Metal additive manufacturing for the design of moulds for expanded polymers

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Outline of the talk

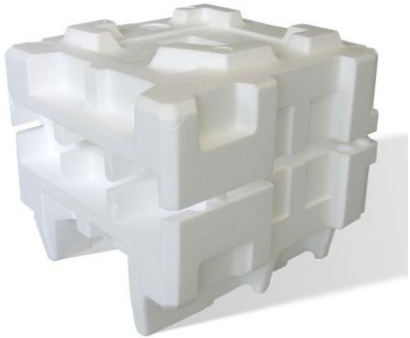
- ✓ Expanded polymer chest moulding (current state-of-art and limitations)
- ✓ Opportunities offered by AM for mould design
- ✓ A case study – mould for EP helmets
- ✓ Alessiohitech view for innovative moulding systems
- ✓ Performance of the proposed solutions

Expanded polymer sector

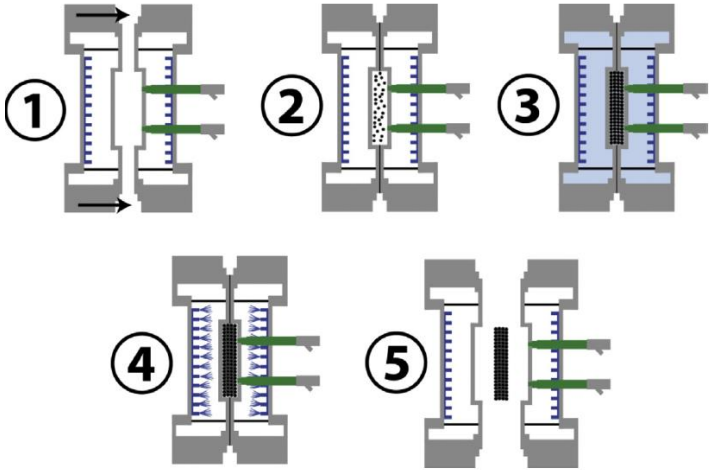
Polymer foams is class of materials where the polymer matrix contains a large amount of pores providing special properties:

- ✓ very low density
- ✓ low thermal conductivity
- ✓ acoustic insulation
- ✓ energy absorption capacity

Polypropylene, polystyrene and polyurethane are used for a wide range of applications including packaging, sport and safety equipment, crash absorbers and bumpers, insulating panels, car interior, in the transportation, military and building sectors



Expanded polymer chest moulding

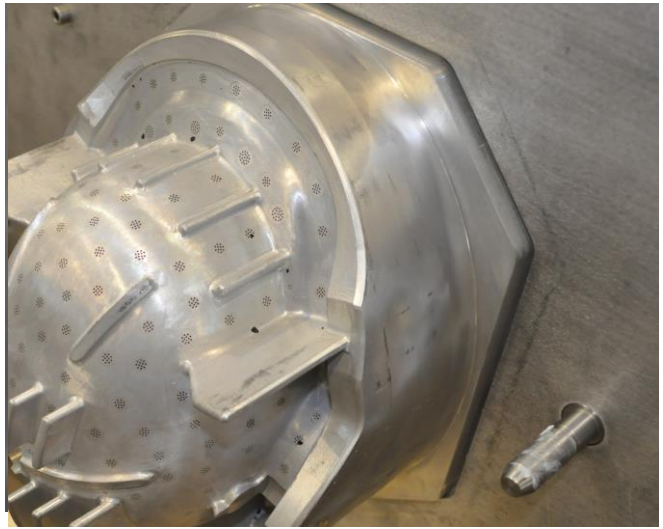


D. Raps et al. / Polymer 56 (2015) 5–19

Bead foam processing in a steam-chest moulding machine:
1: closing and 2: filling the mould, 3: steaming, 4: cooling, 5: ejection of moulded part

- ✓ The feedstock material are expandable or already expanded foamed beads that are injected into a mould by air pressure
- ✓ Beads get sintered under the action of pressure and temperature given by a steam flow (temperature up to 150°C, pressure up to 8 bar)
- ✓ Strict control of the processing environment is required to ensure a temperature distribution as uniform as possible throughout the volume of the part.
- ✓ The cooling stage is also important since it affects the dimensional stability.

Expanded polymer chest moulding



- ✓ Moulds for steam-chest moulding of EP are traditionally built by massive aluminium-alloy castings
- ✓ Significant thermal fluctuations during processing that promote consistent energy wastes

- ✓ Cycle times for the process are ruled by the rate at which the whole system can follow the desired thermal history
- ✓ Energy requirement is set by the overall heat capacity of the moulds + part system

Opportunities offered by AM

Reducing the overall thermal capacity of the mould would lead to lower energy requirements and shorter thermal/production cycles

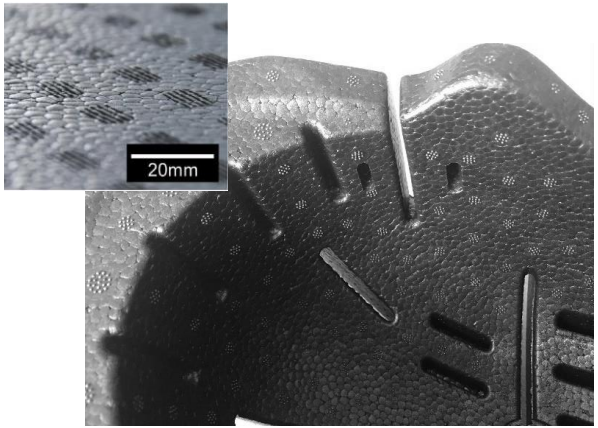
A **new design approach** was used to developed more sustainable and energy efficient moulds for steam-chest moulding of expanded polymers

