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RECYCLING SYSTEM FOR THE FDM/FFF METHOD MATERIAL DESIGNED FOR SMALL AND MEDIUM-SIZED PRODUCTION BATCHES

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Abstract: With fast growing industry in the field of additive technology, possibilities of DIY (Do It Yourself) projects grow as well. This also gives the opportunity for non-expert's users to project and develop some complex products on their own. The reaction was global overflow of the 3D printer's sale worldwide. If we look in the long term, environmental pollution caused by their disposed polymer is their biggest flaw. Recycling process sometimes can be very expensive, and in certain cases unavailable for some users. In this paper, low-cost recycling system for materials that are most commonly used for FDM/FFF method is presented. The main goal was to reduce environmental pollution and 3D printing costs by presenting the possibility of making its own polymer made of scrape plastic. Moreover, this allows users to make their own recipe by mixing different types of scrape polymer, or adding reinforcing material such as chopped dry fibre, metal powder, etc.

Key words: Recycling, Environmental Pollution, Additive Technology, FDM/FFF, Filament Extruder..

1 INTRODUCTION

An only decade ago, additive manufacturing processes were available only for big corporations that have been worked in the field of aviation, automobile, defense industry, etc. Even nowadays, every discovery in the field of additive manufacturing first appears in those industries, and after several years that technology translates to the widespread additive manufacturing technologies. The main reason is the cost of this type of manufacturing. On the other hand, since of the opportunity that additive

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technology gives for non-expert's users, DIY (Do It Yourself) community has been growing so much [1], that additive manufacturing mostly becomes available for every human on Planet Earth [2, 4]. It seems that trend of technology accessibility is similar to mobile technology.

High accessibility of additive technology, like every technology, has its pros and cons. One of the biggest advantages is the acceleration of technology development. On the other hand, this can lead to environmental pollution increasing [5]. When using additive manufacturing, even if it is not subtractive technology, some of the materials were being wasted, such as support structures, build plate adhesion structures, etc.

With the goal to reduce this negative effect on the environment, most of the waste materials can be recycled. This, not only can lead to a green environment but also can reduce the cost of 3D printing. On the other hand, when the focus is on the development of the current technology, by recycling, users have the possibility to make their own recipe of the filament by mixing different types of scrape polymer or adding reinforcing material, such as chopped dry fiber, metal powder, etc.

As the recycling process is not yet fully implemented worldwide, similar to the additive technology when was introduced, recycling may be unavailable for most 3D printing users [6, 7]. In this paper, a low-cost recycling system for filament extrusion based on the wasted FFF/FDM material is presented. Such a system can be used for small and medium sized production batches, on the most commonly used filament materials.

2 RECYCLING SYSTEM CONCEPT

The whole idea of making user own filament through recycling is based on the fact that not a small percentage of the polymer has been wasted during and after printing. By recycling these materials, cost savings of 3D printing can be achieved.

The proposed recycling process is achieved through several steps (Fig. 1). The first step is to prepare wasted material in the way of pre-processing it into the small granules. In this step, additional supplementary material in the form of reinforcing material can be added. This can drastically influence the physical/mechanical properties of the final product after the 3D printing is done.

The next step is to process material in the way of extrusion. In this way, a filament of specific cross-section shape has been producing. In order to achieve constant dimensions of the cross-sections, e.g. diameter, calibration is necessary to be done.

