Improving the Strength of Acrylonitrile Butadiene Styrene Filament Used in the 3D Printer: A Review

Mehtab Alam[1], Dr. Mohd Anas[2]

[1]*M.Tech, Production and Industrial Engineering, Integral University, Lucknow, India.*
[2]*Associate Professor, Department of Mechanical Engineering, Integral University, Lucknow, India.*

---***---

Abstract - *This review paper studied to increase the strength of the Acrylonitrile Butadiene Styrene filament with a different technique, and a summary of all research papers is available in the literature survey. The demand for 3D printed materials has increased as the number of people using 3D printers has grown. Several materials have been used to experiment with the printing process since the invention of this technology. The materials that can be printed range from polymers to biological tissues. According to a Forbes survey from 2018, plastics are the most widely used 3D printing materials, accounting for around 88 percent of all materials used globally. This is due to the low cost and widespread availability of plastics. Plastics have a better processability than most other 3D printing materials.*

ABS is appropriate for 3D printing because to its thermoplastic nature. ABS has unique mechanical capabilities due to its composition, including excellent toughness, impact resistance, stiffness, and strength. As a result, ABS is used in a wide range of products, from everyday things to automobile parts and complex medical gadgets. The challenge of how to recycle and dispose of the material arose as a result of the increased demand and consumption of the material. Any incorrect disposal of ABS poses a significant environmental risk. As a result, there is more room for study on ABS recycling patterns.

Key Words: 3D printer, filament, Strength, Acrylonitrile Butadiene Filament, the strength of the filament.

1. INTRODUCTION

Market statistics suggest that income from 3D-printer vending and services quadrupled between 2009 and 2013, and maintain to expand significantly (Park, 2014). Even though these technologies "were initially meant primarily for (heavy) industrial usage," "continuous cost reductions have brought them within reach of [subject matter experts] SMEs and individual entrepreneurs". Moreover, client markets uncover Associate in Nursing expanding propensity by and large deals in organizations like Staples and Walmart (Rayna and Striukova, 2016). on-line retailers like 3DXTech (2017a), Stratasys (2017), and Makerbot (2017) sell restrictive materials along with their synthetic substances, while Amazon, eBay, and various merchants sell outsider materials and 3D printing administrations to ordinary clients and huge producers (Rayna and Striukova, 2016,). Through a layering approach, 3D printing employs computer-aided design (CAD) to build three-dimensional things. 3D printing, also known as additive manufacturing, is the process of stacking materials such as plastics, composites, or bio-materials to make items that vary in shape, size, stiffness, and colour. The figure of the 3D printer are given below:

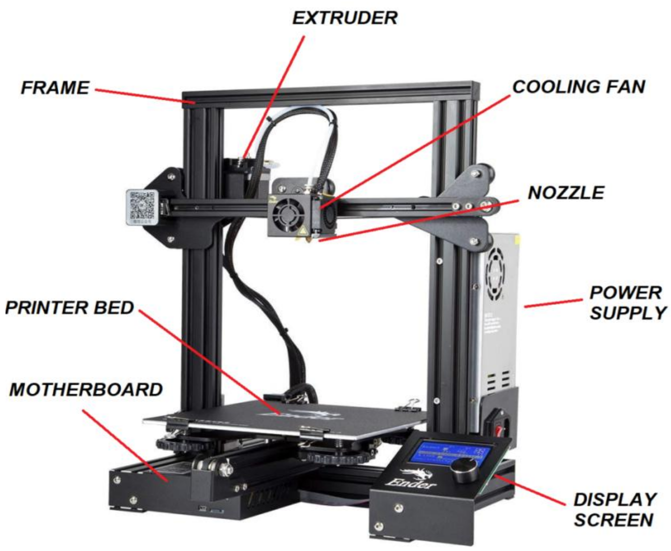

Figure-1: 3D Printer

1.1. Principle of Working

3D printers are part of the additive manufacturing family and work in a similar way to inkjet printers, although in three dimensions. To make a three-dimensional thing from scratch, you'll need a combination of top-of-the-line software, powder-like materials, and precise equipment.

1.2. ABS Filament

ABS is manufactured from the monomers Acrylonitrile, 1,3-Butadiene, and Styrene, as well as petroleum. This kind of plastic is noted for its strength and resistance to impact. This filament will allow you to print long-lasting 3D items that will withstand a lot of use and wear.

