Integrated recycle system concept for low cost 3D-printer sustainability

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ABSTRACT – Plastic prototypes that are produced by a low cost 3d printing process may contribute to the increases of plastic waste due to its post-process or from the waste from prototype building error. In this paper, with the goal to sustain and reuse the plastic waste, a recycle system which integrated to the low cost 3D-printer was proposed. This system concept which consisted of 13 parts was designed and analyzed by computer modelling and computer aided engineering software. Afterwards, most parts were built by 3D printer before they were assembled together and attached to the low cost 3D printer in order to prove the working design concept. From the result of the analysis, it shows that all parts were safe to produce where the factor safeties were in the range of 3 to 10 and the working concept of the system was proven.

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1. INTRODUCTION

The popularity and the growth of low cost 3-D printers are in the extreme level. The attraction to build product for concept visualization that is working, reliable and cheap, demands not only the needs of a low cost machine but also the needs of cheaper building materials. Thus, in order to sustain the plastic materials that are produced by low cost 3D printer, a system to recycle the plastic waste and extruding the filament of the 3-D printer is required. This was already initiated by projects and works from RecycleBot and Filamaker [1,2]. These systems utilized the principle of plastic extrusion where it utilizes a screw to move material through a heated barrel, the plastic material was melted, compressed and forced through a die [3]. However these systems are separated from the low cost 3D printer itself, therefore the needs to operate two separate systems are not practical in term of time and cost. Furthermore, these recycle system machine have separated filament extruder and plastic shredder. This lead to the increases of produce time as one process should be complete before another.

In order to overcome this problem, a new concept of recycle system that able to recycle plastic waste into filament and integrated with the 3-D printer was proposed. To reduce the energy used in 3-D printing, the recycle system was developed without the uses of filament. This attempt will reduce the cost of feedstock 3-D printer even further. The system feed directly from the shredded plastic waste during printing using the concept of commercial filament extruder. The recycle system developed and analyzed using computer aided engineering software and the concept was produced by the 3D printing process.

2. METHODOLOGY

The concept design started with the concept generation presented by morphology chart which considered the following criteria; mechanism to decompose plastic materials, mechanism to extrude and draw out the filament, heating element, working mechanism and cooling element. Afterwards, the design concept was assessed by using evaluation matrix that emphasized on the following criteria of cost; ease of use; automation; adaptability to RepRap; quality; and energy use. The final concept design was prepared by solid modeling software and is illustrated in Figure 1. Each of the integrated system part is explained in Table 1. The design was then analyzed using computer aided engineering software by considering forces acted on each part when the system was assembled with the low cost 3D printer. The von Mises Stress and factor safety for each part were obtained.

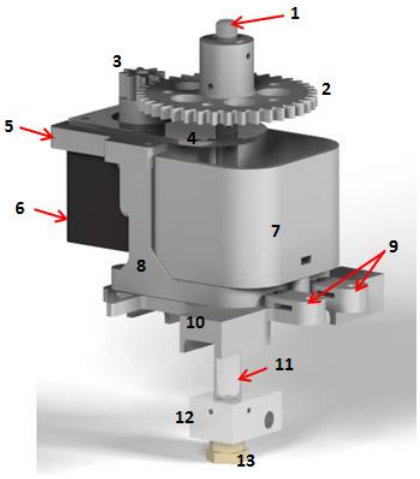

Figure 1 Concept Design of Integrated Recycle System

Table 1 Integrated recycle system parts description

Part No	Part Name	Material	Description
1	Auger drill bit	Steel	To transfer the shredded plastic to the hot end (Ø8 mm)
2	Gear A	ABS	To rotate drill bit (Ø 67 mm, t=38)
3	Gear B	ABS	To rotate Gear A (Ø 17 mm, t=8)
4	Drill bit holder	ABS	To grip the drill bit in fix position
5	Motor mount	ABS	To clench the motor and the auger drill bit holder
6	Motor		To rotate Gear B (NEMA 17)
7	Hopper	ABS	Contain shredded material and to guide their flow to the auger drill bit
8	Body	ABS	To hold the motor mount, hopper and is attached to the slider
9	Bell Mount	ABS	To mount the x-axis belt to the slider
10	Slider	ABS	To move the body, motor, motor mount, hopper, and every parts correspondent
11	Barrel	Aluminum	To transfer the shredded plastic material
12	Hot end	Aluminum	Heating section
13	Nozzle	Brass	To force the molten plastic through

For the assembly purpose, the integrated recycle system part was printed out using Mendel Low Cost 3D Printer Machine and the material used are ABS plastic. The printing process began from the exporting of the STL file of each part to the Sli3er software. The software will slice the parts based on requirement of the wall thickness, density of infill, and the infill pattern of the parts. Then the printed tool path and the temperature of the hot end and the bed which were set to 230°C and 110°C respectively by using the Pronterface software. On the bed surface, acetone was mixed with the ABS filament at the ratio of 3:10 The printed parts were then produced and each parts are assembled together. The assembly fitted on top of the low cost 3D printer and substituted the original extruder. The working concept of the recycle system was then investigated by the smoothness of the movement of the system.

3. RESULTS AND DISCUSSION

The factor safeties of all the analyzed recycling system parts are more than 2 which demonstrate that all of the parts are strong and safe to produce. In addition, most machine component should able to safely operate if they are in range of the recommended or ideal value of 3 to 5. Selected parts of the analysis results were summarized in Table 2 below.

Table 2 Stress analysis of selected recycle parts

Part No	Part Name	Max von mises stress (MPa)	Factor safety
1	Auger drill bit	70.82	3.5
5	Motor mount	4.75	3.4
8	Body	5.4	7.4

The prototype of the recycle system shows that small shredded plastic part was able to extrude smoothly by the auger drill bit. This was because of the hopper design angle transferred the shredded material efficiently. For the system assembly, the integrated system was capable to move in the x-axis direction smoothly. This phenomenon has been observed by the constant speed of the recycle system movement with the speed of motor. Thus, from this result it shows that the working concept of the recycling systems was established.

4. CONCLUSIONS

A new concept of recycle system was developed where the recycle system replaced the extruder head of the 3-D printer. Analysis of the recycle system proved that the component of the systems able to hold the load applied to it and the concept of recycle was working as predicted. In the future, a combination of shredder and extruder will be proposed to speed up the process of recycling of plastic waste.

5. ACKNOWLEDGEMENT

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