*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 21, Issue 4 Ser. 1 (July. – August. 2024), PP 38-42*
*www.iosrjournals.org*

# Effect Of Process Parameters On Accuracy Of Composite Filaments For 3d Printing

Aditya T N[1], P Ravinder Reddy[1], P Ramesh Babu[2]
[1](Mechanical Department, Chaitanya Bharathi Institute Of Technology, India)
[2](Mechanical Department, University College Of Engineering, Osmania University, India)

***Abstract:*** *Fused deposition modeling is one of the addittive manufacturing technology where a thermoplastic filament is heated above its melting point and each layer deposited one over the other. In this process filament is extruded from the nozzle and 3 d printed, hence filament is vital element in the process. In this study ,composite filament of PLA(poly-lactic acid) and bioactive glass is prepared by a desktop filament extruder and the effect of process parameters like extrusion speed and temperature on the accuracy of filaments produced is studied. Bioactive glass is added in weight percentage of 2.5% to the PLA matrix. The extrusion speed of 6 rpm and temperature of 170°C is found to give the best results.*

*Background: Composites have an advantage of tailor -made properties and benefits of individual elements can be utilized. In biomedical applications, Scaffolds are structures used to support the bone and help in bone regeneration. Many materials like Metals, polymers, ceramics are used, but each of them have some inherent deficiencies. The combination of polymer and ceramics provide advantage of mechanical strength of polymer and bioactivity of bioactive glass.*

*Materials and Methods: In this study, PLA polymer of pellet size 3-5mm are mixed with 45S5 bioactive glass powder which is manufactured by sol-gel process and fed into RP desktop extruder. The mixture with various percentages is extruded with different extrusion temperatures and barrel speed and nozzle diameter of about 1.75 mm diameter to get continuous filaments.*

*Results: The accuracy of the filaments with different extrusion speeds and temperature is measured with vernier callipers and it is found that deviation to actual dimensions is very less with extrusion speed of 6 rpm and temperature of 170°C.*

*Conclusion: The composite filaments are successfully manufactured and the effect of parameters on the accuracy of the filaments produced is studied. The filaments produced can be 3d printed and Scaffolds of required dimensions can be manufactured.*

***Key Word:*** *Extrusion, PLA, Bioactive glass , filament,Accuracy.*

---

Date of Submission: 16-07-2024 Date of Acceptance: 26-07-2024

---

## I. Introduction

Bone defects which occur due to accidents or certain diseases require support material for bone growth ,polymers like polylactic acid(PLA) which are biodegradable can be 3d printed and utilized[1].Bioactive glasses, especially 45S5 bioactive glass has found to stimulate the new bone growth and has ability to strongly bond with the bone tissue[2].PLA-Bioactive glass blends has found to have positive effects on bone regeneration[3,4].Also the acidic effects of PLA degradation is neutralized by basic nature of bioactive glass[5].3d printing has found to be effective and beneficial manufacturing process as customized and complex parts can be produced[6].Fused deposition modeling is an additive manufacturing process in which thermoplastic polymer is heated above its melting point and extruded by nozzle to get the part of required geometry and dimensions[7].Composite filaments of polymer and bioactive glass can be obtained and be used in FDM process[8].

## II. Material And Methods

Polymer pellets of size 3-5 mm are procured from Terra safe industry. Bioactive glass 45S5 consisting of $SiO_2$, $Na_2O$, CaO, $P_2O_5$ with weight proportion of 45%,24.5%,24.5% and 6% is prepared by sol-gel technique. ·PLA pellets and bioactive glass powder are blended together in a single screw extruder machine. The specifications of machine are given in table no 1. The accuracy of the filaments produced is measured by digital vernier calipers. The speed of the extruded barrel is measured by using Digital Tachometer. The filament produced is collected with the help of spool winder. Figure 1 shows the extruder machine with spool winder.

**Table no 1** shows specifications of RP desktop extruder machine.

| Parameter | Value/remarks |
|---|---|
| Maximum extrusion speed | 4400mm/min |
| Materials | ABS, PLA, Nylon, wood plastic etc. |
| Operating temperature | Below 320°C |
| Temperature control accuracy | ± 1°C |
| Accuracy of filament | 1.75±0.05 mm |
| Power requirement | 220 v,50 Hz |
| Nozzle | 2 (1.8mm,3.2mm) |


**Figure 1** Desktop filament extruder machine

**Procedure methodology**

The parameters taken for extrusion are Barrel speed and Extruder temperature. Table 2 shows the factors for the parameters. Experiments are conducted according to taguchi design of experiments. L9 orthogonal array design is used and total of 9 experiments were carried out for each composition.

