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3D printing of weft knitted textile based structures by selective laser sintering of nylon powder

M Beecroft[1]

Dept. of Design, Manchester School of Art, Manchester Metropolitan University, Benzie Building, Cavendish Street, Manchester, M15 6BR England

E-mail: m.beecroft@mmu.ac.uk

Abstract. 3D printing is a form of additive manufacturing whereby the building up of layers of material creates objects. The selective laser sintering process (SLS) uses a laser beam to sinter powdered material to create objects. This paper builds upon previous research into 3D printed textile based material exploring the use of SLS using nylon powder to create flexible weft knitted structures. The results show the potential to print flexible textile based structures that exhibit the properties of traditional knitted textile structures along with the mechanical properties of the material used, whilst describing the challenges regarding fineness of printing resolution. The conclusion highlights the potential future development and application of such pieces.

1. Introduction

There has been an explosion of hype and interest around 3D printing for textiles and fashion over the last few years. We've seen fully printed dresses on the catwalk [1] alongside the recent fully printed fashion collection printed on Desktop printers [2]. However, the majority of these works act as a form of body sculpture rather than functional flexible textiles. There have been more subtle examples combining 3D printed structures with traditional textiles [3]. This paper builds on previous research into the possibility of printing knitted textile based structures by Selective Laser Sintering that exhibit the flexibility, stretch and strength of traditional textiles [4]. Current published research has found SLS limited in terms of flexibility [5]. This paper challenges these results by demonstrating the potential to print fully flexible weft knitted structures using SLS of nylon powder.

In order to print 3D structures, a 3D Computer Aided Design (CAD) drawing is required. This 3D CAD drawing needs to consider the wall thickness and distance between objects, particularly interlocking structures i.e. chainmail, knitting, weaving. The 3D CAD drawing is then sliced into layers by the machines host software then printed out layer by layer. In the SLS process a C02 laser is used to fuse fine powder into solid material. The laser is directed by a computer guided mirror and builds objects in layers of 0.1mm, the building platform lowers down by this measurement each time allowing the next layer of powder to be rolled onto the surface. The non-sintered powder acts as a support for the build [6]. The excess powder is then removed by high pressure after printing. This paper explores the results of SLS using nylon powder to create both single-faced and double-faced weft knit structures with various thickness, documenting the effect on flexibility, stretch and strength.

2. Experimental Method

As previously mentioned despite the hype, the printing of flexible textile structures is still in its infancy. Previous research papers have explored the potential of printing weft knitted structures but have found SLS of Nylon too rigid to create fully flexible structures. This paper builds on earlier research in which weft knitted structures were combined with machine knitted textiles [7].

In order to print 3D structures, a 3D CAD drawing is required. Initial investigations utilised the free software Autodesk 123D design to generate a 3D model of the weft knitted structure. This model was created by using the spline tool to draw a single knitted loop. A polygon circle was then used to extrude along the spline. This single loop was then copied and pasted to create the horizontal rows (courses) of loops. The row of loops was then copied, angled and then pasted. This method was repeated to create the desired vertical rows (wales) of loops. This method resulted in the initial structures demonstrating alternating rows (courses) of plain knit and purl knit.

Due to the limitations of this software, McNeel Rhinoceros software has been used to generate the 3D CAD models discussed in this paper. Once drawn, these designs were run through the Magic 3D printing software to make sure all neighboring and intersecting parts have a distance of at least 0.4mm.

The printed structures discussed in this paper have been printed by London based bureau Digits 2 Widgets using an EOS Formiga P1 machine. The machines are calibrated up to ±0.15% on the X and Y-axis and built with 0.1mm layers on the Z-axis [8].The material used is nylon powder (Nylon PA12)mixed to a ratio of 1:1 of new to used powder. The mechanical properties of Nylon PA12 include good dimensional stability and superior flexibility [9].