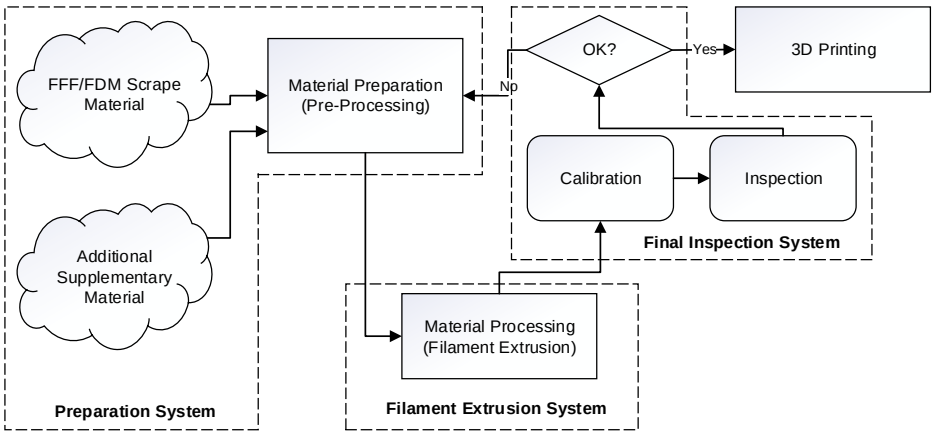

Figure 1. *Schematic of the concept of FFF/FDM material recycling*

The final step is to inspect produces filament. This is one of the most crution steps, e.g. during variation of filament diameter, various side effects on the 3D printed part can occur.

Based on this, recycling must be through several systems: *Preparation System*, *Filament Extrusion System*, *Final Inspeciton System*. In this paper only *Filament Extrusion System* is presented.

3 IMPLEMENTED DESIGN

Proposed designe of the *Filament Extrusion System* is presented in the Fig. 2. The design is based on the fact that initial polimer need to be processed in the form of small pellets (chops).

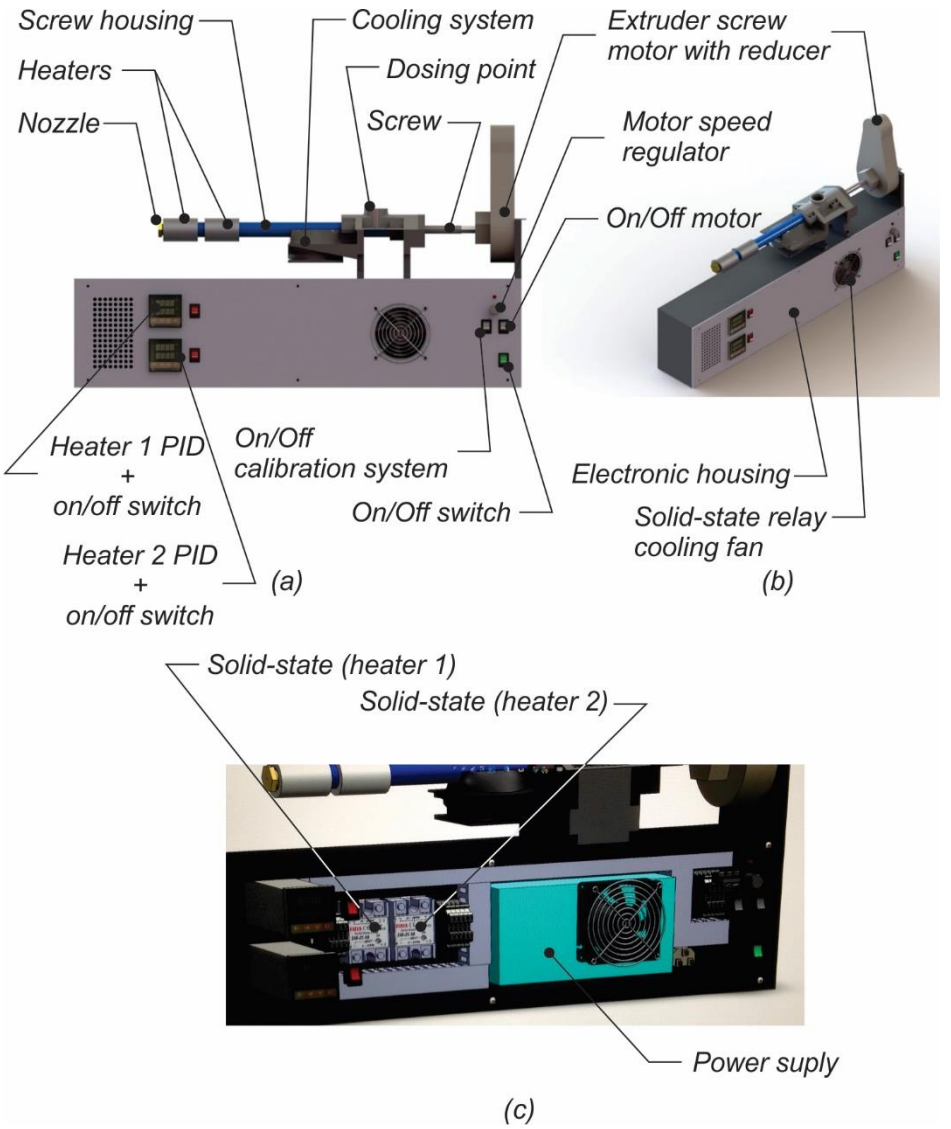

Figure 2. *Design of filament extrusion system for recycling process in (a) frontal and (b) isometric view, with (c) internal cross section*

