Additive manufacturing of polymer foams design principles and applications

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Curriculum: Tecnologie e Sistemi di Produzione

Due to the recent development of Additive Manufacturing in the industrial and civil fields, it has been considered to realise polymeric foams with this technology. The aim of the project will be to design and manufacture 3D printers capable of in-line foaming of any thermoplastic polymer, in particular by developing filament and granule extruders. It will then be possible to realise foams structures and determine a design criterion to guarantee their industrial applications and predict their mechanical characteristics.

The project will make it possible to easily and inexpensively produce foams with variable density and morphology by varying the printing parameters online, the aim is to obtain extremely light structures with complex geometries by predetermining their mechanical characteristics, you will be able to reduce foam processing waste by directly obtaining the foam in the desired shape.

The established state-of-the-art technology consists of two stages, additive manufacturing of the part and subsequent foaming this process makes it difficult to control the shape of the parts as they deform due to residual stresses in the parts, and does not allow the control of morphology in line.
The technology we are studying is instead characterised by a single stage during which the raw material, made of any thermoplastic polymer, is preliminary treated and foams during printing this allows precise control of the shape, density and morphology.

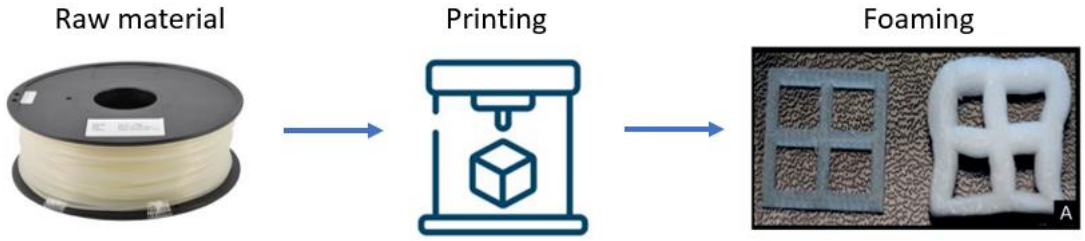


Figure.1 Technological process for the production of foam parts in Additive Manufacturing in two stages

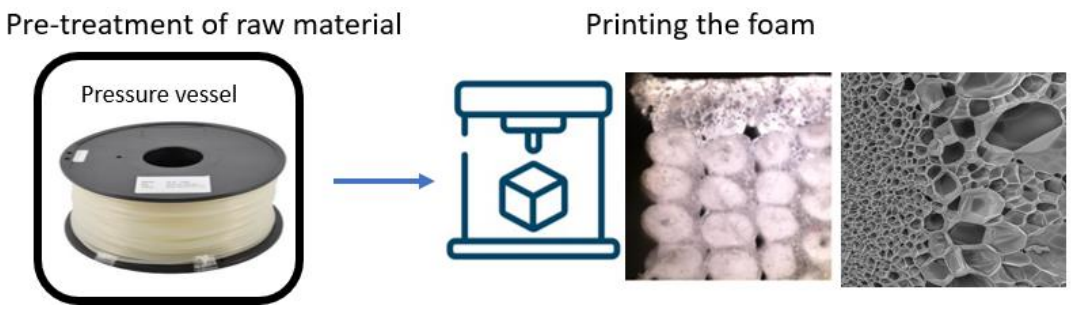


Figure..2 Technological process for the production of foamed parts in Additive Manufacturing in a single step

The first step is to evaluate the different possible technologies for the production of AM foams by designing and producing extruders with both filament and granules capable of foaming directly in the printing phase, we will then move on to the characterisation of parts produced by additive foam manufacturing, and creating a model through which the mechanical characteristics of structures made in AM can be predicted knowing the layering strategy.

The figure below is the result of an initial screening of various thermoplastic polymers that have been foamed through the additive foam manufacturing process, in order to demonstrate that this technology is applicable to each thermoplastic polymer, each will have different results and process parameters.

