Evaluation of the tensile properties of fabricated dead snail shell powder ABS composite filament

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ABSTRACT

In the present scenario, 3D printing plays an important role in manufacturing engineering and product design and development. In terms of the quality of the product in the 3D printing process, the filament plays a vital role. At present, the majority of the 3D printing components are produced with commercial filament available on the market. The properties and characteristics are restricted by the availability of the filament on the market. A tailored filament gives a promising solution; hence, the present work on a tailored composite filament is fabricated and characterized by its tensile properties. The base matrix material is selected as ABS, and death snail shell powder reinforcement is considered. Reinforcement with and without hydrothermal decomposition is considered. The ABS, ABS with and without reinforcement are fabricated using a mini filament extruder, and the results are compared.

Key words: Additive Manufacturing, Filament, Composite, Tensile properties

1. Introduction

With the development of technology, Additive manufacturing using layer-by-layer material deposition began. Fused filament fabrication (FFF) was conceived in 2010 as a low-cost fast prototyping technology. The next stage was discovered to be manufacturing bespoke material filament. The filament in 3D printers can be compared to the ink cartridge in traditional printers. Similarly, to paper printers, a succession of cartridges with specific properties are utilized based on the intended results. Composite materials, as the name suggests, are made up of two or more elements. In the case of 3D printing filament, a filler material that is insoluble in the matrix material, which is a thermoplastic polymer such as PLA, ABS, or Nylon. As a result, the filler material creates discrete and distinct zones inside the matrix material, imbuing the material with characteristics unique from those of the individual component. The type of filler material used, its volume, the shape and size of the filler particles, and how well they interact with the matrix material will all have an impact on the composite's properties. The matrix substance will depend on several factors, including the type of filler material present, its amount and also the shape and size of the filler particles and how well they interact with the matrix material. The matrix material will also influence the characteristics of the resulting material. In the case of FDM thermoplastic composites, the final material must retain thermoplastic behavior to enable fabrication of the composite. For most of these composite filaments, the material of choice for the plastic matrix is PLA. Being one of the most widely used 3D printing filaments, most 3D printing hobbyists and professionals already have a deep understanding of how to get good results with PLA. As mentioned previously there are several reasons for 3D printing composite materials. 1.Complex objects with unique features are now routinely manufactured using additive manufacturing. As it develops, it is finding application in a variety of industries, including biomedicine, aerospace, automotive, and consumer. The composite materials with additive manufacturing is particularly alluring because it has the potential to change, alter, and diversify the properties of standard materials by adding reinforcements [1]. [2]There are certain material availability restrictions with this additive manufacturing process. The intricate dependencies of AM processes on various associated technologies, such as material modeling, designing tools, STL format computation, and process design, pose a serious challenge for both practical and basic research, despite the fact that the popular view of AM technologies is simple to grasp [2]. 3.V. Miron et.al. A tailored 3D printing PLA filament processed and its tensile properties are compared with commercial filament and concluded that time and cost is reduced [3]. 4. Syed Muhammad Raza et.al. This study is an initiative to reuse discarded plastic products into something useful. Thus, failed prints of PLA material are used as the raw material and processed to get filaments of desired thickness in order to be used for 3D printing again. The thickness of the filament and rpm variation is studied with respect time [4]. 3. Katarzyna Mikula et.al focused on production of filaments for 3D printers from recycled polymers as the alternative to present approach of central selective collection of plastics. The idea is that consumer can produce goods directly from his own used materials. This provides several savings: environmental and buying commercial plastic goods and enables to close the loop of circular economy [5]. Ruben Bayu Kristiawan et al Aspects that have been stated to influence the results are as follows: filament material composition, extrusion working parameters such as those related to extrusion speed and temperature, extrusion machine specifications and type of filament polymer [6]. Aluri Manoj et.al Reviewed on the development of various 3D printing biofilaments and their fabrication process reported in the different literature. The biodegradable filaments for 3D printing, they are not widely accepted by industries due to their lower mechanical strength, poor dimensional accuracy according to design specifications, and poor layer adhesion[7]. The research on combinations of diverse biofibers and resin systems utilized in various three-dimensional additive manufacturing processes, such as powder-based, material extrusion, solid-sheet, and liquid-based systems, was summarized by Jiang et al. Each technique is detailed in detail, including the materials used and the process design, and the mechanical properties of the finished products are compared to those of printed parts made from pure resin or other material combinations. [8]. With reference to the above, composite filament processing needs to be improved with process design; hence, in this work, the processing of composite filament with reinforcement of dead snail shell powder and its tensile properties are compared.