White is the colour of a raw version of ABS material. It may simply be dyed to your prefered hue throughout the production process because to its neutral colour. The ABS filament figure is as follows:

Figure-2: ABS Filament

2. REVIEW OF THE LITERATURE

The relevant literature has looked into fused deposition modelling (FDM), ABS with a discussion of tensile strength, carbon fibre reinforcing in ABS with a discussion of tensile strength, CFR ABS producers, and tensile strength changes dependent on the orientation of 3D printed strands.

2.1. Fused Deposition Modeling (FDM).

According to Brooks, Kinsley, and Owens (2014), S. Scott Crump, who co-founded Stratasys, introduced FDM in the 1980s and began developing it into what we know as FDM today. Since the patent on FDM expired, the cost of commercial 3D printers has dropped dramatically as more businesses and open-source communities embrace the idea of creating a machine or material for one. According to these academics, "businesses are now beginning to grasp the possibility of employing this technology inside their business model for competitive advantage" since FDM's inception. Companies can, for example, utilize a wide range of materials to service a greater range of clients.

FDM techniques may make a broad variety of items such as "prototyping, tooling, and manufactured goods" from several materials such as "paper, nylon, wax, resins, metals, and ceramics," according to Bhargava, Bhargava, and Jangid (2014). "A wide range of sectors, including automotive, aerospace, medicinal, consumer, electrical, and electronic devices, can benefit from FDM," the researchers conclude (p. 4). FDM has this benefit because, "unlike certain additive production techniques, FDM requires no specific equipment or ventilation and includes no toxic chemicals or by-products." Furthermore, parts created with FDM are ready to use with "very little delay and work," while also removing expensive components like tooling"Additive manufacturing (AM)" (Fudali, Witkowski, & Wydrzyski, 2013) refers to "production systems that generate products through a sequential layering process." Fused Filament Fabrication (FFF), also known as fused deposition modeling (FDM), and 3D printing are two of these technologies. 3D printing "refers to a class of technologies for the direct fabrication of physical products from a 3D computer-aided design (CAD) model by a layered manufacturing process" 3D printing "alludes to a class of innovations for the immediate creation of an actual product from a 3D pc helped style (CAD) model by a slept with delivering process" (Huang, et al., 2012). AM is utilized to make a virtual 3D model of an item that might be 3D composed. Successive level cross segments are arranged exploitation programming bundles, and each cross segment is imagined as a second mathematical item with a firm level.

By expelling a thin strand of a semi-molten thermoplastic, typically ABS, through an intensity safe spout/opening, a 3D printer produces (or develops) structures for each layer in turn (Berman, 2007; NovakovaMarcincinova and Kuric, 2012). The flat thin cut of the model made by programming bundle is constructed utilizing a spooled fiber of thermoplastic, typically.07 inches (1.75 mm) or.12 in. (3 mm) in width. The fiber is warmed to an arranged temperature degree and expelled using a little spout (with a roundabout opening usually.0079 in. (.2 mm) to.28 inches (.7 mm) in breadth) to get down a strand of plastic onto a form stage to that the underlying layer of plastic rapidly joins. further courses are made till the layer is finished. Shell strands are unexceptionally put down on the border of every layer of the model. Inside locales are normally molded of strands set down at a framed point, (for example, +45° to the build platform's x-axis, which runs left and right) if the model is mentioned to be made with a strong inside (NovakovaMarcincinova and Kuric, 2012). when the machine advances to the resulting layer by tricky the forming stage somewhere near the number simple by each layer thickness, the ensuing layer is huge opposite to and on prime of the past layer (for instance, at 45° to the x-axis), any place it sticks. Inside zones in certain models aren't strong anyway typify honeycomb or option mathematical material directions to try not to squander material utilization, development time, or model thickness.

Upholds are likewise made once there are essential shades of 3D composed material or on the other hand on the off chance that a superior layer is ineffectively upheld in certain areas by the layer underneath it (at times with dissolvable or generally basically removable materials). when the model's bond to the forming stage is lean, a specific arrangement of establishment layers known as a pontoon or an edge is made (as a pristine stage for the model to be planned on) to keep away from it from getting unstuck all through creation. Pontoons overflow, and supports are eliminated once the model has huge. the texture follows the CAD model's cross-sectional structure layer by layer all through the expulsion strategy, at long last changing into the concluded item.