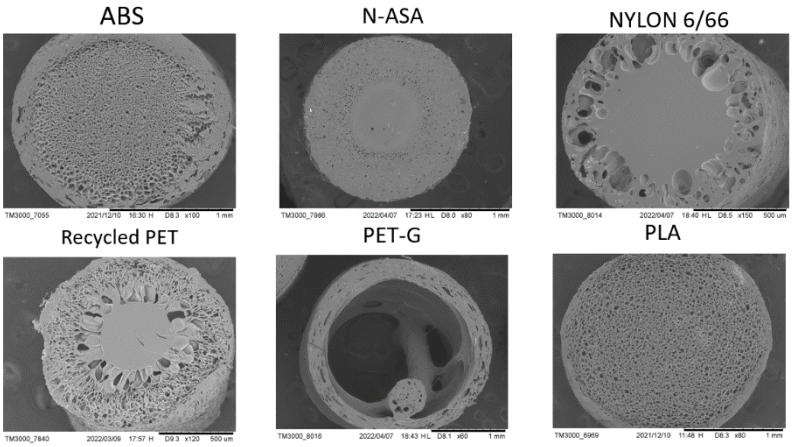
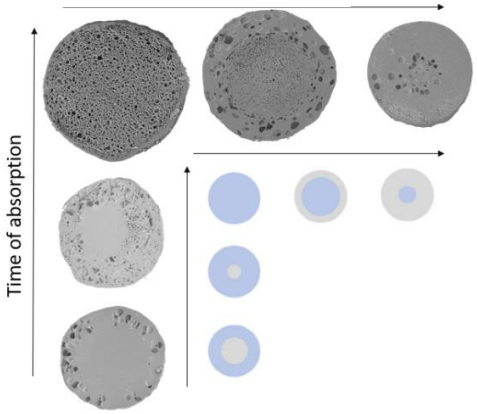


*Figure **Errore. Nel documento non esiste testo dello stile specificato.**.3 Strands of foams made from different thermoplastic polymers*

One-step foaming
technology offers the possibility to control many parameters in particular the study addressed so far and now aims to understand the influence of the 6 most important on foam morphology, in order to better control the morphology in line.



Through a response surface methodology (RMS) the influence of parameters on the density diameter elastic modulus and tensile strength of PLA polymer foams made in additive manufacturing is being investigated. In the figure on the right it can be seen how the filament solubilization parameters affect the position of the foam in the strand. By increasing the absorption time the feed gas, in this case Co2, enters inside the strand section this allows during the extrusion phase to choose to foaming only on the outside of the strand. In a similar way by increasing the desorption time the co2 exits the outer section of the filament this allows during extrusion to foam only on the inside.

Figure.4 Scanning electronic microscope (SEM) images of foamed strands by varying only the absorption and desorption times of the blowing gas

The figure below is a demonstration of the first sandwich structure made in a single print in a single material (PLA) by only varying the printing parameters it was decided to foam only the central part of the bending specimen in order to increase the inertia, the foamed specimen was then comforted with a specimen of the same weight made without foam.

The foamed specimen during the flexural test withstood 40 % more load.

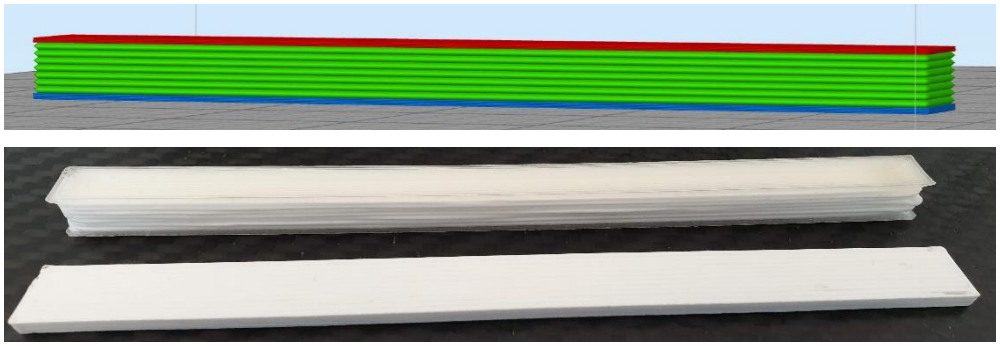


Figure5 First sandwich specimen made in a single print, PLA foam in the middle and PLA bulk at the extremities

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