Technical Article

Transforming Plastic Waste into Functional 3D-printed Products

Prepared and Edited by:
Ts Dr Chan Ming Yeng[1] and Ir Ts Dr Koay Seong Chun[2]
[1]Centre for Advanced Materials, Faculty of Engineering and Technology, Tunku Abdul Rahman University of Management and Technology, Jalan Genting Kelang, Setapak, 53300 Kuala Lumpur, Malaysia.
[2]Lee Kong Chian Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Bandar Sungai Long, 43000 Kajang, Selangor, Malaysia.


Additive manufacturing (AM), also known as three-dimensional (3D) printing technology, involves creating 3D objects by depositing materials layer by layer on top of another layer. This technology allows users to fabricate objects with complex geometries while minimizing material wastage compared to traditional fabrication methods. Among a variety of AM technologies, fused filament fabrication (FFF) is the most popular choice for 3D printing technology used by hobbyists, engineers, and researchers. This is because the equipment is inexpensive and offers a wide range of materials choices, such as poly(lactic) acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate (PETG), polycarbonate (PC), and nylon. All these materials are the most used thermoplastic polymers in the FFF process due to their low melting points, and ease of operation, as well as their printed objects with good dimension accuracy. As the popularity of FFF printing continues to increase, the demand for the raw materials used in 3D printing will also increase. This raises concerns about the sustainability of the raw materials in the 3D printing industry. Moreover, various policymakers are promoting the use of more sustainable materials, for example using recyclable materials instead of materials relying on fossil sources. Recycled plastic materials are among the potential materials for FFF printing. In this regard, many researchers are currently focused on the utilization of plastic waste in 3D printing. Various types of plastic waste have been reported in several papers, with researchers using this plastic waste to fabricate filament and then 3D print the final product directly.

The recycling rate of plastic waste remains low because pre-consumer plastic waste, such as rejected parts and scraps from manufacturers, is preferable to recycle as compared to post-consumer plastic. This is because pre-consumer plastics are more easily collected from manufacturers in bulk with minimal sorting, making the recycling process more efficient. Due to this reason, most of the post-consumer plastics are sent to landfills rather than the recycling centers. According to the report by Ferrari et al. [3], plastics constitute a significant portion of municipal solid waste, with production increasing from 1.3 billion tons in 1990 to 3.8 billion tons after 25 years. Approximately 80% of synthetic polymers originate from packaging, containers, and textile fiber production. The massive amount of post-used plastic waste has a serious impact on the environment if not close to the loop of material. Given the abundance of plastic waste, converting them into 3D printing filament can be economically feasible. This is because the selling price of the filament can be ten times higher than plastic resin at the same weight.

Additionally, according to a report claimed by Stina Inc. [4], the total energy consumed during the production of recycled plastic resin is much lower than that required to produce virgin plastic resin. Thus, recycling plastic waste into recycled plastic resin offers significant energy savings. Furthermore, the amount of carbon dioxide released in the production of recycled plastic resin is lower than that in virgin plastic resin production. Therefore, greenhouse gases such as carbon dioxide can be reduced [4]. These are also benefits associated with transforming plastic waste into usable products via the 3D printing process. The application of transforming plastic waste into directly usable products using 3D printing reported by researchers will be discussed in the following sections.

Post-consumer polypropylene used in 3D printing

Post-consumer polypropylene (PP) is typically sourced from food and beverage packaging. The utilization of this post-consumer PP can yield environmental benefits, such as reducing PP waste, given that a significant portion of plastic waste originates from post-consumer PP. In a study conducted by Tan et al. [1], research was undertaken using recycled materials, including post-consumer PP and disposable chopsticks, as fillers to fabricate filament. The authors claimed that this filament not only be used for prototyping but also for direct-used products such as face shield frames, drill guides, and other non-bearing products.

Household plastic waste used in 3D printing

A report from Dreambot [5] revealed that the Tokyo Olympics utilized 98 3D-printed podiums, which were created from 24.5 tons of donated plastic waste sourced from the Japanese public. This waste primarily consisted of household plastics, including 400,000 plastic bottles of washing powder, and was collected from more than 2,000 locations in Japan, including schools, stores, offices, and oceans. These 3D-printed podiums will serve as displays and will be repurposed after the Tokyo 2020 Olympic Games, demonstrating their sustainability.

Marine plastic waste used in 3D printing

Based on the report by Cañado et al. [6], there were 370 million tons of plastic produced in 2019 and estimated that 12.7 million tons of plastic end up in the ocean annually. Furthermore, the presence of plastic waste in the sea results from the dumping of plastics from landfills and several aquatic human activities, for example, fishing, ultimately leading to marine pollution. To mitigate marine pollution and reduce plastic waste in the ocean, researchers have been working on reusing marine plastic waste in 3D printing.

Maldonado-García et al. [7] was focused on 3D printing by using ocean plastic waste mixed with low-cost, sustainable carbon from agro-industrial waste to form complex-shaped prototypes via FFF. Ferrari et al. [3] also conducted research on 3D printing using plastic waste from the seaside. Ferrari and co-authors reprocessed and recycled PET bottles collected from the seaside for use in 3D printing.

Styrofoam used in 3D printing

A report from Ng et al. [8] stated that styrofoam, also known as expanded polystyrene, was produced at approximately 17 million tons worldwide in the year 2025. If the generation of styrofoam waste remains at the current rate by the end of 2050, it might reach 360 million tons of styrofoam waste. This is due to the low recycling rate of styrofoam. Therefore, there are a few papers that have reported research on styrofoam waste in 3D printing [8-11]. The researchers transformed the Styrofoam into a 3D printing filament and used it in the 3D printing process to produce sample prototypes, which were also applied in non-load-bearing applications.

Conclusion

Transforming plastic waste or recycling plastic waste into 3D printing filament and usable 3D printed parts allows for more effective utilization of plastic waste than simply discarding it, thereby reducing environmental impacts. Additionally, by reusing discarded plastic or plastic waste, the process contributes to waste reduction, mitigates landfill usage, and minimizes the need for new plastic production. This approach also has the potential to raise awareness about recycling, sustainability, and the environmental impact of plastic.

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HIGHLIGHTS

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INSTITUTE OF MATERIALS, MALAYSIA

Suite 1006, Level 10, Block A, Kelana Centre Point, No. 3 Jalan SS 7/19, 47301 Petaling Jaya, Selangor.

Tel: 03-76611591
03-76611592

secretariat@iomm.org.my

www.iomm.org.my

+60 18-911 3480

Institute of Materials, Malaysia