2.2. Acrylonitrile Butadiene Styrene (ABS)

The beginnings of ABS plastic (chemical formula mentioned above) may be traced back to the mid-1940s, according to

Olivera, Muralidhara, Venkatesh, Gopalakrishna, and Vivek, (2016). The initial formulation omitted butadiene (C4H6), which produced problems in the acrylonitrile styrene copolymer. Bulletproof armor was manufactured in World War II after combining this rubber monomer and forming the terpolymer we now know as ABS, which had strong impact resistance and "poor thermoplastic flow characteristics." "Great toughness (even in freezing circumstances), acceptable stiffness, strong thermal stability, and high resistance to chemical assault and environmental stress cracking characterize ABS polymers." ABS is a highly sought-after thermoplastic in engineering, according to Ghanbari (2014), because of its numerous desirable attributes, which include but are not limited to: "acceptable mechanical properties, chemical resistance, and adequate processing characteristics."

(C8H8 C4H6 C3H3N)n

Numerous far and wide properties semiconductor diode to the reception of ABS in fields like trim, any place parts like lines were made, following Olivera et al. (2016). In the Nineteen Fifties, ABS made its methodology into fields like "materials, style, toys, and private purposes." ABS was started used in 3D printing inside the Nineties, as a result of added substance delivery systems. "Common ABS consolidates a dissolving or mellowing reason somewhere in the range of 401 and 473 degrees Gabriel Daniel Fahrenheit (205 and 245 degrees Celsius), that considers direct utilization in many business 3D printers," Satches (2015) composes.

"ABS might be a far and wide designing thermoplastic, and it's the chief successive material used in amalgamated statement demonstrating (FDM) innovation," composes Savvakis (2014). ABS is open in a real type of synthetic structures, as well as expulsion grade, plating grade, and shaped grade (Mat web, 2017a); subsequently, a satisfactory compound synthesis of ABS should be picked for a specific expulsion application. relax stream file, water assimilation, lastingness, and warm conduction are a large number of the requirements which might disallow these gifts (Mat web, 2017b). once referencing, Savvakis et al. (2014) give understanding into the acknowledgment of study designated on this substance.

ABS is broadly utilized in an extreme type of area because of its particular capacities, which encapsulate pleasant mechanical reactions, synthetic obstruction, fine surface end, and exceptional cycle qualities. Thus, different investigations are led to gauge the mechanical attributes of this material and its composites underneath various things and to build up those characteristics.

These attributes will be worked on in an extreme type of ways that. Vairis, Petousis, Vidakis, and Savvakis (2016) examined the impact of strain rate on the lastingness of ABS and ABS models and found that a specialist layer thickness (in contrast with any or all various models assessed) was the least difficult option for greater lastingness discoveries. The objective of this study was to "assess anyway changed check speeds influence the mechanical strength of 3D composed things." Solid ABS three-dimensional composed examples with a 45-degree infill point had rigid qualities beginning from 3,190 psi (22 MPa) to five,221 psi (36 MPa).

According to Tymrak, Kreiger, and Pearce (2014). "The fundamental tensile strength and elastic modulus of produced components under realistic environmental circumstances for standard users of a variety of open-source 3D printers," these experts said. "The link between deposition pattern orientation and layer height to tensile strength, strain at tensile strength, and modulus" was investigated in the paper. They claimed a final average tensile strength of 4,133 psi for their 3D printed ABS pieces (28.5 MPa). When creating items on 3D printers, the researchers pointed out that various options and other factors must be considered. "Settings, tuning, and operation of each unique printer, as well as the kind, age, and quality of polymer filament used" are only a few of them. "Within the limitations of their mechanical qualities, functionally strong components may be manufactured with open source 3D printers," the researchers conclude.

2.3. Carbon Fiber Reinforcement (CFR) / Loading In 3D Printing.

Carbon fibers are anisotropic and contain at least 92 wt percent carbon (Huang, 2009, p. 2369). Graphite fiber is a fiber that contains at least 99 percent carbon by weight. Anisotropic properties may improve the strength of 3D printing materials in particular orientations. Some physical characteristics of carbon fibers that refer to anisotropy include, but are not limited to, being brittle or easily damaged, not absorbing water, not changing dimensions in humid environments (Vasiliev & Morozov, 2013), and "yields different values of mechanical and thermal characteristics in the longitudinal and transverse directions."

These researchers "examined the potential for load-bearing components in particular...results reveal that composites with highly dispersed and highly orientated carbon fibers may be manufactured using the FDM technique [sic]," according to the researchers. They discovered that within test samples, fibers are primarily orientated in the direction in which the material is deposited on the 3D printer build platform, enhancing tensile strength.

