OPTIMISATION OF ENTRY-LEVEL 3D PRINTERS TO IMPROVE THE QUALITY OF PRINTED PRODUCTS

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Abstract – This work in progress describes certain aspects that must be controlled in and around an entry-level rapid prototyping 3-dimensional technology platform to investigate printing quality and optimisation of the process.

Index Terms — Rapid Prototyping, Additive Manufacturing, Entry-level Rapid Prototyping, Bow Warping.

I. INTRODUCTION

Rapid Prototyping (RP) or Additive Manufacturing (AM) technology can be better explained as a layer-by-layer printing process, adding new material with each layer. With the help of a Computer Aided Design (CAD) model, physical 3-Dimentional (3D) models can be printed. Specific printing software converts the computer-generated CAD image into horizontal slices. The slice thicknesses are determined by the user's preference and also the 3D printer's limitations [1]. Figure 1 demonstrates a computer designed toy model. All the necessary components can be printed and assembled to develop a fully functional product.

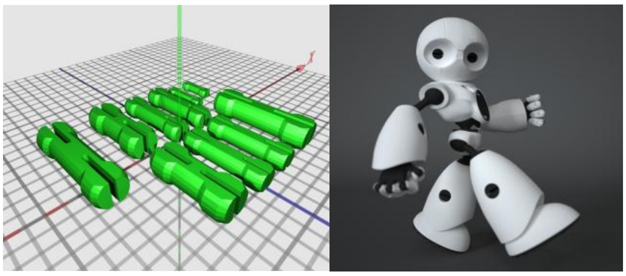

Figure 1 Mark II toy model designed by P. Ferro

RP/AM is the collective name for the established technologies available in the market today. These technologies include, amongst others, Stereo-lithography, Laser Sintering, 3-Dimensional Printing (3DP) and Fused Deposition Modeling (FDM). Public demand for layered manufacturing technologies increased significantly over the last 15 years. Initially, it has been used mostly for RP. However, it is not the case any longer. With significant improvement of materials in parallel with process control and technology platform development, different technologies have been contributing to a diverse range of applications to deliver production-quality products [3].

Terry Wohlers, industry consultant, analyst, author and president of Wohlers Associates, maintains that despite the improvements in technology, for RP/AM to better penetrate new markets, systems must become more affordable, easier to use and simpler to maintain. He furthermore suggests that even more importantly, the cost of ownership must drop significantly, with a simultaneous improvement of material quality [1, 2]. Until recently, 3DP has been seen as the entry-level RP/AM process, which was recognized as a competitive process in terms of cost and speed, as reported by Dimitrov *et al*. [3] and Wohlers [5]. This trend was altered in 2006 with the introduction of significantly cheaper systems called entry-level rapid prototyping (ELRP), which operates on the same principle as FDM technology mentioned before, and is showing promising results in terms of dimensional accuracy, speed and cost effectiveness [3, 5].

II. ENTRY-LEVEL RAPID PROTOTYPING

The idea to create a solid part from the comfort of one's home grabbed the world when the first cheap ***open-source*** desktop RP printer was introduced by H. Lipson, called the FAB@HOME 3D printer. The FAB@HOME 3D printer was developed at Cornell University in 2006, and was capable of printing parts from thermoplastic polymer material based on an Additive Manufacturing Fused Deposition Modeling (AMFDM) concept. The FAB@HOME 3D printer is small enough to stand on a table and is capable of printing physical models from CAD images. After the FAB@HOME 3D printer was launched successfully, interest in creating desktop RP printers increased significantly, especially with regards to finding new methods to produce, not only cheaper parts, but also cheaper 3D printers [6].

After the first ELRP 3D printer was introduced in the market, companies and universities introduced numerous 3D printers that work on the same concept as the FAB@HOME 3D printer. The RAPMAN 3D printer was released shortly after the FAB@HOME 3D printer by Dr. Adrian Bowyer from the University of Bath in England in 2009. The RAPMAN 3D printer was sold in kit form that made it cheaper than its predecessors by reducing manufacturing costs. After the RAPMAN 3D printer, the Makerbot 3D printer was the next to be released, and recently the UP 3D printer followed. The UP 3D printer is smaller than its predecessors [6, 7].