Such a processed polymer goes through the dosing point, from which is being pushed through screw housing with the screw that is being propelled with extruder screw motor with reducer. At the end of the screw housing, polymer pellets are premelted and melted with two heater systems. Each of them is composed of one heater, PID regulator, thermocouple, solid-state relay, and on/off switch. After the polymer is being melted, it is further pushed through the nozzle. After exiting the nozzle, the formed filament needs to be finally processed in the *Final Inspection System.*

The value of the nozzle diameter is set to 1.7 mm (Fig. 3). In order to acquire different filament diameters, only the speed of the screw needs to be adjusted. Depending on the material, the melting temperature can be set based on the recommendations for such material [8-10].

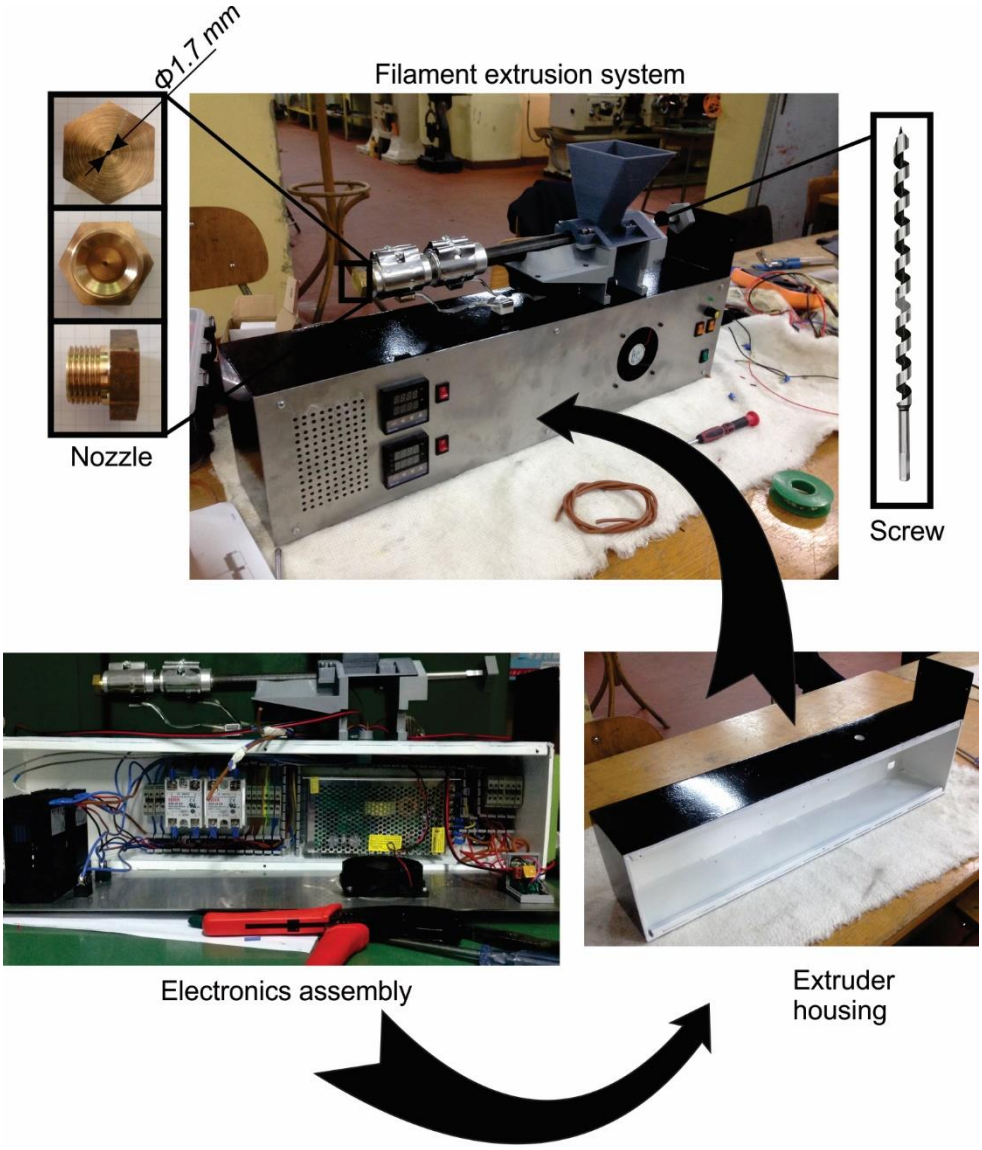

Figure 3. Asembly of *filament extrusion system for recycling process*

In order to prevent the melting of the polymer in the dosing area, a cooling system is attached next to the dosing point. Based on the user needs to the different diameter of the filament or cross-section, the nozzle can be easily changed.

4 CONCLUSION

In this paper schematic view of the concept of FFF/FDM material recycling is presented. Also, a detailed design and fabricated solution of the *Filament Extrusion System* is presented. Such system can be used for recycling scraped polymer made during 3D printing.

It is intended for a smaller volume of production and DIY users, considering low build costs. With such a recycling system, a big impact on the reduction of environmental pollution can be acquired. Not only scraped polymer is made during 3D printing, but also, bottle caps, bottles, broken toys, etc. can be recycled using this type of recycling system.

The main disadvantages of these systems are:

- Compromised consistency of formed filament,
- Low production speed,
- Nessesety for preprocessing the polymer,
- Not suitable for large production.