As indicated by Tekinalp et al. (2014), carbon filaments have a brilliant potential for load support, though the thermoplastic framework ties, encompasses, and safeguards the carbon strands while conjointly moving the strain to them. Carbon fiber incorporates a more grounded lastingness than ABS (Fernandez Vicente, Calle, 2014) and would so legitimately work to help it once extra to its science. "One of the possible methods is embedding reinforced materials (like carbon strands) into plastic materials to make thermoplastic framework carbon fiber fortified plastic (CFRP) composites," Carbon fiber fortifications in thermoplastics square measure utilized in area designing, the auto area, medical procedure/other clinical activities, and property drives, per Biron (as referenced in Ning et al., 2015).

3. CONCLUSION

After studying all the above research papers, the following conclusion found which are given below:

The increasing biomass loading caused a decrease in melt flow and impact strength and an increase in flexural modulus for both biodegradable polylactide/hemp hurd and biodegradable polylactide/BP biocomposites, increased tensile strength and flexural strength for biodegradable polylactide/ hemp hurd whereas decreased corresponding properties for biodegradable polylactide/ bamboo powder, attributed to the reinforcement by hemp hurds with fibrillary structure and enhanced interfacial adhesion between hemp hurd and polymer matrix. The surface roughness of fused deposition modeling -printed items was negligibly affected by the particle size of biomass when it was less than the printing layer thickness. Only when the particle size was larger than the printing layer thickness, the surface roughness would increase.

REFERENCE

[1] T. Pereira, J.V. Kennedy, J. Potgieter, A comparison of traditional manufacturing vs additive manufacturing, the best method for the job, Procedia Manuf. 30 (2019) 11–18. https://doi.org/10.1016/j.promfg.2019.02.003.

[2] B.P. Conner, G.P. Manogharan, A.N. Martof, L.M. Rodomsky, C.M. Rodomsky, D.C. Jordan, J.W. Limperos, Making sense of 3-D printing: Creating a map of additive manufacturing products and services, Addit. Manuf. 1–4 (2014) 64–76. https://doi.org/10.1016/j.addma.2014.08.005.

[3] T. Peng, K. Kellens, R. Tang, C. Chen, G. Chen, Sustainability of additive manufacturing: An overview on its energy demand and environmental impact, Addit. Manuf. 21 (2018) 694–704. https://doi.org/10.1016/j.addma.2018.04.022.

[4] A. García-Dominguez, Claver, M.A. Sebastián, Integration of Additive Manufacturing, Parametric Design, and Optimization of Parts Obtained by Fused Deposition Modeling (FDM). A Methodological Approach, Polymers. 12 (2020) 1993. https://doi.org/10.3390/polym12091993.

[5] A. Haleem, M. Javaid, Additive Manufacturing Applications in Industry 4.0: A Review, J. Ind. Integer. Manag. 04 (2019) 1930001. https://doi.org/10.1142/S2424862219300011.

[6] J. Faludi, C. Bayley, S. Bhogal, M. Iribarne, Comparing environmental impacts of additive manufacturing vs traditional machining via life-cycle assessment, Rapid Prototyp. J. 21 (2015) 14–33. https://doi.org/10.1108/RPJ-07-2013-0067.

[7] M. Attaran, The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing, Bus. Horiz. 60 (2017) 677–688. https://doi.org/10.1016/j.bushor.2017.05.011.

[8] D. Bourell, J.P. Kruth, M. Leu, G. Levy, D. Rosen, A.M. Beese, A. Clare, Materials for additive manufacturing, CIRP Ann. 66 (2017) 659–681. https://doi.org/10.1016/j.cirp.2017.05.009.

[9] D. Han, H. Lee, Recent advances in multi-material additive manufacturing: methods and applications, Curr. Opin. Chem. Eng. 28 (2020) 158–166. https://doi.org/10.1016/j.coche.2020.03.004.

[10] S. Upcraft, R. Fletcher, The rapid prototyping technologies, Assem. Autom. 23 (2003) 318–330. https://doi.org/10.1108/01445150310698634.

[11] A. Bandyopadhyay, B. Heer, Additive manufacturing of multi-material structures, Mater. Sci. Eng. R Rep. 129 (2018) 1–16. https://doi.org/10.1016/j.mser.2018.04.001.

