Feasibility study on 3D-printing of bio-inspired composite ballistic products

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The assignment comprised of an exploratory study into the feasibility of using fiber-reinforced 3D printing to create ballistic products. As the largest manufacturer of aramid fibers, Teijin Aramid is investing in finding new applications for the high strength fibers they produce. In recent years, 3D printing has gained in popularity as an industrial production process, especially since it is now possible to create high-strength 3D prints through (continuous) fiber reinforcement. As this market is currently mostly geared towards carbon fiber reinforcement[1], Teijin is interested to see how aramid fibers can be implemented as well. The main objective of this assignment is to find out if a functional ballistic product, inspired by composite structures found in nature, can be created by means of 3D-printing. This is an exploratory study into the possible application of 3D printing in one of the areas in which aramid fibers are traditionally used, ballistic (body) armor.

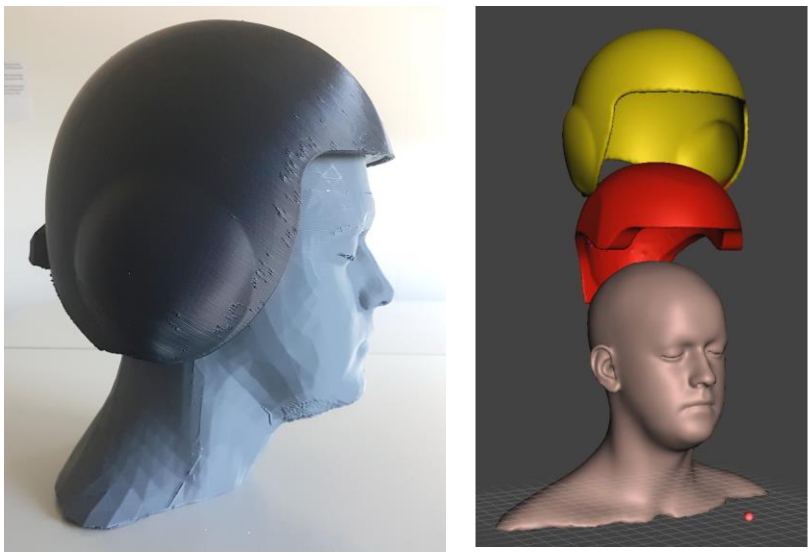
The assignment consists of three main parts. First, the suitability of the technology and production process is evaluated on both the machine and the material level. Second, research is done on naturally occurring composite structures. Third, the ballistic performance of the printed material is evaluated through high speed impact testing.

For the evaluation of the technology and the production process, the capabilities of the in-house fiber reinforcing 3D printer as well as the capabilities of other (soon-to-be) available 3D printers are analyzed. Static and dynamic testing of the base material used by the 3D printer allows the performance to be compared to that of traditional aramid material. This provides baseline performance of the 3D printable material and knowledge of the (dis)advantages of using 3D printing for production.
One of the most notable drawbacks is the relatively low strength of the parts created with a (traditional) Fused Filament Fabrication (FFF) printer. Both due to limitations of the material used (thermoplastic) and to the method of production (layer-by-layer buildup), parts are relatively weak and do not optimally use the advantages offered by fiber reinforcement. This knowledge led to additional manufacturing methods being implemented in the creation of the testing prototypes.

The composite structure of a biological creature can be somewhat recreated by a 3D printer, which allowed to test and compare the performance of natural composite structures to traditional structures currently in use in industry. Exploratory testing showed potential for the bio-inspired structures in improving certain ballistic properties of armor, but more testing is required to determine the exact effects.

Ballistic testing of several variations in armor structures is done to evaluate and compare the performance of both bio-inspired and traditional structures. From the performance standpoint, a true functional ballistic product is not viable using the current 3D printing technology. However, the results of the testing show clearly in what aspects the technology can be improved. The results still show there may be potential for using 3D printing in the production of protective gear.

Besides testing the functional performance of the 3D printed composites, a conceptual armor application was designed as well. This design demonstrates some unique advantages of using 3D printing in the production of personal armor, assuming future technology solves the current limitations of 3D printing. One of the clear advantages utilized by printing is the low waste in material and low active labor involved in creating products. 3D printing is often considered to be less suitable for large scale production and more useful in small batch, customized production. One of the strengths of 3D printing demonstrated by the concept product is this customizability, as the product shows the ease at which (hard) body armor can be made to precisely fit the individual. The design also shows that it is easily possible to add additional (complex) functionality to a product without the need for expensive tooling.



(a) (b)

Figure 1. (a) Photo of a 3D printed demo. (b) The helmet contains a hard shell (yellow) and insertion (red) to improve the fitting.

The research concludes that with the current state of technology, a true functional ballistic product is not yet viable. This may change in the coming years with the advances in technology and material. The testing has showed that the ballistic resistance of the 3D printed material is not on the same level as traditional production methods yet. However, the technology shows potential as a relatively low cost/low waste production method for fiber reinforcement. Recommendations are done to Teijin in what aspects continuous fiber printing can be improved in the near future as well as how the technology could be implemented in applications other than armor.

REFERENCES

[1] Stratview Research, '3D Printed Composites Market', Feb 2019. [Online]. Available: https://www.stratviewresearch.com/271/3D-Printed-Composites-Market.html [Accessed: 25-7-2019]