2. Methodology:

The filament making is important at the same time it is also important evaluate the parameters for further use. In first aspect is to make filament with and without reinforcement using Mini filament extrusion machine setup. Second aspect is the testing the filament to evaluate the properties. In this view the filament making and testing is carried as flow chart given below fig.1.

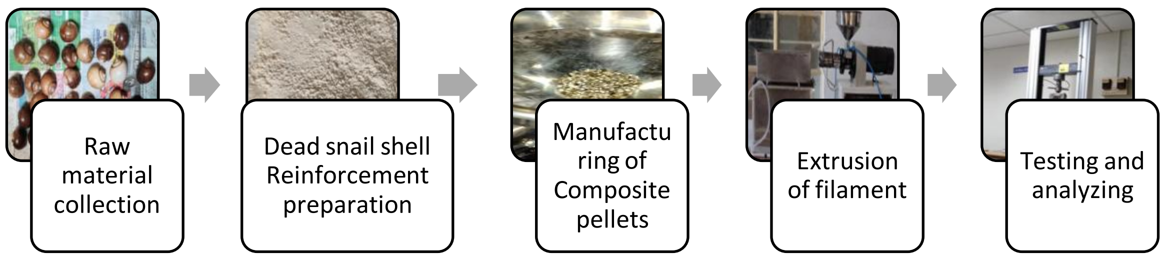


Fig.1.Flow chart of Methodology

2.1. Raw material collection: The quality raw material is important in the filament making. The main raw material is ABS polymer as matrix material and reinforcement is discarded snail shell powder. This thermoplastic material has excellent chemical, stress and creep resistance. ABS offers a good balance of impact, heat, chemical and abrasion resistance, dimensional stability, tensile strength, surface hardness, rigidity and electrical characteristics. ABS plastic remains hard, rigid, and tough even at low temperatures and good dimensional stability. The death snail shells are collected from the local pond bank, Mattirimitta, near Tada. Shells with an average width of 42 mm and a height of 45 mm were chosen for testing.

2.2. Dead snail shell Reinforcement preparation: The inside of the death snail shell is cleaned from sand. The bucket is filled with fresh water and the dead snail shells are added. The water is gently stirred with a hand or a soft wooden piece. The water is removed, and the process is then repeated two or more times using fresh water until the quality is satisfactory. The cleaned shells, are crushed by placing the shells in the rubber bag with the help of a wooden mallet, tapping on the top of the rubber bag. The crushed shells are again (the complexity of the geometry is simplified) cleaned with water for better purification quality. The cleaned crushed shells are further pulverised to powder using the disc milling process. The pulverised powder, as shown in is used for further processing, i.e., hydrothermal decomposition using an autoclave in combination with muffle furnace. The process of hydrothermal decomposition is explained separately below. The decomposed solvent contains water matter and solid matter to be separated. The cellulose filter paper is the size of A1 and is placed over the top of the small container to collect water after filtration.

Traditionally, the grade is used in qualitative analytical separations for precipitates. The filtered substance is now dried in the open atmosphere until it dries.

2.3. Manufacturing of Composite pellets: In making of composite pellets, the blending and mixing of the death snail shell powder particles is made carefully. The mixing of Dead snail shell powder with and without reinforcement of 5gms is added for 100gms ABS granules. To get homogenous mixing of powder particulates with polymers initially a weighed quantities of both reinforcement and ABS granules fed into the hand injection mould machine and extruded through the die as presented in fig 3. The extruded composite is cut into pallets for further use in mini filament extrusion machine.