[12] I. Ribeiro, F. Matos, C. Jacinto, H. Salman, G. Cardeal, H. Carvalho, R. Godina, P. Peças, Framework for Life Cycle Sustainability Assessment of Additive Manufacturing, Sustainability. 12 (2020) 929. https://doi.org/10.3390/su12030929.

[13] J. Liu, A.T. Gaynor, S. Chen, Z. Kang, K. Suresh, A. Takezawa, L. Li, J. Kato, J. Tang, C.C.L. Wang, L. Cheng, X. Liang, Albert.C. To, Current and future trends in topology optimization for additive manufacturing, Struct. Multidiscip. Optim. 57 (2018) 2457–2483. https://doi.org/10.1007/s00158-018-1994-3.

[14] M. Orme, I. Madera, M. Gschweitl, M. Ferrari, Topology Optimization for Additive Manufacturing as an Enabler for Light Weight Flight Hardware, Designs. 2 (2018) 51. https://doi.org/10.3390/designs2040051.

[15] V. Kandemir, O. Dogan, U. Yaman, Topology optimization of 2.5D parts using the SIMP method with a variable thickness approach, Procedia Manuf. 17 (2018) 29–36. https://doi.org/10.1016/j.promfg.2018.10.009.

[16] G.W. Melenka, J.S. Schofield, M.R. Dawson, J.P. Carey, Evaluation of dimensional accuracy and material properties of the MakerBot 3D desktop printer, Rapid Prototyp. J. 21 (2015) 618–627. https://doi.org/10.1108/RPJ-09-2013-0093.

[17] U.M. Dilberoglu, B. Gharehpapagh, U. Yaman, M. Dolen, The Role of Additive Manufacturing in the Era of Industry 4.0, Procedia Manuf. 11 (2017) 545–554. https://doi.org/10.1016/j.promfg.2017.07.148.

[18] T.D. Ngo, A. Kashani, G. Imbalzano, K.T.Q. Nguyen, D. Hui, Additive manufacturing (3D printing): A review of materials, methods, applications, and challenges, Compos. Part B Eng. 143 (2018) 172–196. https://doi.org/10.1016/j.compositesb.2018.02.012.

[19] K.R. Ryan, M.P. Down, C.E. Banks, Future of additive manufacturing: Overview of 4D and 3D printed smart and advanced materials and their applications, Chem. Eng. J. 403 (2021). https://doi.org/10.1016/j.cej.2020.126162.

[20] L. Hirt, A. Reiser, R. Spolenak, T. Zambelli, Additive Manufacturing of Metal Structures at the Micrometer Scale, Adv. Mater. 29 (2017) 1604211. https://doi.org/10.1002/adma.201604211.

[21] S. Lim, R.A. Buswell, T.T. Le, S.A. Austin, A.G.F. Gibb, T. Thorpe, Developments in construction-scale additive manufacturing processes, Autom. Constr. 21 (2012) 262–268. https://doi.org/10.1016/j.autcon.2011.06.010.

[22] H. Bikas, P. Stavropoulos, G. Chryssolouris, Additive manufacturing methods, and modeling approaches A critical review, Int. J. Adv. Manuf. Technol. 83 (2016) 389–405. https://doi.org/10.1007/s00170-015-7576-2.

[23] A.A. Bakır, Atik, S. Özerinç, Mechanical properties of thermoplastic parts produced by fused deposition modeling: a review, Rapid Prototyp. J. 27 (2021) 537–561. https://doi.org/10.1108/RPJ-03-2020-0061.

[24] N. Volpato, J. Aguiomar Foggiatto, D. Coradini Schwarz, The influence of support base on FDM accuracy in Z, Rapid Prototyp. J. 20 (2014) 182–191. https://doi.org/10.1108/RPJ-12-2012-0116.

[25] G.P. Kumar, S.P. Regalla, Optimization of Support Material and Build Time in Fused Deposition Modeling (FDM), Appl. Mech. Mater. 110–116 (2011) 2245–2251. https://doi.org/10.4028/www.scientific.net/AMM.110-116.2245.

[26] J. Vanek, J. a. G. Galicia, B. Benes, Clever Support: Efficient Support Structure Generation for Digital Fabrication, Comput. Graph. Forum. 33 (2014) 117–125. https://doi.org/10.1111/cgf.12437.