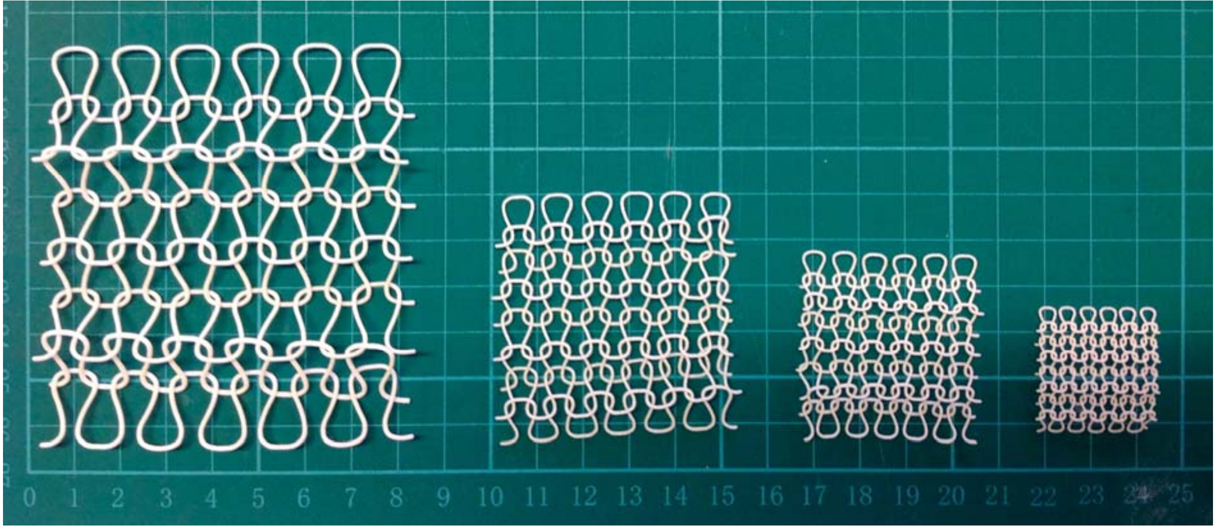

Figure 1. Initial results of weft knitted structures printed form Autodesk 123D CAD model.

3. Results

The first experiments aimed to reproduce plain weft knit single-faced structures at various thickness to test the flexibility, stretch and strength (Fig. 1), later experiments focused on developing the 3D structure to produce an interlock knit structure (double-faced weft knitted structure).

3.1. 3D Printing single-faced weft knitted structure

To print the weft knitted structure a 3D CAD model was created in Rhinoceros. A single loop unit was initially drawn as curves then piped with thickness (Figs. 2 and 3). Once created the cell unit can be repeated to create desired width (courses) and length (wales).

Figure 2. CAD Line drawing of repeat loop unit.

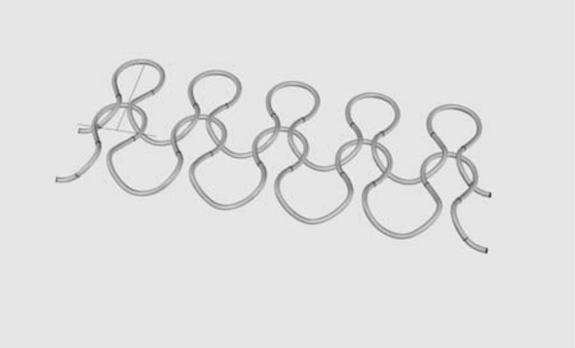

Figure 3. Piped version of 3D CAD model.

Once drawn the 3D CAD model was run through Magic software to ensure all neighboring and intersecting parts have a minimum distance of 0.4mm. Initially the model was piped with a thickness of 0.4mm thickness. The printed structure was too fine so the piece wasn’t strong enough to retain its structure. Following this the piece was reprinted with a pipe thickness of 0.5mm. This enabled the printed piece to be strong enough to hold the knitted structure and flexible enough to articulate like a fabric. Figs. 4 and 5 show the sample contracted and expanded. The piece also exhibits stretch horizontally across the courses. Figs. 6 and 7 demonstrate the flexibility of the printed piece. Due to the mechanical properties of the Nylon PA12 the piece bounces back to its original form.