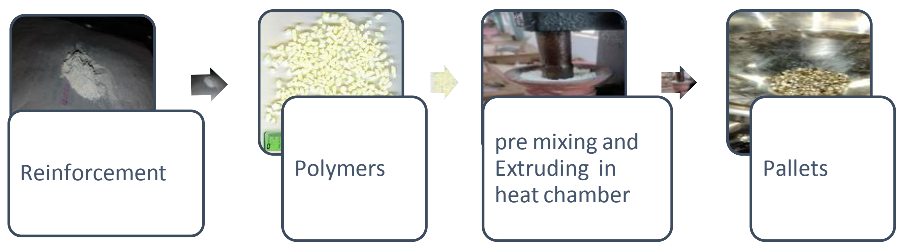
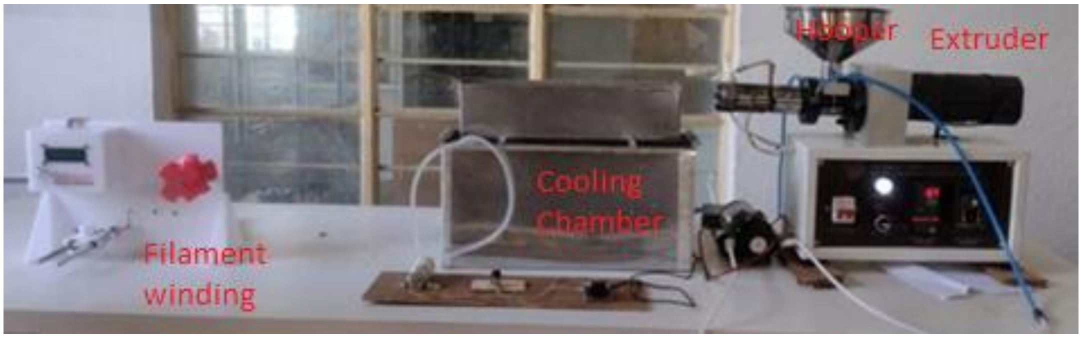


Fig.3.Sequence of steps of composite pellets manufacturing

2.4. **Extrusion of filament**: The mini filament extruding machine is shown in Figure 3. For the filament fabrication process, the raw materials in the form of pellets or granules of ABS polymer or ABS composite are fed into the barrel via Hooper. A weighed quantity of preheated raw material is considered to avoid moisture absorption. The barrel consists of two heaters embedded on the top of lateral surface of the barrel. The fed raw material is heated and softened in the form of paste for extrusion. The single screw conveyor rotates slowly at variable speeds, driven by a reduction gear box coupled to screw conveyer shaft. The barrel is divided into three zones in the axial length: the feed zone to feed the raw material into the annular path of the inside barrel; the transition zone where the raw material is softened; and the metering zone, where the softened raw material is pressurized against the nozzle to extrude the filament. The nozzle with conical shaping zone and straight cylindrical surface with required diameter is fixed to the other end of barrel to extrude filament of required size. The extruded filament, which is soft and hot, is passed through the cooling chamber. The cooling chamber consists of two tanks: the lower tank is used as a sump to supply the upper tank, and the upper tank maintains a constant level of cooling water. The hot and soft extruded filament is passed through the water. The cooled and cured filament is winded using a filament winding machine.



2.5. Testing and analyzing

The filaments are produced and tested using Instron universal testing machine and Max load (N), Load at braking point, Maximum tensile stress (Mpa), Young's modulus and tensile strain (mm) are obtained and presented below. The results of pure abs filament, composite filament with reinforcement without decomposition results and another composite filament with reinforcement with decomposition results are presented in the table.1. The fig. 3-6 shows the results of stacked line plots of ABS, composite filament with decomposition and composite filament without decomposition.

