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# Thermoplastic Composite Waste Recycling and Utilization of Materials for Sustainable 3D Printing

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***Abstract*—**This work discusses the different types of materials with their significant properties utilized for 3D printing for various applications in the current scenario. As the application of 3D printing is enhancing day-by-day in every field because of its great benefits like light weight, any complex shape, porous structure, good strength and better mechanical and other properties, the researchers are making more and more materials which can be used as input material for 3D printer. The biodegradable and recyclable materials are getting more popular as compared to others because they will less harm our environment. Also, waste material recycling has become an important task these days.

***Keywords:*** *Additive manufacturing, plastic waste, composite recycling, sustainable 3DP*

## I. INTRODUCTION

Thermoplastic or recycled plastic materials offer a large variety of application which utilize chemical and mechanical properties. Sadly, plastic waste and its non-degradability issue affect the environment [1-3]. Though, recycling waste accounts for a very small age (approximately 14%) globally [4]. Nowadays there is a strategy of circular economy which is gaining popularity. The circular economy makes effort for the issue of sustainable development of industrial application [5-6] which concern the principle of linear economy i.e take, make and dispose of and also tackles the negative effects which are caused by the natural resources depletion, generation of waste, loss of biodiversity and water, air pollution [7].

On the other hand, the conversion from linear to a circular economy can be achieved by manufacturing capabilities of 3D printing which is also known as additive manufacturing. 3D printing techniques are expected to reconstruct the production methods, as they can transform [8-10] a computational model into the accumulation of material to fabricate the 3D object [11]. The 3D printing market is estimated to reach the U.S dollar 23.33 billion globally by the year 2026. However, deciding how and when to take favor from the benefits is remaining a challenge for conventional means of production. From the other's point of view [9], it is reported that the complete scenario of production changed from traditional to agile processes by the year 2030.

Still, there is a large number of products that are already be fabricated with the help of 3D printing, affecting the density of value chains and geographic extent [12]. It is estimated that the range of 3D printable objects will be much higher in the future, as the fabrication of multi-material and built-in characteristics can be possible. To the extent of this, the fabrication of spare parts can be processed on-site, makes the work much easier for the supplier [13]. So there will be less need for transportation of parts or can be manufactured at the customer's premises [14-16]. This will lead to a reduction in market entry barriers, reduce market capital requirement, gains the optimum range of production and distribution efficient [17]. So additive manufacturing technology can be a driving force for the transition in the globally distributed production system to local production facilities.

The opportunities for the fabrication of 3D printing parts with plastic waste is at the beginning stage and need to be explored. As conventional plastic recycling methods turn out to be ineffective [18]. With the combination of additive manufacturing and circular economy unlocks the circumstances to use consumer waste [19] and reduce the environmental effect of resource exploitation. Therefore, additive manufacturing could be a recycling tool to utilize thermo-plastic waste material, and by achieving this resource utilization efficiency can be improved. To perform the operation a better understanding of recycling is required. Both the technical and logistical practicability of recycling with 3D printing needs to be explored globally [20]. Also, different levels associated with the transformation of plastic waste into raw material for 3D printing are needed to be discovered. Therefore, this work presents a systematic review of the literature study based on the improvement and

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limitations of the thermo-plastic recycling method via 3D printing.

## II. MATERIAL TECHNOLOGY

Melting temperature, melting viscosity and coagulation time are the main parameters for printing. Application; Cloth, house, bridges, teacups to bikes can medical, living tissue, organs, jewelry to food. In near future, 3D printing is used to produce a product that needs customization in size color and a small quantity can produce in no time, the product which is uncertain in the large market, the one which is having a short life.

## III. CONTEXT THEORETICS PLASTIC CHALLENGES

Various challenges like economical [21], political [22], social [23], technical [24], legality [25-26], etc have been identified to make plastic recyclable. Hence making theories that will advance the quality of recycling plastic are an important aspect to find so that values can be generated from the resources [27]. Primary, secondary, tertiary and quaternary are the four essential stages for recycling industrial plastic waste [2][28-30]. Primary and secondary stages are executed as mechanical operations which include reprocessing to fabricate new parts with the techniques of dissolution, purification, reduction in size, melting and fabrication [2][28][30-32]. It is noted that expenditure of recycled plastic depends on the usual oil prices [2]. Hence chemical recycling is a desirable choice for complex and polluted wastes [33].