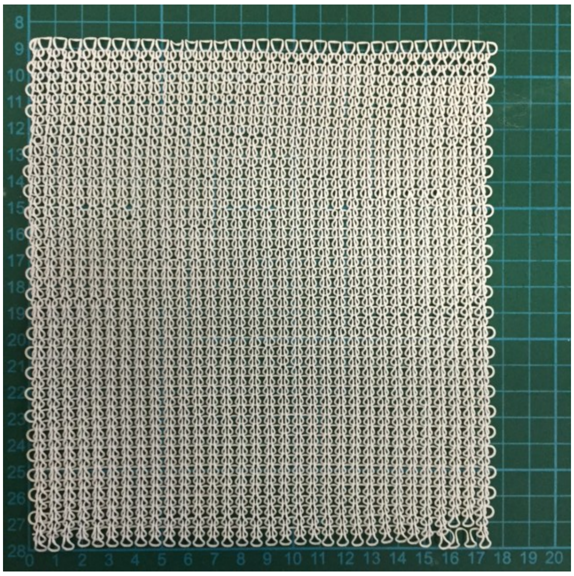

Figure 4. Weft knitted structure contracted.

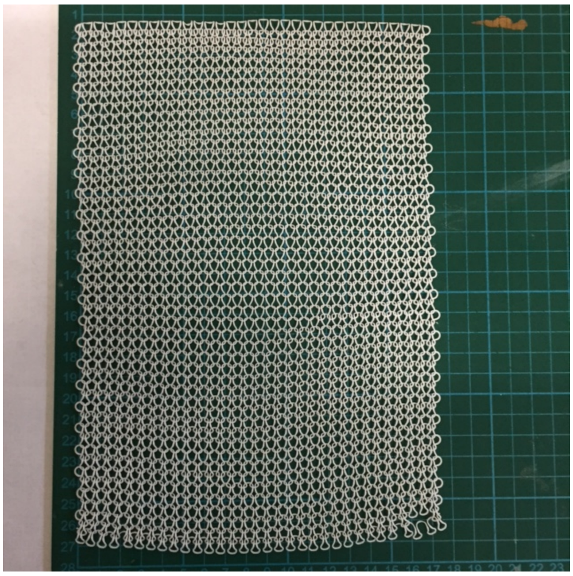

Figure 5. Weft knitted structure expanded.

Figure 6. Flexibility of weft knitted piece.

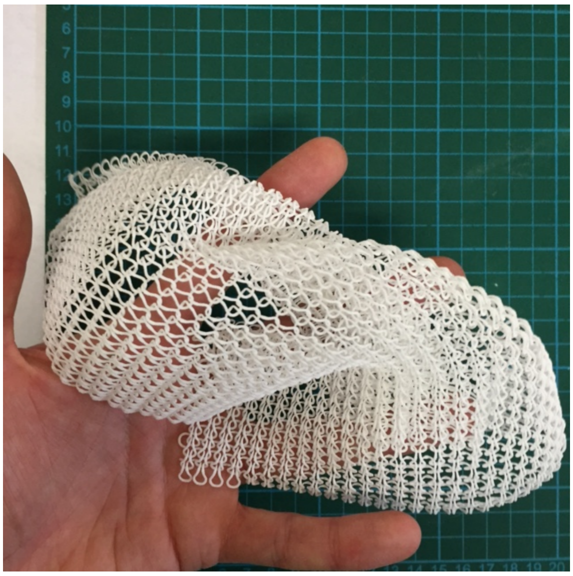

Figure 7. Bounce back of weft knitted piece.

3.2. 3D modelling interlock double- faced weft knit structure

A 3D CAD model was created in Rhinoceros to represent double-faced interlock weft knitted fabric structure. Fig. 8 shows the CAD line drawing (black and blue highlighting each of the interlocking layers). Due to the interlock structure a rib is created across the weft face. Fig. 9 shows the piped CAD model. The model was initially piped at 1.2mm thickness to test the structure and its flexibility, strength and stretch.

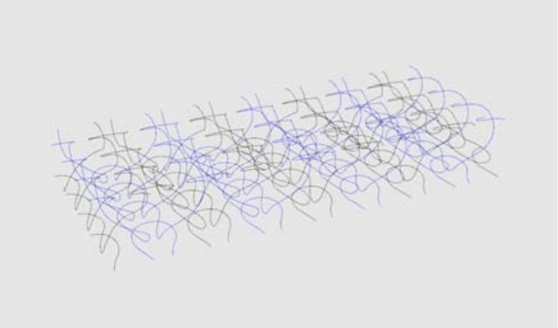

Figure 8. Rhino 3D line drawing of interlock structure.

