Study on Additive Manufacturing Waste Recycling

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INTRODUCTION

Over the last decade, 3D printing, also known as additive manufacturing (AM), has become an important part of the manufacturing industry. Developed in the 1980's and based on layer-by-layer manufacturing method, this technology offered fast, cheap, automated production without almost any waste or limitations to geometry complexity. Today, AM is already being used in a wide range of industries, including aerospace, construction, automotive, medicine. 3D printing has several advantages over traditional production methods, which have led to its rapid growth. Most of the time the main waste of this technology are support structures or unsuccessful prints. After 40 years of development and evolution, the main materials used in AM are still thermoplastics. As the usage of additive manufacturing increases, it is important to talk about the generated waste. This research shortly overviews the situation and opportunities for plastic waste reusability at AM technologies.

OPPORTUNITIES FOR PRINTING PROCESS WASTE RECYCLING USING AM

Fused Deposition Modelling

In FDM technology, the main waste is prototypes, support structures, failed prints, and filament residues.
Solutions:

- Natural decomposition. For example, PLA is made from renewable raw materials such as sugar cane, corn or potatoes and is therefore biodegradable. This means that PLA can be broken down to water, carbon dioxide and biomass. Unfortunately, PLA degradation requires special environmental conditions that are not available in landfills.
- Recycling. This process can be difficult as 3D printing waste often does not have the necessary labelling. Nevertheless, several FDM raw materials, such as PLA, cannot be classified and recycled together with the main groups of plastics due to certain properties. In the case of PLA, it is lower melting point than of standard plastics, which prevents PLA from being processed with other plastics in recycling centres.
- Recycling and reusing the waste yourself. Unfortunately, recycling of FDM printing waste is still a relatively expensive and undeveloped process because the equipment for part shredding, and remelting to filament is expensive. One of the problems of plastic recycling is the maintenance of the mechanical properties of the printed parts, which means that not all products can use recycled filament. A possible solution to this problem is to mix recycled thermoplastic with new pellets of the same plastic, but this is still in the development phase.

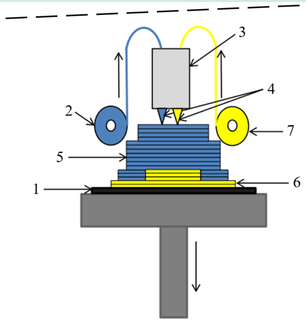

Fig. 1 FDM process scheme: 1 – printing platform, 2 – model material, 3 – printing head, 4 – nozzles, 5 – part, 6 – support structure, 7 – support material

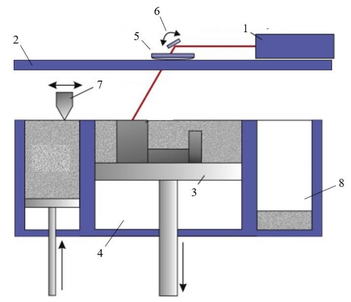

Fig. 2 SLS process scheme: 1 – laser, 2 – heating element, 3 – retractable platform, 4 - printer chamber, 5 – optical components, 6 – scanner system, 7 – recoater

Waste in SLS Technology

Due to the nature of the process, SLS production of parts generates very little waste, as most of the powder can be reused.
Key aspects:

- The powder remaining after the printing process must be sieved to remove conglomerations of powder. The sieved powder can be then returned to the 3D printer container and used again.
- Unfortunately, all powders in the printer container undergo thermal changes during printing and the quality of the powder decreases with each reuse, thus decreasing the quality and mechanical properties of the parts produced. Because of that, is recommended to mix the powder with unused powder to minimize degradation. However, after a certain number of printing cycles, the powder should still be fully replaced with the new one to ensure maximum product quality and properties.
- Most materials used in SLS are suitable to produce filament for FDM 3D printing. So unused parts can be shredded and used for producing filament. Another advantage of SLS waste is that it is non-contaminated compared to conventional polymer waste. SLS waste reusability as FDM filament can make additive manufacturing even more efficient, cost-effective, and environmentally friendly.

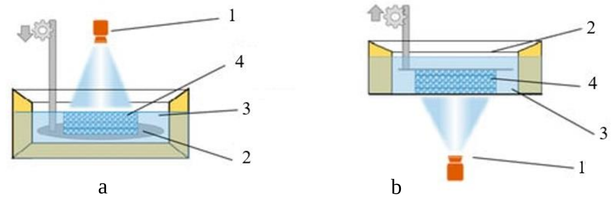

Fig. 3 SLA process scheme: a) bottom-up, b) top-down; 1 – light source or laser, 2 – platform, 3 – reservoir, 4 – printable model

Waste in SLA Technology

Unfortunately, possibilities to recycle waste from the SLA technology are very limited. The reason for this problem lies in the raw materials used in this technology. Unlike FDM or SLS, SLA uses thermosets rather than thermoplastics. Both thermoplastics and thermosets are polymers, but they have different structures and react differently to high temperatures. Processed thermoplastics can still melt when heated, whereas processed thermosets retain their shape and remain solid when heated. Due to their low melting point, thermoplastics are often used in processes using recycled materials, while thermosets are valued for their durability as they can withstand high temperatures without losing their shape. However, unused resin left from previous printing process can be reused.

Opportunities for general plastic waste reusability using AM

One of the biggest environmental problems today is large quantities of plastic packaging which remains in landfills and pollutes the environment. Some of this plastic can be used to produce FDM technology filament. Using this waste to produce raw materials for 3D printing can not only reduce environmental problem but also save costs. Polyethylene terephthalate (PET) is often used for soft drinks, water, and food packaging due to its water and moisture resistance. Research has shown that both virgin and recycled PET have similar mechanical properties [7]. In addition, the mechanical properties of PET remain unaffected after recycling it up to 5 times. Even after that recycled PET can then be blended with virgin raw material to maintain the high mechanical properties of the product. When recycling PET, it is important to avoid moisture and contamination of the plastic with other materials, as this can severely affect both the physical and chemical properties of the polymer and reduce product quality.

CONCLUSIONS

Although 3D printing is promoted as zero-waste technology, it is important to acknowledge the actual waste and act on reducing it. FDM technology waste from broken, unused parts or support structures can be remelted to filament. For SLS technology it is possible to reuse powder material multiple times considering mechanical properties degradation. Also, SLS waste and parts can be remelted to FDM filament. SLA method is like SLS, meaning that it is important to reuse unaffected leftover resin, however broken or not usable parts cannot be remelted and reused. Additive manufacturing offers and opens door not only for reusability of waste generated from printing process, but also gives the opportunity to recycle and reuse general thermoplastic waste.