[27] S.L. Messimer, A.E. Patterson, N. Muna, A.P. Deshpande, T. Rocha Pereira, Characterization and Processing Behavior of Heated Aluminum-Polycarbonate Composite Build Plates for the FDM Additive Manufacturing Process, J. Manuf. Mater. Process. 2 (2018) 12. https://doi.org/10.3390/jmmp2010012.

[28] K. Singh, Experimental study to prevent the warping of 3D models in fused deposition modeling, Int. J. Plast. Technol. 22 (2018) 177–184. https://doi.org/10.1007/s12588-018-9206-y.

[29] A.S. de León, A. Domínguez-Calvo, S.I. Molina, Materials with enhanced adhesive properties based on acrylonitrile-butadiene-styrene (ABS)/thermoplastic polyurethane (TPU) blends for fused filament fabrication (FFF), Mater. Des. 182 (2019) 108044. https://doi.org/10.1016/j.matdes.2019.108044.

[30] T.-M. Wang, J.-T. Xi, Y. Jin, A model research for prototype warp deformation in the FDM process, Int. J. Adv. Manuf. Technol. 33 (2007) 1087–1096. https://doi.org/10.1007/s00170-006-0556-9.

[31] R. Polak, F. Sedlacek, K. Raz, Determination of FDM Printer Settings about Geometrical Accuracy, in B. Katalinic (Ed.), DAAAM Proc., 1st ed., DAAAM International Vienna, 2017: pp. 0561–0566. https://doi.org/10.2507/28th.daaam.proceedings.079.

[32] M.S. Alsoufi, A.E. Elsayed, How Surface Roughness Performance of Printed Parts Manufactured by Desktop FDM 3D Printer with PLA+ is Influenced by Measuring Direction, Am. J. Mech. Eng. 5 (2017) 211–222. https://doi.org/10.12691/ajme-5-5-4.

[33] R. Singh, S. Singh, I.P. Singh, F. Fabbrocino, F. Fraternali, Investigation for surface finish improvement of FDM parts by vapor smoothing process, Compos. Part B Eng. 111 (2017) 228–234. https://doi.org/10.1016/j.compositesb.2016.11.062.

[34] I. Gajdoš, E. Spišák, L. Kaščák, . Krasinskyi, Surface Finish Techniques for FDM Parts, Mater. Sci. Forum. 818 (2015) 45–48. https://doi.org/10.4028/www.scientific.net/MSF.818.45.

[35] N. Jayanth, P. Senthil, C. Prakash, Effect of chemical treatment on tensile strength and surface roughness of 3D-printed ABS using the FDM process, Virtual Phys. Prototyp. 13 (2018) 155–163. https://doi.org/10.1080/17452759.2018.1449565.

[36] F. Rayegani, G.C. Onwubolu, Fused deposition modeling (FDM) process parameter prediction and optimization using group method for data handling (GMDH) and differential evolution (DE), Int. J. Adv. Manuf. Technol. 73 (2014) 509–519. https://doi.org/10.1007/s00170-014-5835-2.

[37] R. Coelho de Macedo, R.T.L. Ferreira, K. Jayachandran, Determination of mechanical properties of FFF 3D printed material by assessing void volume fraction, cooling rate and residual thermal stresses, Rapid Prototyp. J. 25 (2019) 1661–1683. https://doi.org/10.1108/RPJ-08-2018-0192.

[38] A.A. Bakır, Atik, S. Özerinç, Effect of fused deposition modeling process parameters on the mechanical properties of recycled polyethylene terephthalate parts, J. Appl. Polym. Sci. (2020) 49709. https://doi.org/10.1002/app.49709.

[39] M. Schouten, G. Wolterink, A. Dijkshoorn, D. Kosmas, S. Stramigioli, G. Krijnen, A Review of Extrusion-Based 3D Printing for the Fabrication of Electro- and Biomechanical Sensors, IEEE Sens. J. 21 (2021) 12900–12912. https://doi.org/10.1109/JSEN.2020.3042436.

[40] I. Calafel, .H. Aguirresarobe, M.I. Peñas, A. Santamaria, M. Tierno, .I. Conde, B. Pascual, Searching for Rheological Conditions for FFF 3D Printing with PVC Based Flexible Compounds, Materials. 13 (2020) 178. https://doi.org/10.3390/ma13010178.

[41] M. Vaezi, S. Chianrabutra, B. Mellor, S. Yang, Multiple material additive manufacturing – Part 1: a review, Virtual Phys. Prototyp. 8 (2013) 19–50. https://doi.org/10.1080/17452759.2013.778175.