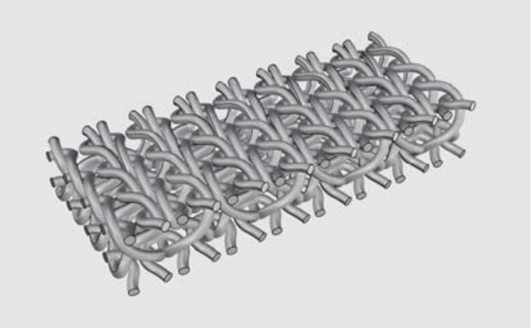

Figure 9. 3D piped model of interlock structure.

3.2.1. 3D printing interlock double-faced weft knitted structure 1.2mm. The model was initially printed at 1.2mm thickness to test the structure and its flexibility, strength and stretch (Fig. 10). Fig. 11 shows the flexibility of the piece. Both Fig. 12 and Fig. 13 show the interlock structure viewed from top to bottom. Like the single faced weft knit structure the interlock demonstrates great flexibility, bounces back to original form and stretches across the horizontal courses. The 1.2mm thickness is strong and resilient.

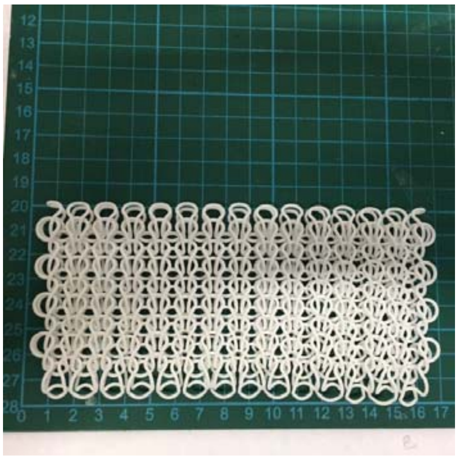

Figure 10. Contracted interlock structure.

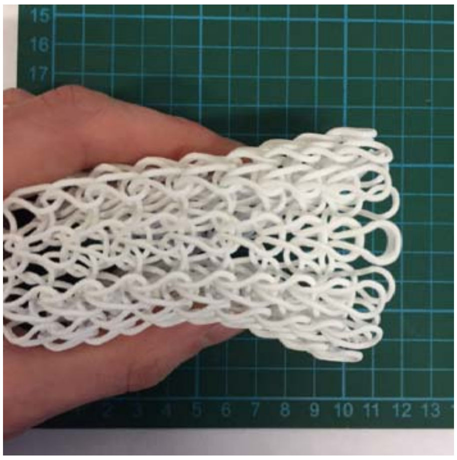

Figure 11. Flexibility of the interlock structure.

Figure 12. Interlock structure top view.

Figure 13. Interlock structure bottom view.

3.2.2. 3D printing interlock double-faced weft knitted structure 6mm. The model was subsequently printed at 0.6 mm thickness to test the structure and its flexibility, strength and stretch (Fig. 14). Again the printed sample exhibits flexibility (Fig. 15) and stretches across the horizontal courses with the structure returning back to its original form. The piece is strong but less so than the 1.2mm model.

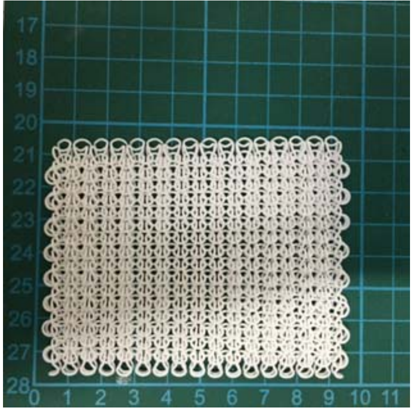

Figure 14. Contracted interlock structure 0.6mm.

Figure 15. Flexibility of the interlock structure.

3.2.3. 3D printing interlock double-faced weft knitted structure 0.4mm. Finally, the model was piped at 0.4mm thickness to test the structure and its flexibility, strength and stretch (Fig. 16). Due to the finer resolution the rib structure across the weft face is more visible (Fig. 17 & Fig. 19).The printed sample exhibits flexibility and the piece bounces back to original form. The stretch across the horizontal courses is very limited, due to the 0.4mm thickness the loop structure is prone to break more easily whilst the close distance between the interlocking weft faces starts to fuse at intervals (Fig. 18& Fig. 19).

