Project acronym: SeaBioComp

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Project Number 2S06-006

O 5.1

Biocomposite pilot product through adapted additive manufacturing.

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Abstract

This report describes the large-scale 3D-printer being operational at Poly Products (Werkendam, The Netherlands) for printing biopolymers. It is a printer with FDM-technique where the polymer is applied by means of an extruder. From the deliverable D 2.3.2 activities for a large scale 3D print demonstrator were undertaken.

Based on the results obtained a "show-case" product will be defined, based on short and long fibre reinforced biocomposites produced via additive manufacturing. The product will demonstrate the future possibilities of 3D printed biocomposite products of large parts for a variety of potential end markets.

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Introduction

Within the SeaBioComp-project a large-scale 3D-printer is to be made operational for the production of products made of biopolymers. This also comprises biopolymers with natural fiber (NF) reinforcements. In October 2019 at Poly Products (Werkendam, The Netherlands) a large-scale 3D-printer has been installed that operates with FDM-technique (Fused Deposition Modelling), using a movable extruder for the deposition of the molten thermoplastic polymer compound.

Prior project activities concentrated around installation qualifications reported in O4.1. This report describes the pilot production activities performed on the large-scale 3D-printer using natural fiber materials.

A wide variety of different applications were studies in order to determine a useful sample. Challenges concentrate around the fact that marine applications often require to withstand the constant contact with (salt) water. The supplied natural fiber-based material is not able to withstand water.

Preselection of use case demonstrators included;

Figure 1: Crab cage/coral

Description of the 3D-printer and printing process

The FDM-printer that is used for the SeaBioComp project has been built by CEAD in Delft (The Netherlands) and is installed at Poly Products in Werkendam (The Netherlands) in October 2019. The machine is depicted in the photo in Image 1. The machine can print very large products with dimensions up to (LxWxH) 4 x 2 x 1.5 m, which makes it a very interesting technique for printing biocomposite products for marine applications as very little assembly is required after production of complex geometries.

Figure 2: FDM-printer of Poly Products

Main components of the machine are:

- Structural frame for the support of the x-y-displacement system
- X-Y-displacement system
- Extruder with integrated melt-pump
- Built plate that can be moved in z-direction
- Isolated casing
- Pre-drying installation
- System control

The process of 3D-printing starts with the drying of the polymer granulate. For most polymers the drying is an essential step to prevent polymer degradation and, in case of thermoplastic polyesters the formation of corrosive substances.

After drying the granulate is fed into the extruder and is plasticized by the heated zones in the extruder in combination with the heating by the shear of the viscous polymer. On the control screen the temperature settings and measured temperatures at different locations in the extruder, in the melt pump and in the nozzle are displayed, see photo in Image 2.

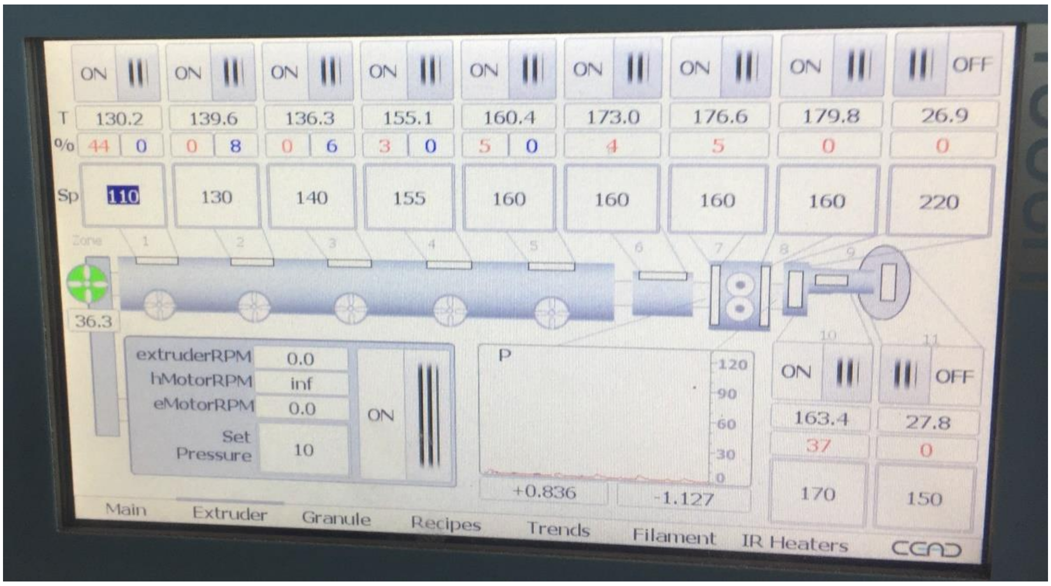

Figure 3: Display of temperatures in extruder, melt pump and nozzle

From the nozzle, the molten polymer is deposited on the previous layers. This is done in a space that is isolated for maintaining a constant temperature, see Photo 3 (left). An IR-image (made by IMT Lille) shows the heat distribution of the nozzle and deposited material, see photo in Image 3 (right).