**Table no 2** shows process parameters and their levels.

| **Process Parameter** | **Level-1** | **Level-2** | **Level-3** |
|---|---|---|---|
| **Barrel speed** | **2 rpm** | **4 rpm** | **6 rpm** |
| **Extrusion temperature** | **165 °C** | **170 °C** | **175 °C** |

The deviation of filament diameter from the standard diameter of 1.75 mm is measured. The effect of parameters on dimensional accuracy is studied by Taguchi analysis and Analysis of Variance (ANOVA). Table 3 shows experiments conducted according to L9 orthogonal array. In Taguchi analysis S/N ratio is calculated with smaller the better characteristic as the deviation must be minimum. It is calculated using following formula

S/N ratio=$-10 \log (1/n\sum_{i=1}^{n} y_i^2)$

n is the number of observations.

$y_i$ is the observed value of the response variable for the i-th replication.

The significant parameter and the level which effects the deviation is found out by S/N ratio. Analysis of variance is studied and the main effects and interaction plots are plotted to identify the effect of variables extrusion speed and barrel temperature on deviation from the standard diameter of 1.75 mm.

**Table no 3** shows Taguchi L9 experimental design.

| **Experiment** | **Extrusion speed(rpm)** | **Extrusion temperature(°C)** |
|---|---|---|
| 1 | 2 | 165 |
| 2 | 2 | 170 |
| 3 | 2 | 175 |
| 4 | 4 | 165 |
| 5 | 4 | 170 |
| 6 | 4 | 175 |
| 7 | 6 | 165 |
| 8 | 6 | 170 |
| 9 | 6 | 175 |

## III. Result

The experiments are conducted according to sequence and deviation in diameter is measured by digital vernier calipers and table 3 , table 4 shows response table for S/N ratio and Means for 2.5 % bioactive glass

composition. From the response tables, extrusion speed has largest delta value and it is the most significant parameter effecting deviation and optimum level for extrusion speed is level 3 (6rpm) and for extrusion temperature is level 2(170°C).

**Table no 4** shows Response Table for Signal to Noise Ratios
Smaller is better

| Level | Extrusion speed | Extrusion temperature |
|---|---|---|
| 1 | 23.16 | 24.78 |
| 2 | 26.14 | 28.79 |
| 3 | 30.80 | 26.53 |
| Delta | 7.64 | 4.01 |
| Rank | 1 | 2 |

**Table no 5** shows Response Table for Means

| Level | Extrusion speed | Extrusion temperature |
|---|---|---|
| 1 | 0.07000 | 0.06000 |
| 2 | 0.05000 | 0.04000 |
| 3 | 0.03000 | 0.05000 |
| Delta | 0.04000 | 0.02000 |
| Rank | 1 | 2 |

Figure 2 and figure 3 shows main effect plots for mean and SN ratios. From figure 3 it can be observed that as the extrusion speed is increased, the deviation is decreased and hence dimensional accuracy is increased whereas best dimensional accuracy is obtained at temperature of 170°C.