## THE RMOPLASTIC POLYMERS UNDER 3D PRINTING HISTORY

3D Printing is a fabrication technology in which part is manufactured through material addition in a layer-by-layer manner. There are majorly seven types of techniques used in 3D Printing. They are direct energy deposition, binder jetting, material jetting, material extrusion, vat photopolymerization, powder bed fusion, sheet lamination. Though different technique uses different principle but the fundamental principle of joining material is the same for all. Material extrusion technique is also known as fused deposition modeling (FDM) is the most commonly used technique in additive manufacturing as it offers simplicity in design, operation, a wide range of material fabrication and finds its application in almost all the related fields. A basic overview of FDM additive manufacturing is shown in figure 1.

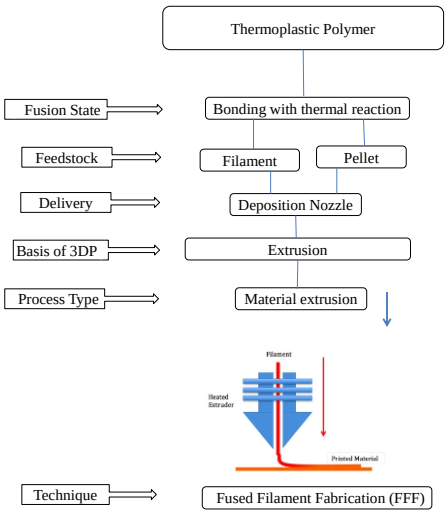


Figure: 1 Overview of FDM Additive Manufacturing

## IV. METHODOLOGY

To achieve sustainable additive manufacturing using waste plastic, a lot of studies is required. Nowadays additive manufacturing can be used in the medical field, even to print the heart valve [34-45]. 3D printing can be used to control vibration in beams. There are several application like piezoelectric material with sensors and actuators which are under development [46-61]. Also, there is some application of 3D printing which can be proved with the help of mathematical analysis. There are various parameters in FDM 3D printing by changing them, one can get the product with different characterization. Also to get the optimum results they can be improved with the help of an optimization tool and can be verified using various algorithms [62-67].

## V. CREATIVE POLYMER MATERIALS, WITH RESEARCH DEVELOPMENTS IN FDM 3D PRINTING

There is various material under additive manufacturing but FDM 3D printing gains the popularity among them. The thermoplastic polymers are ABS, PETG, Nylon other materials include PEEK, composites, etc. Some additive manufacturing techniques are discussed in detail.

### FUSED DEPOSITION MODELING (FDM)

In FDM material is added layer by layer which is extruded through a nozzle to form fibre based composites. The filament which is used in FDM has better flowability and low-melting temperature, but they are limited in number. FDM is a rapid prototype technique and simple to operate, with low cost so, can be used to incorporate additives in the polymer in an easy way [68-69].

### DIRECT WRITING (DW)

The material which is used in Direct Writing [70] is viscous ink. This ink is driven by pneumatic pressure and extruded with the help of a shringe. The syringe moves along all the three-dimensional axes to print the part. the epoxy polymer can be used for printing in DW additive manufacturing technology. Both the FDM and DW printing technology respond to the rheology of the filaments as it is an important property for printability [71].

### INKJET PRINTING

The inkjet printing is more capable of fabricating the parts with better quality and with more fine structure [72] than the FDM and DW printing technique. Powder along with ceramics and polymers are used as a raw material in inkjet printing. Inkjet uses two types of drop-on-drop heads i.e. thermal and piezoelectric head, one is chosen according to the required properties needed in the finished product. The piezoelectric head gains more advantages over the thermal head like production of homogeneous droplet size, uniform ejection and binders are not exposed to heat stressors.

## VI. RESULT AND DISCUSSION

In the initial stage of the processes, information and data/logistics about the plastic wastes are collected. Though a significant amount of data about the recycling composite is collected to achieve the sustainable 3D printing but it is not enough to conclude irrespective of the best effort made. Nevertheless, further study is needed to evaluate and measure the plastic waste collection and to know about the impact on social and environmental aspects. In this study, various polymers for recycling are discussed to achieve sustainable Additive manufacturing.

## CONCLUSION

This study took the utilization of the different materials under observation for sustainable 3D printing with the help of mainly the Fused deposition modelling technique. Additive manufacturing with recycled, bio-based plastic, waste utilization, biodegradable material, enhanced the fabrication process and contribute towards the circular economy. Various techniques and stages involved in the process of 3D printable parts using plastic waste and thermoplastic composites were also discussed.

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