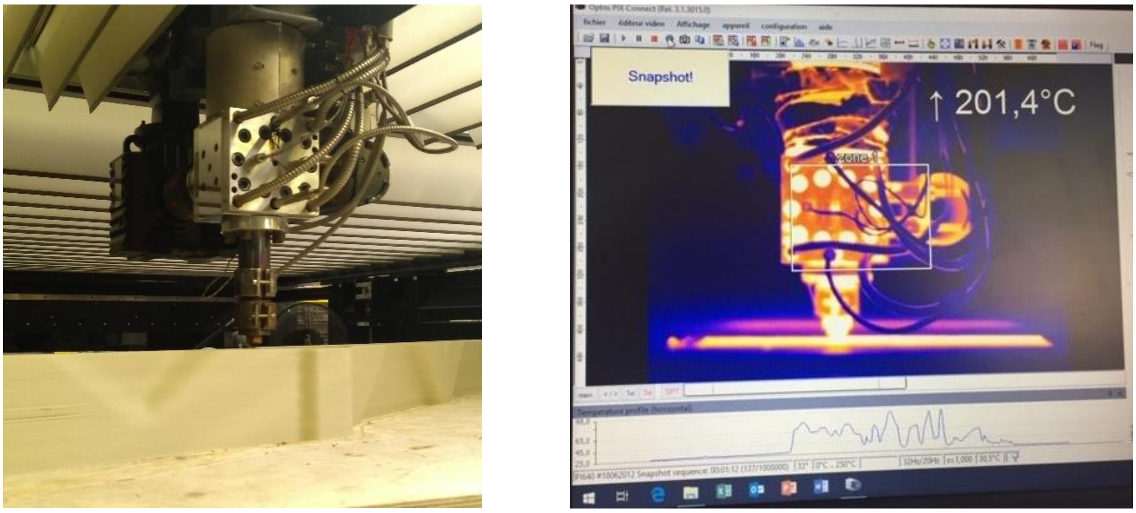

Figure 4: Printing in action (left) and IR-image of temperature distribution (right)

Use case

The introduction of this report listed two considered 'use case' examples. Both require constant contact with water. The project provided a flax/PLA compound. Based on the high weight percentage of natural fiber this material is not able to withstand constant contact with water very well.

Orientation
Inspiration of for a use case was found during a fieldtrip to the local harbor in the city of Werkendam, the Netherlands.

Figure 5: Harbor of Werkendam

During the field trip a selection of 3D printing opportunities were identified which could qualify based on the listed requirements.

Significant wear of wooden support structures requiring direct maintenance.

Redundant round shaped 'boat bumper' constructed from multiple parts.

Large sized, rigid stootwil applied for inland vessels. One piece rubber part featuring an internal structure allowing the stootwil to absorb external forces.

Bollard cap. Product that helps to prevent water from draining into the top side of the bollard.

Figure 6: Field trip outcomes obtained during orientation trip to Werkendam harbour

Material

The obtained material is described as a flax/PLA. The flax is a natural fiber combined with Purapol L130 PLA. Apart from the demonstrator production a standard set of 3D print settings were determined. Best results were obtained after multiple hours of drying at 80 degrees C.

Figure 7: Delivered flax/PLA material

Base 3D printing settings for the FGF setup are;

Nozzle size:	3 mm
Extrusion width:	4,8 mm
Layer height:	1,5 mm
Printing speed:	3.000 mm/min
Build plate:	Wood
Build plate temperature:	40

Design and fabrication

Based on the reported orientation phase the following sketches were made to get an idea of the final application and size.