3. EXPERIMENTS

The filament is fabricated using ABS as a matrix material and death snail shell powder as reinforcement. The above reinforcement is obtained as explained earlier. The experiments are conducted on three types of filaments: pure ABS filament, addition of reinforcement with and without decomposition. The process parameters are important to get quality filament from the mini filament extruder. The trails are made at different process parameters, and the results are tabulated in the table.2. It is observed that temperatures in the range of 155 to 165 °C and speeds in the range of 1210 to 1250 are found suitable from the above results. Hence, the filament is produced with six filaments at different process parameters, i.e., temperatures of 155 °C, 160 °C, and 165 °C, and speeds of 1210 and 1250. The experiments are conducted as presented in Table 5.2 below. Each filament is produced at given process parameters, such as extrusion temperatures and speeds, using a mini filament extrusion machine.

Sl. no.	Raw material	Extruder Parameters		Remarks
		Temperature (^{0}C)	Speed (RPM)	
1	ABS pallets	230	10	Filament forms a porous structure & high fluidity.

2	ABS pallets	210	9	High fluidity, variations in diameter & wrinkles.
3	ABS pallets	190	7	Fluidity isreduced, Diameter is not constant, rough surface.
4	ABS pallets	170	6	A Fine filament is obtained with goodfinish but brittle
5	ABS pallets	155	5	A better filament is obtained Variations in size
6	ABS pallets	165	10	A better filament with good quality
7	ABS pallets	150	10.5	A better filament with good quality

Table.1. Parameters for trail runs for selection of the best parameters

The filaments are manufactured with Pure ABS polymers, Composite filament with decomposed death snail shell powder, and Composite filament without decomposed death snail shell powder. Each material used for manufacturing six filaments had different process parameters, as shown in Table 3. The above table six experimental process parameters values are repeated for Composite filament without decomposition and Composite filament with decomposition

Table 2. Process parameters of experiments.

Experiment.no	**Material**	**Temperature(^{0}c)**	**Speed RPM**
FA1	Pure ABS	155	10
2		155	10.5
3		160	10
4		160	10.5
5		165	10
6		165	10.5

4. **RESULTS AND DISCUSSION**:

To investigate the tensile properties of ABS composite filament with reinforcement of discarded snail shell powder after decomposition using above mini filament extruding machine of the experiments according parameters in table.2 are conducted and results presented in the Table 3.Effect of process parameters on the tensile properties ABS fabricated filaments, ABS composite without decomposition filaments and ABS Composite with decomposition filaments are analysed. Maximum load, Load at braking point, Maximum tensile stress, young's modulus and tensile strain composite filaments with ABS filaments are compared.

Table.3: UTM results of the filaments produced

Tensile properties of ABS Filaments						
Temperature (0c)	Speed RPM	Max load (N)	Load at braking point (N)	Maximum tensile stress (Mpa)	Young's modulus MPa	Tensile strain (mm)
155	10	80.78	74.04	2.69	64.27	0.07858
155	10.5	76.11	69.32	2.54	49.82	0.84763
160	10	66.59	64.53	2.22	70.15	0.0515
160	10.5	74.67	67.61	2.49	58.35	0.15717
165	10	80.43	71.08	2.68	70.8	0.30817
165	10.5	87.18	81.79	2.91	73.16	0.13784
UTM results Without decomposition filaments						
155	10	78.89	76.89	2.63	62.27	0.08683
155	10.5	76	75.89	2.53	51.6	0.07333
160	10	46.31	19.33	1.54	35.99	0.11467
160	10.5	80.09	75.59	2.67	58.48	0.17
165	10	99.67	95.89	3.32	70.68	0.11133
165	10.5	69.48	67.67	2.32	70.47	0.054
UTM results With decomposition filaments						
155	10	92.67	86.63	3.09	66.85	0.125
155	10.5	94.23	90.91	3.14	43.71	0.111
160	10	84.13	80.4	2.8	69.92	0.11033
160	10.5	80.09	75.21	2.67	58.48	0.17
165	10	77.41	75.59	2.58	48.04	0.11533
165	10.5	72	70.5	2.4	35	0.16683