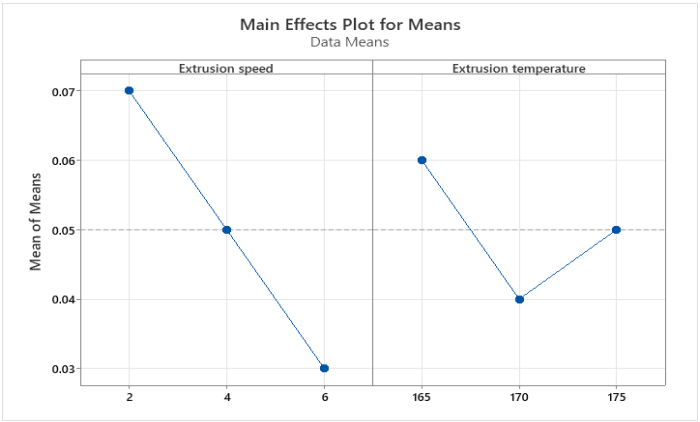


**Figure 2**: Main effects plot for Means

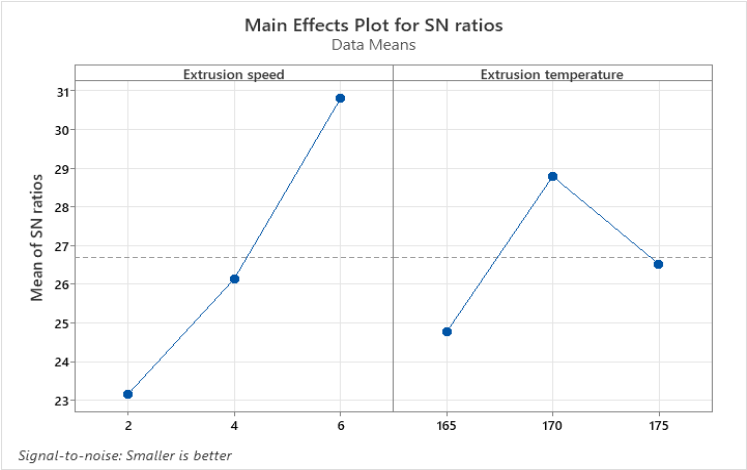


**Figure 3:** Main effects plot for SN ratios

Analysis of variance is performed to understand the effect of process parameters and their interaction effects. Figure 4 shows interaction plot. Parallel lines indicate no corelation between the factors.

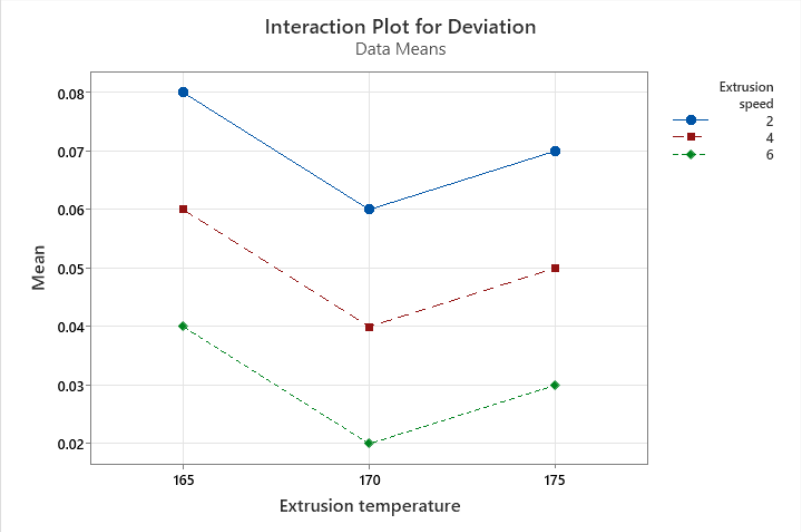


**Figure 4** Interaction plot for Deviation

## IV. Discussion

The effect of process parameters in extrusion process for manufacturing composite filament of PLA(poly-lactic acid with 2.5 % bioactive glass by weight is evaluated .Taguchi design is used to conduct experiments with L9 orthogonal array. The effect of process parameters extrusion speed, extrusion temperature on deviation from standard diameter of 1.75mm is determined.

## V. Conclusion

It is observed that extrusion speed is the most significant parameter effecting the accuracy of the filament produced. The best dimensionally accurate filament is produced with extrusion speed of 6 rpm and extrusion temperature of 170°C.The interaction effect of parameters are found to be insignificant on the dimensional accuracy of parts produced. The dimensional accuracy of filaments produced is very crucial for 3d printing as variation in filament dimension leads to clogging of nozzle of 3d printer. The study provides optimum parameters to be used for fabrication of composite filaments useful for research experiments in small scale and successful fabrication of customized parts especially finding applications in biomedical field.

## References

[1] Arif Zu, Khalid My, Noroozi R, Et Al. Recent Advances In 3d-Printed Polylactide And Polycaprolactone-Based Biomaterials For Tissue Engineering Applications. Int J Biol Macromol. 2022;218:930–968. Https://Doi.Org/10.1016/J.Ijbiomac.2022.07.140.

[2] Hench Ll, Jones Jr. Bioactive Glasses: Frontiers And Challenges. Front Bioeng Biotechnol. 2015;3:194. Https://Doi.Org/10.3389/Fbioe.2015.00194.

[3] Blaker Jj, Gough Je, Maquet V, Et Al. In Vitro Evaluation Of Novel Bioactive Composites Based On Bioglass-Filled Polylactide Foams For Bone Tissue Engineering Scaffolds. J Biomed Mater Res A. 2003;67(4):1401–1411. Https://Doi.Org/10.1002/Jbm.A.20055.

