CQFA CARREFOUR QUÉBÉCOIS DE LA FABRICATION ADDITIVE

CASE STUDY

3D PRINTING OF HIGH-PERFORMANCE POLYMER COMPOSITES FOR THE LUNAR ROVER APPLICATION

Project duration

Ongoing since early 2018

Partners

Academia (École de technologie supérieure (ETS, Laval University)

Government (Canadian Space Agency - CSA))

Industry (ArianeGroup, NanoXplore, Mekanic, Dyze Design)

Materials

Polymers (PLA, PEEK, PEI) and composites (Carbon fiber reinforced PEEK)

Processes

Fused deposition manufacturing (FDM)

Application fields

Space and aeronautics industry

OBJECTIVES

To lower the total weight of the rover while keeping its high mechanical properties using hybrid fabrication processes.

To decrease the heat losses of the rover structure, preventing the internal electronics from reaching destructive cold temperatures during lunar nights.

BACKGROUND

The main objective of our project is to design and manufacture a lightweight lunar rover through a collaborative project between an academic researchers from Polytechnique Montréal, École de Technologie Supérieure (ÉTS) and Université Laval, the Canadian Space Agency (CSA) and four industrial partners (ArianeGroup, NanoXplore, MËKANIC, and Dyze Design). To reach this goal, the team is working on different objectives such as material design, additive manufacturing (AM), numerical work to predict the mechanical and thermal behavior of the structures, induction welding to attach different parts of the lunar rover and finally assembly of different rover components. Our focus is on the additive manufacturing section of the project which aims to fabricate the sandwich panels with the desired cell distributions on a planar and non-planar surface to maintain the mechanical properties while lowering the overall rover weight (Fig 1).

THE CHALLENGE

The harsh condition on the moon such as its temperature variation that can alter from more than 100 °C during the day to lower than -150 °C during nights which last for 14 days, requires systems that can tolerate and function in this temperature range. The body of the rover should be also sturdy enough to tolerate the weight of the components needed to be attached or carried during its cruising on the moon and also not to get damaged by the corrosive dust and sharp-edged rocks. One way to improve the mechanical properties of the rover structure is to add to the thickness of the body's structure or to build it with stronger materials. The usual approaches to improve the mechanical properties of the rover body will lead to the addition of mass which results to a heavier rover that consumes more energy for its functions. The advanced composites offer high mechanical performance and using AM techniques allows us to even lower the weight by decreasing the amount of material where the applied forces are lower. On the other hand, the printability of advanced polymers and composites are still challenging mainly due to their high melting point.

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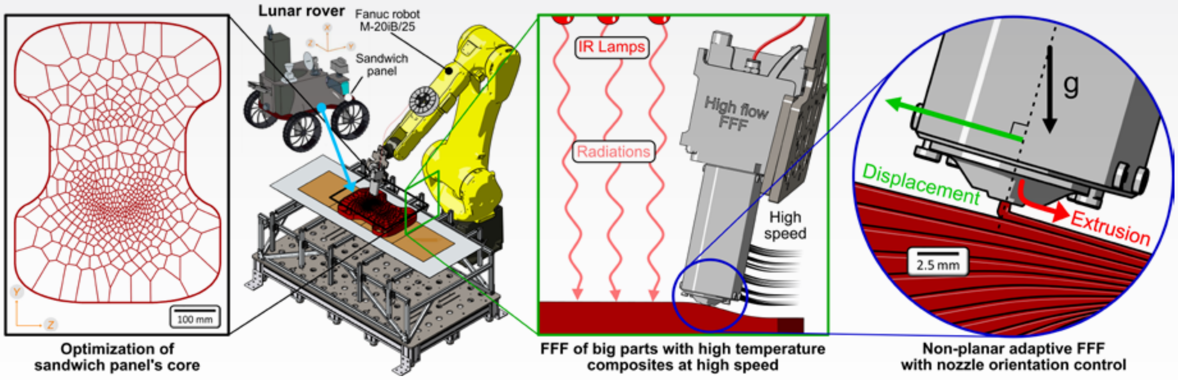

Figure 1 – Schematics showing the cells distribution design in the sandwich panels and FFF printing process for fabrication of the lunar rover's body structure.

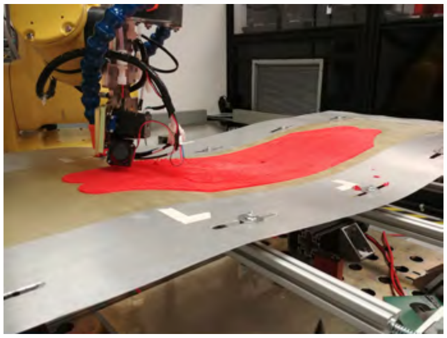

Figure 2 – 3D printing of PLA on a non-planar surface using FFF system mounted on a Fanuc 6 axis-robot.

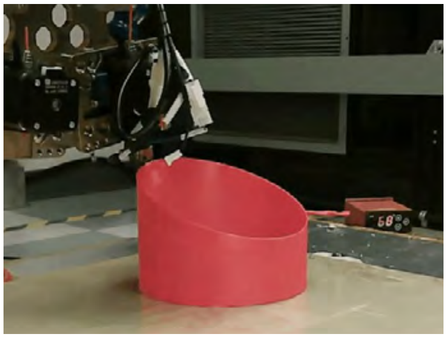

Figure 3 – 3D printing of a truncated cylinder with a 2:1 front to back ratio with constant number of layers from PLA by FFF method.

THE SOLUTION

In order to maintain the temperature inside the rover during cold nights to protect the electrical circuits and batteries, the material we are targeting is a high-performance polymer called PEEK and also PEEK-based composite with a much lower heat transfer than aluminum which was used previously for the CSA rover body structure. The rover's body we are designing is made of sandwich panels with honeycomb infill. We decrease the overall mass of the rover by concentrating the honeycomb cells where there will be higher applied forces and decrease the number of cells where the stress will be potentially lower. The Fused Filament Fabrication (FFF) method is used to additively manufacture the cells with different arrangements inside the sandwich panels and their final mechanical properties is tested. Since we needed to 3D print large structures, we developed an FFF system on a Fanuc six-axis robot that enables us to print structures large dimensions up to 110 cm, depending on the printing bed size. We are also developing a slicer program, which generates toolpaths using Python programming language to adapt the slicing program to the six-axis robot movement for printing on non-planar surfaces. In another creative attempt, geometries with varying heights were fabricated by varying the printing filament extrusion rate.

BENEFITS/RESULTS

Honeycomb structures with specific cells distribution were designed to improve the mechanical properties of the sandwich panels while keeping their total weight constant. These sandwich panels were additively manufactured from Polylactic acid (PLA) using FFF technology. PLA allowed preliminary tests to be carried out and transition to PEEK will take place in the near future. The ultimate strength and stiffness of sandwich panels was more than doubled compared to a honeycomb sandwich panel at equal masses (7% dense core). In order to be able to print on non-planar surfaces, an in-house slicer has been developed using Python and Rhino software, to generate a toolpath following an adaptive non-planar profile (Fig 2). Large PLA geometries (e.g., a truncated cylinder with a 2:1 front to back ratio with constant number of layers) were fabricated by the FFF method following a non-planar printing profile (Fig 3). An infrastructure to print large parts in high-performance thermoplastics and composites on non-planar surfaces is under development.

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