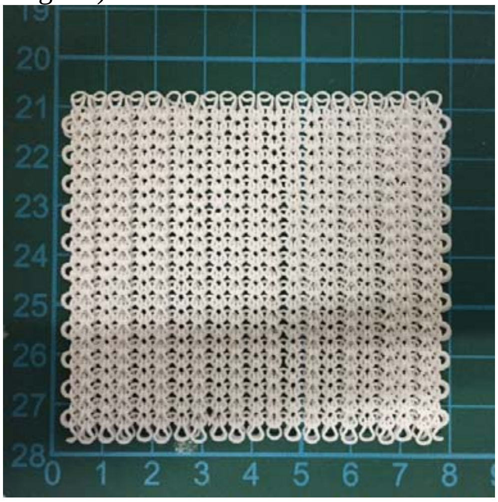

Figure 16. Interlock structure 0.4mm.

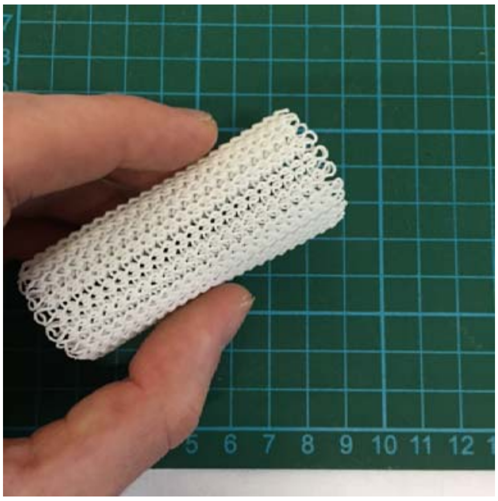

Figure 17. Flexibility of the interlock structure 0.4mm.

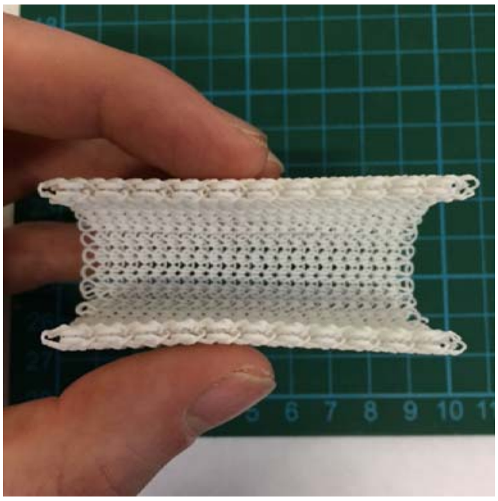

Figure 18. Interlock structure 0.4mm side view.

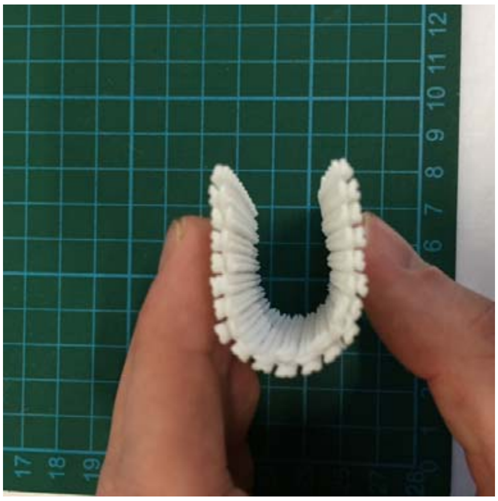

Figure 19. Interlock structure 0.4mm top view.

4. Conclusion/Further research

This paper has demonstrated the possibility of using Selective Laser Sintering of Nylon powder to print both single-faced and double-faced weft knitted structures. These structures when printed at various thicknesses demonstrate the mechanical properties of flexibility, strength and stretch which could make them viable solutions for use in the technical textile industry. Further research into different types of powdered materials i.e. Thermoplastic polyurethane (TPU) may produce softer fabrics, which may be more suitable for a fashion application.

Acknowledgments

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