4.1. Comparison of Maximum load composite filaments with ABS filament

The maximum load of three types filaments and there average values are presented in the fig. a. The maximum load of ABS filament varies from minimum value of 66.59 N to maximum value 87.18 N. The maximum load of composite filament without decomposition varies from minimum value of 46.31N to maximum value 99.67N. The maximum load of composite filament with decomposition varies from minimum value of 72N to maximum value 94.23N. The average value of maximum load are ABS, composite filament without decomposition and composite filament with decomposition are 79.29N, 75.073N and 81.07N respectively presented in the histogram as shown in fig.f. The maximum load of composite filament with decomposition observed lowest deviation from minimum value to maximum value and highest average value.

4.2. Comparison of Load at braking point composite filaments with ABS filament

The Load at braking point of three types filaments and there average values are presented in the fig.b. The Load at braking point of ABS filament varies from minimum value of 64.53 N to maximum value 81.79 N. The Load at braking point of composite filament without decomposition varies from minimum value of 19.33 N to maximum value 95.89 N. The Load at braking point of composite filament with decomposition varies from minimum value of 70.5 N to maximum value 90.91 N. The average value of Load at braking point are ABS, composite filament without decomposition and composite filament with decomposition are 71.40 N,79.70N and 62.7N respectively. The Load at braking point of composite filament with decomposition observed lowest deviation from minimum value to maximum value and highest average value.

4.3. Comparison of Maximum tensile stress composite filaments with ABS filament

The Load at Maximum tensile stress of three types filaments and there average values are presented in the fig.c. The Maximum tensile stress of ABS filament varies from minimum value of 2.22 M pa to maximum value 2.91 M pa. The Maximum tensile stress of composite filament without decomposition varies from minimum value of 1.54 M pa to maximum value 3.32 M pa. The Maximum tensile stress of composite filament with decomposition varies from minimum value of 2.4M pa to maximum value 3.14 M pa. The average value of Maximum tensile stress are ABS, composite filament without decomposition and composite filament with decomposition are 2.58 M pa,2.41 M pa and 2.78 M pa respectively. The Maximum tensile stress of composite filament with decomposition observed lowest deviation from minimum value to maximum value and highest average value.

4.4. Comparison of Young's modulus composite filaments with ABS filament

The Load at Young's modulus of three types filaments and there average values are presented in the fig.d. The Young's modulus of ABS filament varies from minimum value of 49.82M pa to maximum value 73.16 M pa. The stress Young's modulus of composite filament without decomposition varies from minimum value of 51.6 M pa to maximum value 70.68 M pa. The Young's modulus of composite filament with decomposition varies from minimum value of 35 M pa to maximum value 69.92 M pa. The average value of Young's modulus are ABS, composite filament without decomposition and composite filament with decomposition are 64.43 M pa, 54.248 M pa and 53.67M pa respectively. The Average Young's modulus of composite filament are lower than ABS filament. The lower the value indicates for given stress the strain is more it indicates ductility of filament is improved in comparison.

4.5. Comparison of tensile strain composite filaments with ABS filament

The tensile strain of three types filaments and there average values are presented in the fig.e. The tensile strain (mm) of ABS filament varies from minimum value of 0.0515mm to maximum value 0.848 mm. The tensile strain (mm) of composite filament without decomposition varies from minimum value of 0.10169 mm to maximum value 0.11467 mm. The tensile strain (mm) of composite filament with decomposition varies from minimum value of 0.11033 mm to maximum value 0.16683 mm. The average value of tensile strain (mm) are ABS, composite filament without decomposition and composite filament with decomposition0.264 mm,0.1331mm 0.102 mm respectively. The tensile strain (mm) of