III. APPLICATIONS OF ENTRY-LEVEL RAPID PROTOTYPING

Designers recognized the potential of ELRP FDM platforms to create a concept model in the early stages of the design process. This can be called the concept modeling stage or cost effective entry-level stage.

Concept modeling can be used in a number of areas of application, including the early stage of product development/design that can be achieved with an ELRP platform. This approach gives industrial designers an opportunity to develop an even lower-cost concept model to observe the form, fit and function, as well as to optimise the part's design, whether it might be for a model presentation, replacement part or future development. It can save the designer time and reduce development expenses by avoiding reprinting on high-level printers. Concept modeling can be used in the training environment, where members of the public, school children, and students can start to use these platforms to learn through experience, and also facilitate peer-to-peer learning. It can also be used to create new products and parts of products by using inexpensive material, and has the potential to introduce new technologies into the market, and as such, stimulate innovation [2].

IV. Printing distortion in entry-level 3D printing

Most of the ELRP printers have no enclosure around the printing area. The open build chamber concept ensures lower unit manufacturing costs and offers the user a clear view of the printing progress, but unfortunately this also creates delamination problems. Figure 2 displays a recorded image with an FLIR i3 infra-red camera during and after the printing process of a part.

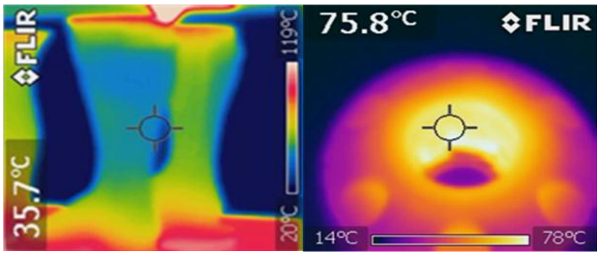

Figure 2 Infra-Red color images of printed parts

The bottom layer making contact with the heated bed has a temperature of approximately 119°C, while the extruded polymer temperature is approximately 260°C, resulting in a surface area temperature of approximately 35.7°C as illustrated by the infrared-camera reading. The uneven temperature is caused by a cooler ambient temperature, which results in the surface of the part cooling at a faster rate than the core, as illustrated in the image. This leads to uneven distribution of temperature, which in turn can lead to uneven shrinkage and cause bow warping on the printed part, as reported by Pei *et al* [2]. Printing parts on an open-design platform can have significant effects on the part's integrity, accuracy and stability, caused by bow warping as shown in Figure 3.

Figure 3 Bow warping effect visible on printed parts

V. Research Objective

The research aim is to: obtain a clear understanding of bow warping deformation in an entry level FDM process and current limitations on printing and design parameters on existing ELRP 3D printers; to establish a controlled environment around the ELRP printer's platform by introducing a chamber; to overcome ventilation restrictions imposed on electrical equipment affected by the above mentioned; to introduce a heating process model of the printing process; to reduce uneven shrinkage in layer-by-layer printing process; to process accurate data obtained from the printing results; to formulate a working model for future optimisation and to develop printing guidelines on ELRP technology.

VI. Objectives Achieved

Work so far on FDM systems; show that higher stacking lengths in the model and uneven reduction in temperature during and after printing can increase printing distortion [8]. An Infra-Red (IR) color camera is currently used to monitor any temperature changes in the printed parts, see Figure 2. The IR camera will help to create a stable chamber around the printing platform and provide the required data to compare environment conditions in an open and closed-platform printing.

VII. References

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Martin Lotz received his undergraduate degree in 2009 from the Central University of Technology, Free State (CUT) and is presently studying towards his MTech at the Vaal University of Technology, Gauteng (VUT), as a Telkom Center of Excellence student working on entry-level rapid prototyping.