On the other hand, the main advantages are:

- Users can mix different polymers,
- Possibility of adding reinforcing material such as chopped dry fiber, metal powder, etc.,
- Low build cost,
- Reduction of environmental pollution,
- Easily upgradable,
- etc.

LITERATURE

[1] Petersen, E. E., Kidd, R. W., & Pearce, J. M. (2017). Impact of DIY home manufacturing with 3D printing on the toy and game market. *Technologies*, *5*(3), 45.

[2] Laplume, A. O., Petersen, B., & Pearce, J. M. (2016). Global value chains from a 3D printing perspective. *Journal of International Business Studies*, *47*(5), 595-609.

[3] 3Dnatives – your source for 3D printing, https://www.3dnatives.com/en/3d-printer-sales-2020-study-210420204/, pristupljeno 30.10.2020.

[4] Statista, https://www.statista.com/statistics/590113/worldwide-market-for-3d-printing/, pristupljeno 30.10.2020.

[5] Rejeski, D., Zhao, F., & Huang, Y. (2018). Research needs and recommendations on environmental implications of additive manufacturing. *Additive Manufacturing*, *19*, 21-28.

[6] Baechler, C., DeVuono, M., & Pearce, J. M. (2013). Distributed recycling of waste polymer into RepRap feedstock. *Rapid Prototyping Journal*.

[7] Woern, A. L., McCaslin, J. R., Pringle, A. M., & Pearce, J. M. (2018). RepRapable Recyclebot: Open source 3-D printable extruder for converting plastic to 3-D printing filament. *HardwareX*, *4*, e00026.

[8] Woern, A. L., Byard, D. J., Oakley, R. B., Fiedler, M. J., Snabes, S. L., & Pearce, J. M. (2018). Fused particle fabrication 3-D printing: Recycled materials' optimization and mechanical properties. *Materials*, *11*(8), 1413.

[9] Zander, N. E., Gillan, M., & Lambeth, R. H. (2018). Recycled polyethylene terephthalate as a new FFF feedstock material. *Additive Manufacturing*, *21*, 174-182.

[10] Zhang, J., Yang, B., Fu, F., You, F., Dong, X., & Dai, M. (2017). Resistivity and its anisotropy characterization of 3D-printed acrylonitrile butadiene styrene copolymer (ABS)/carbon black (CB) composites. *Applied Sciences*, *7*(1), 20.