[4] Roether Ja, Boccaccini Ar, Hench Ll, Et Al. Development And In Vitro Characterisation Of Novel Bioresorbable And Bioactive Composite Materials Based On Polylactide Foams And Bioglass For Tissue Engineering Applications. Biomaterials. 2002;23(18):3871–3878. Https://Doi.Org/10.1016/S0142-9612(02)00131-X.

[5] Lyyra I, Leino K, Hukka T, Hannula M, Kellomäki M, Massera J. Impact Of Glass Composition On Hydrolytic Degradation Of Polylactide/Bioactive Glass Composites. *Materials*. 2021; 14(3):667. Https://Doi.Org/10.3390/Ma14030667.

[6] Ngo, T.D.; Kashani, A.; Imbalzano, G.; Nguyen, K.T.Q.; Hui, D. Additive Manufacturing (3d Printing): A Review Of Materials, Methods, Applications And Challenges. Compos. Part B Eng. 2018, 143, 172–196.

[7] Zhang, P.; Wang, Z.; Li, J.; Li, X.; Cheng, L. From Materials To Devices Using Fused Deposition Modeling: A State-Of-Art Review. Nanotechnol. Rev. 2020, 9, 1594–1609.

[8] Distler, T.; Fournier, N.; Grünewald, A.; Polley, C.; Seitz, H.; Detsch, R.; Boccaccini, A.R. Polymer-Bioactive Glass Composite Filaments For 3d Scaffold Manufacturing By Fused Deposition Modeling: Fabrication And Characterization. Front. Bioeng. Biotechnol. 2020, 8, 552.

[9] T.N. Aditya, P. Ravinder Reddy, P. Ramesh Babu, "Development And Characterization Of Polymer Ceramic Composite For Biomedical Application," Ssrg International Journal Of Mechanical Engineering, Vol. 11, No. 6, Pp. 1-6, 2024. Crossref, Https://Doi.Org/10.14445/23488360/Ijme-V11i6p101.

[10] Ramadhan, M.E.; Darsin, M.; Akbar, S.I.; And Yudistiro, D. Dimensional Accuracy Of 3d Printed Polypropylene Filament Using Extrusion Machine. Teknosains, 2022. 11(2), 162-173

[11] .Haq, R.H.A.; Wahab, M.S.; And Jaimi, N.I. Fabrication Process Of Polymer Nano-Composite Filament For Fused Deposition Modelling. Applied Mechanics And Materials, 2014. 465, 8-12
[12] Selvamani, S.K.; Rajan K.; Samykano, M.; Kumar, R.R.; Kadirgama, K. And Mohan, R.V.. Investigation Of Tensile Properties Of Pla–Brass Composite Using Fdm. Progress In Additive Manufacturing, 2022 ,7(5), 839-851.
[13] Zekavat A.R.; Jansson, A.; Larsson, J.; And Pejryd, L. Investigating The Effect Of Fabrication Temperature On Mechanical Properties Of Fused Deposition Modelling Parts Using X-Ray Computed Tomography. The International Journal Of Advanced Manufacturing Technology, 2019, 100, 287–296.
[14] Irawan, C.; Arifvianto, B.; And Mahardika, M. The Effect Of Extrusion Temperature On Physical, Chemistry And Mechanical Strength Using Ultra High Molecular Weight Polyethylene (Uhmwpe) Filament. Jurnal Teknologi Terapan, 2021 7(2), 76-85.
[15] Grasso, M.; Azzouz, L.; Ruiz-Hincapie, P.; Zarrelli, M.; And Ren, G. Effect Of Temperature On The Mechanical Properties Of 3d-Printed Pla Tensile Specimens. Rapid Prototyping Journal, 2018, 24(8), 1337-1346.
[16] Whulanza, Y.; And Setiawan, J. Realitization And Testing Of Mini Extruder For Biomaterial Filament In Biomedical Application. Journal Of Energy, Mechanical, Material And Manufacturing Engineering, 2017. 1(1), 17-22
[17] Taufik, I.; Budiono, H.S.; Herianto, H.; And Andriyansyah, D. Influence Of Printing Speed To Roughness Products Of Additive Manufacturing Using Polylactic Acid Filament. Journal Of Mechanical Engineering, 2020, 4(2), 15-20.
[18] X. Wang, M. Jiang, Z. Zhou, J. Gou, And D. Hui, "3d Printing Of Polymer Matrix Composites: A Review And Prospective," Compos. Part B Eng., 2017 , 110, 442–458,