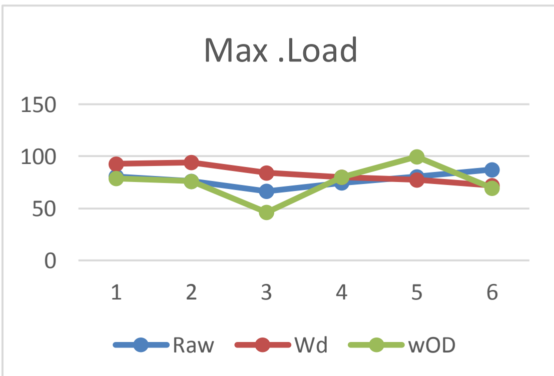


fig. a.Maximum loads of three types of filaments

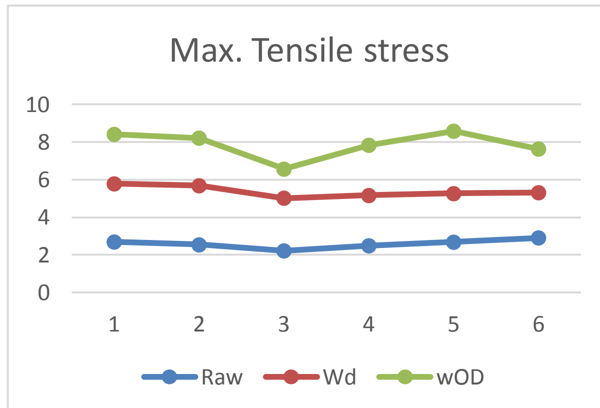


fig. b.Maximum tensile stress of three types of filaments

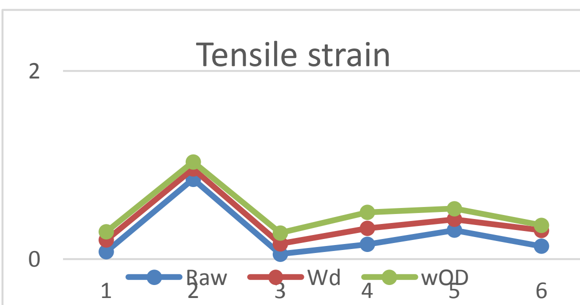


fig.c. Tensile strain of three types of filaments

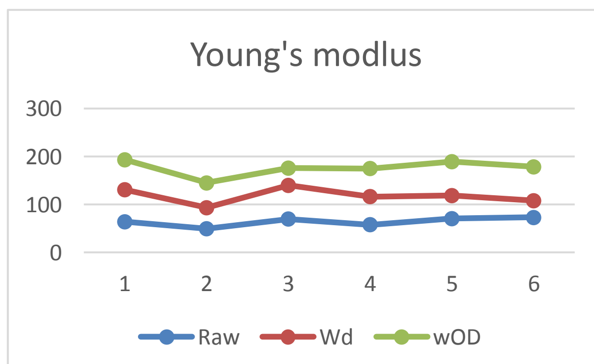


fig.d. Young's modulus of three types of filaments

composite filament with decomposition observed lowest deviation from minimum value to maximum value and the composite exhibits less strain rate, here it is observed that the composite filaments with decomposition are showing little strain rate was improved in comparison with composite filament without decomposition.

