ADDITIVE MANUFACTURING AT UNIVERSITY OF NAVARRA - TECNUN: APPLICATIONS FOR INDUSTRY, MEDICINE AND SPORTS

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ABSTRACT

Additive Manufacturing (AM) is the process of joining materials to build objects layer upon layer from 3D model data. Its importance has grown since the late 1980s to the extent that President Obama said “AM has the potential to revolutionize the way we make almost everything”.

The Design Unit at University of Navarra–TECNUN got its first AM device in 2004. Since then, TECNUN has done many projects—through public funding and bilateral collaborations with companies that lead to Bachelor’s, Master’s and PhD thesis projects—to evaluate the potential of AM.

This paper describes some of these projects to show the trajectory that TECNUN has followed since 2004. In particular, under the umbrella of Industry 4.0, the process for embedding sensors to create smart AM parts and how extrusion devices can print electrical conductive paths is described. Moreover, three AM components built for a Formula Student car (oil sump, accelerator pedal and wheel rim) are explained. Furthermore, the fabrication of insoles for diabetic patients using low-cost printers is illustrated. Lastly, a project to create shin-pads with shock-absorbing properties is presented.

The future of AM at TECNUN is challenging, especially within Industry 4.0, where smart machine components and wearable devices capable of capturing information from machines and/or people are necessary to objectivize user-machine interactions.

PALABRAS CLAVE: Additive Manufacturing, Industry 4.0, Medicine, Sports

1. INTRODUCTION

Since its introduction in 1986, Additive Manufacturing (AM) or 3D Printing has become one of the fastest growing new technologies. It gives engineers the possibility of creating prototypes to tests certain aspects of what they are designing (called Rapid Prototyping), of building production tools (Rapid Tooling)—i.e. moulds and dies—and even of building and then using that prototype as a final part in the final product (Direct Manufacturing). The Design Unit at University of Navarra–TECNUN purchased its first AM device in 2004. To illustrate the trajectory that TECNUN has followed since then, the following sections describe some of the projects that Tecnun staff and students have been involved in.

1.1. SMART COMPONENTS

Industry 4.0 wants to create what has been called a "smart factory". Within this framework, Tecnun carried out a project to create smart components by embedding sensors in the inside of a 3D printed part. The printing process was started and then paused when it got to the last layer that defined the cavity, leaving visible the support material in the interior region and the model material in the outer region of the uncompleted part. The support material was removed from the cavity, the sensor was placed in the cavity and the printing process was resumed until the end of the printing process. This methodology was successfully implemented with other sensors (IR, FSR, Hall's effect) and with other AM technology (Poly- jet). Furthermore, Building smart components not only encompasses the embedding of sensors, but it also takes on the question of how to power the sensors with the electricity needed to run them properly. Taking advantage of AM strengths, we studied here how to create 3D paths made of conductive filaments with carbon fibre (BlackMagic) so as to connect to printed circuit boards without any cupper wire. Before printing the final prototype, various printing settings were analysed to as to minimize the electrical resistance of the path. Finally, following these lines, authors are now working with wearables devices capable of capturing information from machines and/or people to objectivize user-machine interactions.

1.2. AUTOMOTIVE PARTS

The Design Unit at TECNUN started a collaboration with the Formula Student team at TECNUN with the aim of exploring the possibility of replacing some of the car's components with others manufactured via 3D printing. The first pilot study was a redesign of the accelerator pedal. The pedal was modelled in a Computer-Aided Design application and various Finite Element simulations were performed to evaluate three different driving scenarios. Later, two physical prototypes were manufactured using Poly-jet and Fused Deposition Modelling (FDM) technologies. With these physical prototypes, static tests were carried out to verify the computational simulations and to determine the fracture load, while dynamic tests based on an input signal from a real racing scenario were performed to ensure their technical viability. The abovementioned strategy was modified with two other components (oil sump and rim) since one of the major issues with AM parts made of polymers is that they struggle against high thermal and mechanical loads. Hence, a new oil sump and a new rim were created by combining a main ABS-plastic core built with AM and a later manual lay-up process using carbon fibre. During tests, the oil sump worked under realistic temperature conditions (80ºC) without any oil leak while the resulting weight savings was 1kg with respect to the original rim.