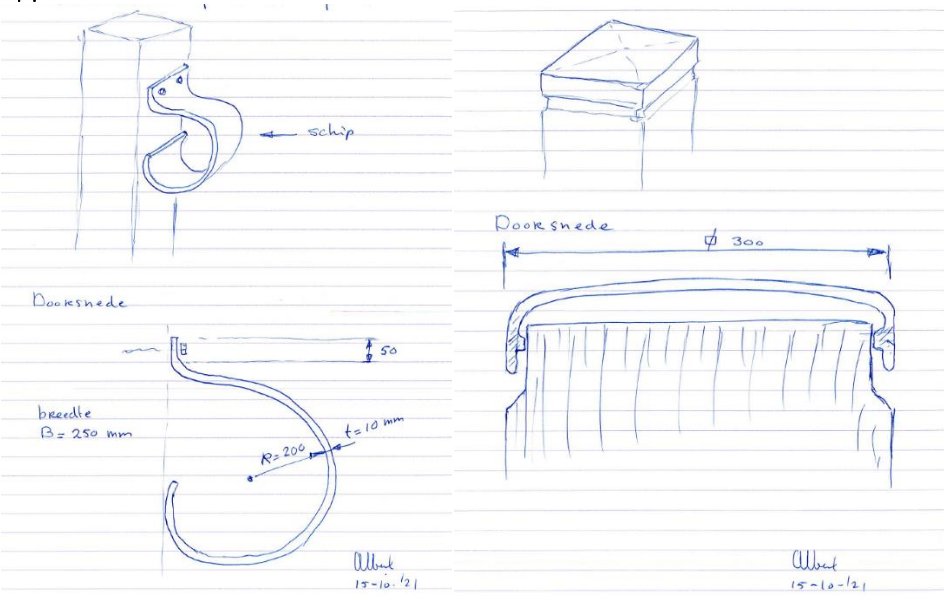

Figure 8: Sketches of the selected use case

Using the sketches 3D CAD files were generated, followed by slicing the model in appropriate layers height. The slicing software generates G-code steering the actual 3D printing nozzle.

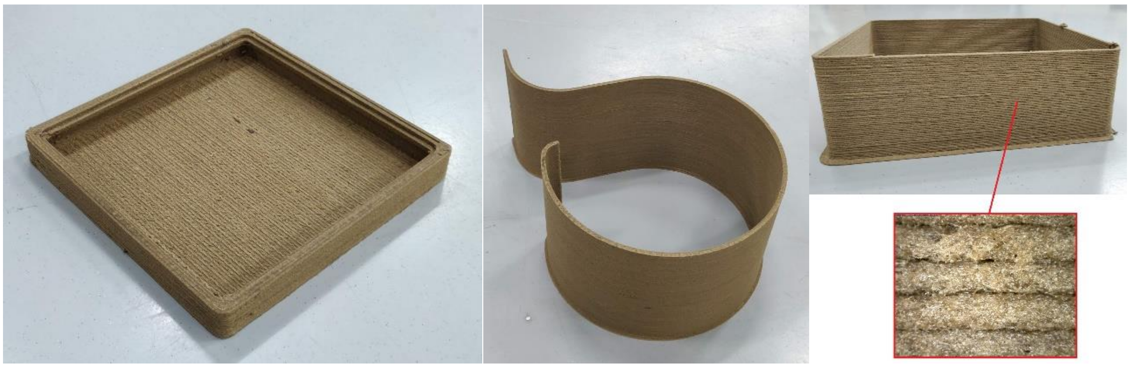

Figure 9: 3D printed demonstrators including detailed imaged indicated layer to layer bonding

Post 3D printing activities included removal of starting layers, softening of product edges and hole drilling for assembly purposes.

In order to bring both samples alive in the real use case environment both products were installed on a bollard featured in the local Werkendam harbor.

Figure 10: Assembled use case featured in Werkendam harbor the Netherlands.

Project partner, university of Portsmouth, received the samples and reported test data on the flax/PLA material to the WP2 project partners.

Figure 11: Representative dog bone specimens of the provided 3D printing materials/composites manufactured at 0° and 90°.

Conclusions

The large-scale 3D-printer that is installed at Poly Products is suitable for the processing the provided flax/PLA material into a TRL-7 proven real life use case.

The overall particle size distribution of the delivered goods is high. The irregular particle size and particle shape make it difficult to transport the material from the bin towards the FGF print head. It is to be recommended to improve this for next batch deliveries.

The material is relatively easy to print it requires settings which are easily within the scope of general available FGF equipment. Setting determination could be time consuming and does require a significant amount of trial and error.

Overall material quality, based on the reported mechanical properties is relative low. Especially the tensile strength at 90 degrees of the printed layer. For actual applications in the marine field these properties would need to be improved.