Design and Development of a Small-Scale Pellet Extrusion System for 3D Printing Biopolymer Materials and Composites

by

Sean Matthew Whyman

Submitted to the School of Engineering and Advanced Technology
in partial fulfillment of the requirements for the degree of

Master of Engineering
Mechatronics

at

Massey University, Auckland

Feb 2018

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School of Engineering and Advanced Technology
Feb 28, 2018

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Abstract

The aim of this research project is to develop a pellet-based 3D printing system that will accept biopolymer pellets to experiment with composite additives. Currently a majority of easily accessible or hobbyist 3D printers use filament as the input material for extrusion. With the goal in mind of printing using biopolymer materials and additive mixes, using filament remains achievable, but it would not provide as much freedom and exploration into unexplored areas. This can be an issue on the research side and a restriction on the hobbyist or consumer side where the material variety and printing capabilities such as recycling are much harder to achieve if not out of reach.

This research report presents the process of designing and developing a pellet-based extrusion system to accept a range of biopolymer pellets for 3D printing. The system has been designed from first principles and therefore can be extended to other materials with slight parameter adjustments or hardware modifications. A robust mechatronic design has been developed using an unconventional yet simplistic approach to achieve the desired operating characteristics. The extrusion system uses a series of control factors to generate a consistent output of material over the course of a print. The platform and surrounding processes are setup so that software can be used to define the printing parameters, thus allowing for easy and simple adaption to dissimilar materials. The utility of the extruder is demonstrated through extensive printing and testing of the printed parts.

Using Polylactic Acid (PLA) as the base material to test and develop the extruder system, the results of the print quality evolved as the extruders design became more robust. Several factors of the extruder contributed to large improvements such as; the hoppers rigidity, the internal geometries, the cooling efficiency and the software parameters. As these features progressed it enabled a much finer print quality and dimensional accuracy similar to what is seen in current Fused Deposition Modelling (FDM) extruders today. The print comparison tests were carried out against FDM

PLA samples to reveal a high similarity in mechanical strength and improvements to some areas of surface quality. Further testing revealed success in testing other materials such as PETG, as well as successfully mixing and extruding Harakeke flax fiber composite additives.

The major limiting factor of the current design is its ability to withstand heat propagation up through the extrusion system. As higher temperatures are required to melt different polymers, the thermal tolerance of the drive motor will quickly reduce causing inconsistencies earlier on during printing. The water cooling block added into the design only prevent heat from travelling through the wall of the extruder and not the screw. A further limitation is that the extruder is made using aluminium as the material. This allows for quick start-up times, but it also wears at a fast rate and the shaved off aluminium ends up contaminating the processed material.

Because this extruder accepts pellets, the range of possibilities for future applications is vast. With further improvements to better refine the process, the material range could expand to more unconventional materials that otherwise could not be printed using popular extrusion methods. As for a business sense, there are few well known methods of pellet printing and especially affordable systems. Therefore, an opportunity could be present to develop a commercially affordable desktop system or spin-off to enter a niche market.

Thesis Supervisors: Dr. Khalid Arif, A/Prof. Johan Potgieter

Acknowledgments

I am grateful for having such a supportive family to which I can rely on in times of need. To my Mother Claire and sibling Brooke, for providing an emotional pillow to help even out the bumpy road and soften any tumbles that occur along the way. To my Father Lee for starting me off on my journey and providing the barriers to my path, keeping me from going astray. He has given me the tools to get me to where I want to be, and for that I cannot thank him enough. I am also grateful to all my other family members and friends who have supported me along the way.

A great thank you to A/Prof. Johan Potgieter for not only being my supervisor, but for taking the time to sort out issues, finding the financial support for my Master's degree and being behind the scenes throughout my entire university degree. A special thank you to Dr. Khalid Arif, for providing long term guidance through undergraduate mentorship and in postgraduate supervision. He is always there to offer his thoughts, providing both focus and encouragement. But more than that, He applies himself to become personally involved with projects and students, thus offering a more structured growth, both personally and professionally. For this I thank him. Further thanks go to Dr. Frazer Noble and all the other staff members in the school of engineering that have poured effort into my university journey.

This research was part of the Extrusion Plus program led by Scion New Zealand, and funded by the Ministry of Business, Innovation, and Employment (MBIE) funding under High Value Manufacturing and Services (HVMS) Enabling Technologies investment contract. A special thanks to Dr. Marie-Joo Le Guen for providing the materials and related expertise.

A special mention to a close group of friends, Andrew Kvalsvig, Cameron Mearns, Dion Mansfield and Hayden Wilson who have stuck by one another from the beginning, through thick and thin, both in and around the workplace. I also appreciate the company of Arno Ferreira, Tim Sutcliffe, Mitchell Hampton and Blair Dixon for providing a stress relief and comedic encouragement around the workplace. I am grateful to Tatiana Daysh for the support and assistance offered, as well as the general company to help balance out the everyday chaos that sometimes occurs.

Without this collective group of people, I would not have ventured this far, I thank you all for the encouragement and look forward to the future.

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