1.3. MASS CUSTOMISATION

One of the major advantages of AM is the mass customization philosophy, that is, the possibility of getting low production volumes. Insoles and shin-pads were the two examples here. With insoles, the hypothesis was to evaluate whether current low-cost extrusion AM devices can deliver a feasible solution. We corroborated that a low cost printer (1000€) that uses Slic3r (free) and FilaFlex filament (20€/250g) can deliver insoles that have better memory for returning to their initial shape and better tolerate dynamics loads relative to a commercial insole. With respect to shin-pads, we analysed a novel method to design and manufacture shin-pads for football players using a multi-material AM device (Objet Connex printer). The shin-pad had three parts: an inner, a middle and an outer shell. The inner and outer shells are supposed to be rigid, while the middle shell is supposed to work as the shock absorbing geometry. Twenty-four different AM geometries were evaluated using a customised rig where a 1kg impactor is released from several heights (10 to 40 cm). Results were compared against two commercially available shin-pads and they showed that two designs had an acceleration reduction between 42% and 68% with respect to the commercial shin pads and when released from the highest height. Regarding the penetration, the improvement obtained with AM specimens ranged from 13-41%, while the attenuation and the contact times are similar.

2. RESULTS FROM THE AM RESEARCH LINE

Additive Manufacturing (AM) still has a huge potential for research by engineers. The authors worked nationally and internationally with public and private funds that lead to published various papers related to those above explained AM research lines in the last 3 years:

- Frances, L.; Morer, P.; Rodríguez, M.I. and Cazón, A. (2016). “Estado del arte de la tecnología werable. Futuras aplicaciones industriales”. Jornada de Ingeniería Gráfica.
- Prada, J.G.; Cazón, A.; Cardá, J. and Aseguinolaza, A. (2016) “Direct Digital Manufacturing of an accelerator pedal for a Formula Student racing car”. Rapid Prototyping Journal. 22(2) pp. 311-321.
- Cazón, A.; Matey, L.; Rodríguez, M.I.; Morer, P. and González. I. (2015) “Direct Digital Manufacturing for Sports and Medical Sciences: three practical cases”. Dyna Journal. 90 (6) pp. 621-627.

- Cazón, A.; Prada, J.G.; García, E.; Larraona, Gorka S. and Ausejo, A. (2015) "Pilot study describing the design process of an oil sump for a competition vehicle by combining Additive Manufacturing and carbon fibre layers". Virtual and Physical Prototyping. 10 (3) pp. 149-162.
- Cazón, A.; Aizpurua, J.; Paterson, A.; Bibb, R. and Campbell, R. I. (2014) "Customised design and manufacture of protective face masks combining a practitioner-friendly modelling approach and low-cost devices for digitising and Additive Manufacturing". Virtual and Physical Prototyping. 9 (4) pp. 251-261.
- Cazón, A.; Morer, P. and Matey, L. (2014) "Poly-jet technology for product prototyping: tensile strength and surface roughness properties". Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 228 (12) pp. 1664- 1675.

This paper has described some projects to illustrate how Tecnun staff has been on the cutting edge of knowledge regarding Additive Manufacturing for more than ten years, transmitting all this knowledge to future engineers through traditional lectures and final projects.

