal steel made gun. If Bullet is loaded with Gun Powder it works similarly to a real gun. And this is the problem if 3D Scanned STL files of the Fire Arms if found in the wrong hands. It could end like the above given picture. That's why some countries have given strict rules for usage of this Additive Manufacturing.

8. FUTURE WORKS

Currently, we have made few tests and several studies of PLA. Although in the upcoming period, we tend to verify all the data of PLA is whether similarly matched during experiments. The tests include Fatigue Test, FEA, Ansys test. Also, we plan to print PLA according to some of its Additive Manufacturing tests that include The Cal Cube Test, Overhang Test, The Bridge Test, Stringing Test, and Temperature Tower. We also plan to take some Mechanical Properties test, Destructive and Non – Destructive tests, etc. This will give a brief knowledge and identify any changes occurred during these tests. Whatever the mechanical tests tend to be carried on, one thing should be kept in mind. It is nothing but our PLA is nothing but a THERMOPLASTIC. Tests which is suited for thermoplastics can only be carried on PLA and tests that don't support these plastics will be a waste of time and money.

We also plan to design a type of 3D Scanning device. This device will be in the form of a treadmill. The main motto of our work is to take the measurements of the feet of people who use the treadmill. So, the exact feet dimensions of the people can be acquired. Then based on the wish of people, the color, design, appearance is selected by the customer and their shoe or slipper will be Additive Manufactured with their own feet dimensions and no more standard feet dimensions and tolerance values. This will be helpful for people who had irregular feet sizes.

9. CONCLUSION

It is observed that PLA is playing a major role in Additive Manufacturing. Because of its properties, it is used in Food, Medical industries specifically. The fabricated PLA material is implied for testing and the readings are discussed with a comparative study of ABS and Nylon. It is also identified that the nut and bolt we manufactured gave results that are similar to the standard data of PLA records. Further tests are also discussed in this journal. The fabrication analysis has given a complete view of PLA in Additive Manufacturing. We hope that this journal will help in providing deep knowledge of Additive Manufacturing to people who view this.

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BIOGRAPHIES

D. B. Naga Muruga,
B.E Mech Engg (3rd year),
Sriram Engineering College,
Perumalpattu,

R. Samuel Sundar,
B.E Mech Engg (3rd year),
Sriram Engineering College,
Perumalpattu,

K. R. Mathivani,
B.E Computer Science and Engineering (3rd year),
Sriram Engineering College,
Perumalpattu,