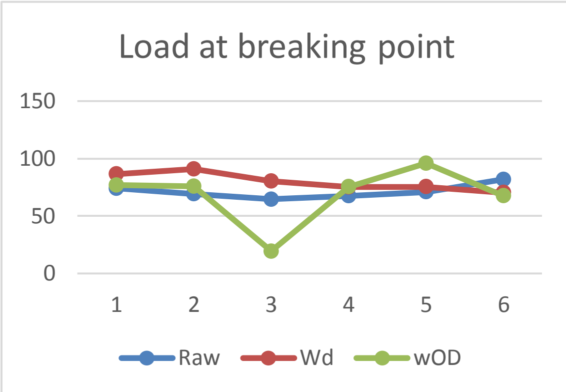


fig. e. Load at breaking point of three types of filaments

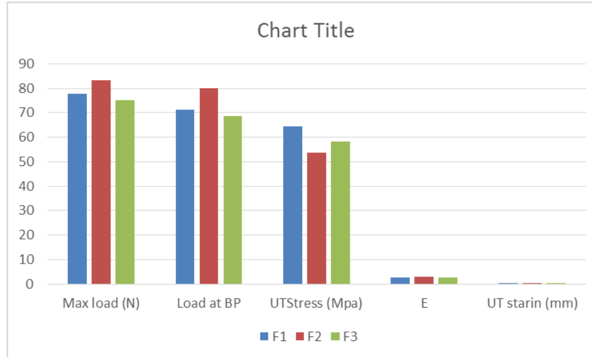


Fig.f.Average values of properties

5. CONCLUSIONS

The manufacturing and characterization of 3D FDM machine filament are fabricated by using ABS as raw material and death snail shell powder as reinforcement, with or without decomposition as reinforcement with the help of a mini-filament extruder. The ABS and composite filaments of each material produced six filaments and were tested for tensile properties; the results are summarized here. The maximum load of composite filament with decomposition observed the lowest deviation from the minimum value to the maximum value and the highest average value. The Load at the breaking point of composite filament with decomposition observed the lowest deviation from the minimum value to the maximum value and the highest average value. The Ultimate tensile stress of composite filament with decomposition observed the lowest deviation from minimum value to maximum value and the highest average value. The Average Young's modulus of composite filament is lower than ABS filament. The lower the value indicates, for a given stress, the strain is greater, which indicates the ductility of the filament is improved in comparison. The Ultimate tensile strain (mm) of composite filament with decomposition observed the lowest deviation from minimum value to maximum value, and the composite exhibits a lower strain rate. Here it is observed that composite filaments with decomposition show a lower strain rate in comparison with composite filaments without decomposition. The average values of all the properties show a minor deviation from the experiment 1 values; hence, it is concluded that the processing at 155 °C and speed 1210 gives better results. It is observed that by modifying the extrusion machine barrel length and the number of heaters with individual temperature control, the quality of filament can be improved.

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References

1. G. D. Goh1, Y. L. Yap1, S. Agarwala1, W. Y. Yeong1*Volume4, Issue1 January 2019 1800271 Advanced materials technologies Online ISSN: 2365-709X

2. W.Gao, Y. Zhang, D. Ramanujan. "The status, challenges, and future of additive manufacturing in engineering", Computer-Aided Design, 2015; 69: 65-89

3.S.Ferrandiz,D Jaurej and A.Mengual Manufacturing Engineering Society International Conference 2017, MESIC 2017, Elsiver Science Direct Procedia Manufacturing 13 (2017) 888–894.

4. Syed Muhammad Raza, Dilawar Singh Master thesis on "Experimental Investigation on Filament Extrusion using recycled materials" Halmstad University 2020-02-24 http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1417092&dswid=-4248

5. Katarzyna Mikula1 & Dawid Skrzypczak1 & Grzegorz Izydorczyk1 & Jolanta Warchołł & Konstantinos Moustakas2 & Katarzyna Chojnacka1 & Anna Witek-Krowiak "3D printing filament as a second life of waste plastics—a review" Environmental Science and Pollution Research (2021) 28:12321–12333.

6. Ruben Bayu Kristiawan, Fitrian Imaduddin*, Dody Ariawan, Ubaidillah, and Zainal Arifin A review on the fused deposition modeling (FDM) 3D printing: Filament processing, materials, and printing parameters , Open Engineering 2021; 11: 639–649, De Gruyter academic publishing, ISSN: 2391-5439

7. Biodegradable Filament for Three-Dimensional Printing Process: A Review Amrita,1,* Aluri Manoj2 and Ramesh Chandra Panda.

8. Jiang, L.; Peng, X.; Walczyk, D. 3D Printing of Biofiber-Reinforced Composites and Their Mechanical Properties: A Review. Rapid Prototyp. J. 2020, 26, 1113–1129.