3. RESEARCH TEAM

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Congreso INGEGRAF Gijón 26, 27 de junio de 2017

NUEVOS MODELOS DE INVESTIGACIÓN Y COLABORACIÓN EN INGENIERÍA GRÁFICA

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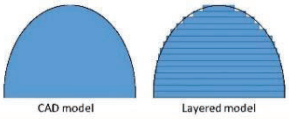
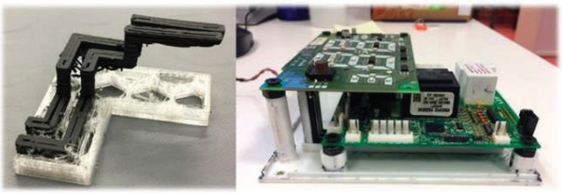
Additive manufacturing and Tecnun

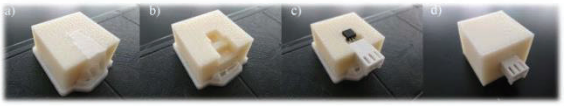
Additive Manufacturing (AM) is the process of joining materials to build objects layer upon layer from 3D model data.



The Design Unit at University of Navarra–TECNUN got its first AM device in 2004. This poster describes some projects to show the trajectory that TECNUN has followed when doing research about AM.

Smart components

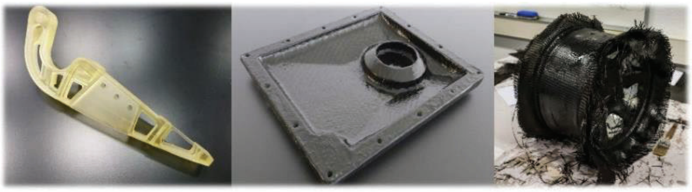




Industry 4.0 wants to create what has been called a "smart factory". Tecnun carried out two projects. Firstly, to create smart components by embedding sensors in the inside of a 3D printed part and, secondly, by creating 3D printed paths made of conductive filaments -so as to connect printed circuit boards without any cupper wire- thanks to the collaboration with CEIT-IK4, IKOR group and Tecnalia and with the funding of the Basque Government.

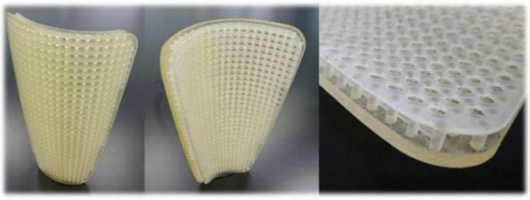
Automotive parts

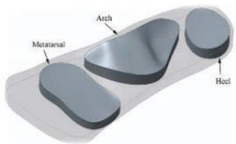
The Design Unit at TECNUN started a collaboration with the Formula Student team at TECNUN with the aim of exploring the possibility of replacing some of the car's components (accelerator pedal, oil sump and rim) with others manufactured via 3D printing.

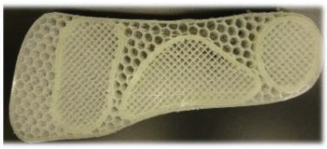


Mass customization

Can AM devices create final products for sports and medical applications? We corroborated that a low cost printer with FilaFlex filament can deliver insoles with better tolerance to dynamics loads relative to a commercial insole. With respect to shin-pads, we analysed a novel design with a middle shell that it is supposed to work as the shock absorbing geometry







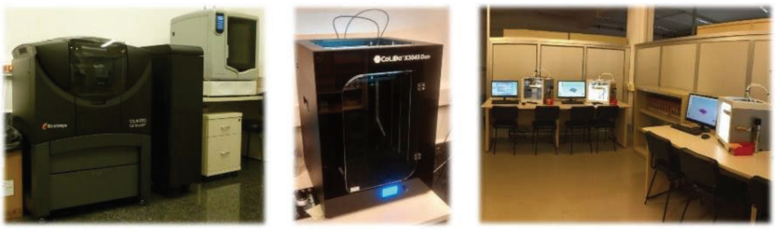
AM facilities at Tecnun

AM devices with material jetting technology:

- 1 x Stratasys Object Connex 3 260

AM devices with extrusion technology:

- 1 x HP DesignJet Color 3D
- 1 x Colido X3045 Duo
- 6 x Tumaker Voladora NX



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