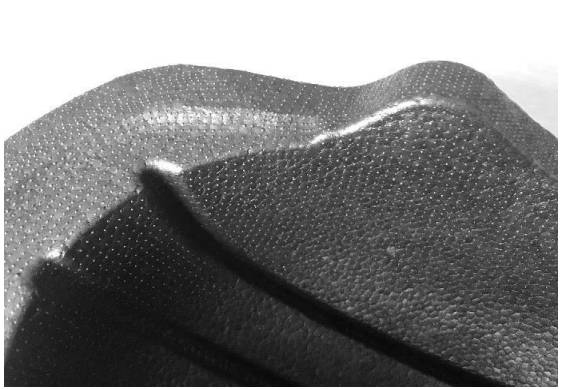
- ✓ **L-PBF** was considered as manufacturing technology
- ✓ The bulky moulds are replaced with **light thin-walled tools** implementing some new functions
- ✓ Several **materials** have been tested according to the different requirement

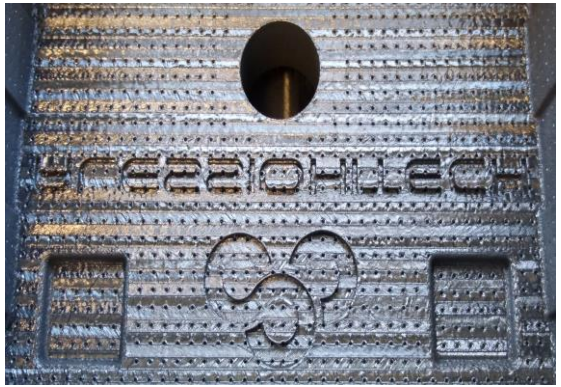
Delivery of steam to the feedstock (1/2)

Steam nozzles are used in traditional moulds to allow the flow of steam from the steam chamber into the mould

- ✓ their imprints become visible on the final surface of parts
- ✓ The discrete nozzles can be replaced by an array of micro-holes (0,2mm dia.) allowing a more homogeneous delivery of heat to the polymer beads and an improved aesthetical aspect



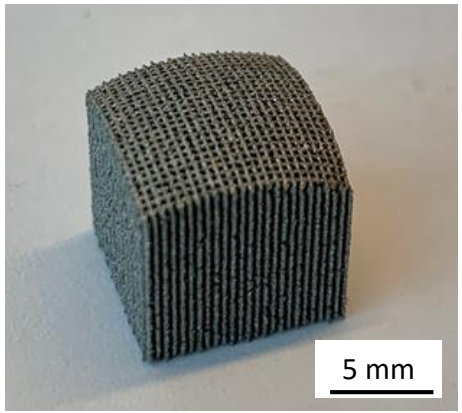


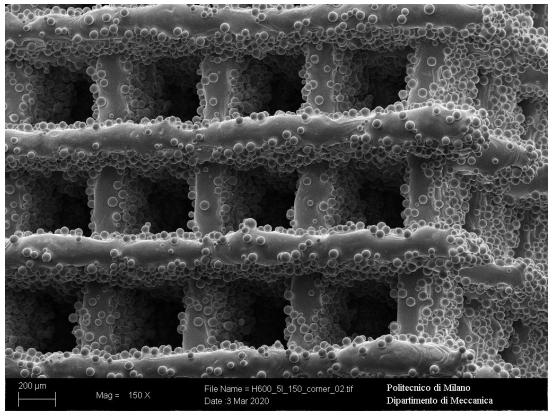


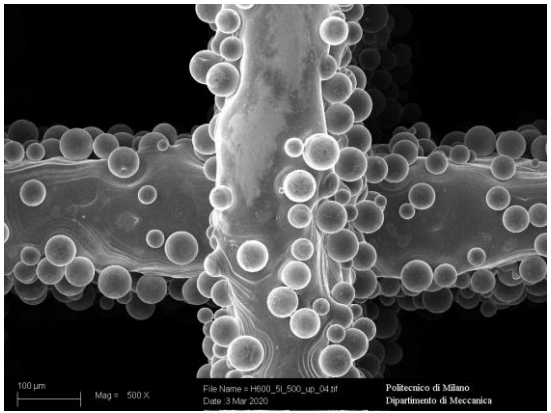
Delivery of steam to the feedstock (2/2)

Porous layers could even be designed and directly manufactured by L-PBF in order to achieve a fully homogeneous distribution of heat to the beads

- ✓ Due to the complex shape of most of the moulds, a trabecular/porous structure is better created by properly setting the processing conditions rather than by including it into the designed part shape
- ✓ Micro-porous structure is achieved by increasing the laser hatch distance and tuning the size of the melt pool in order to generate a distinct and intersecting truss instead of a solid volume



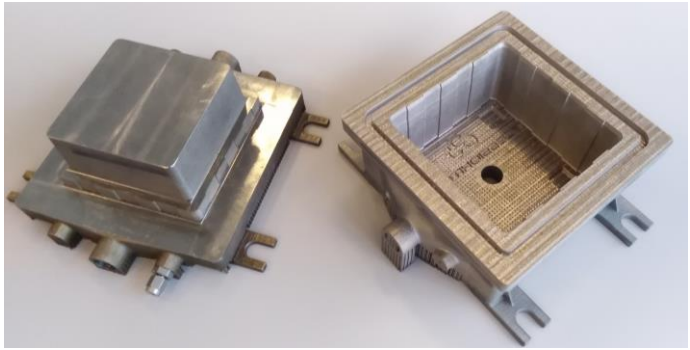


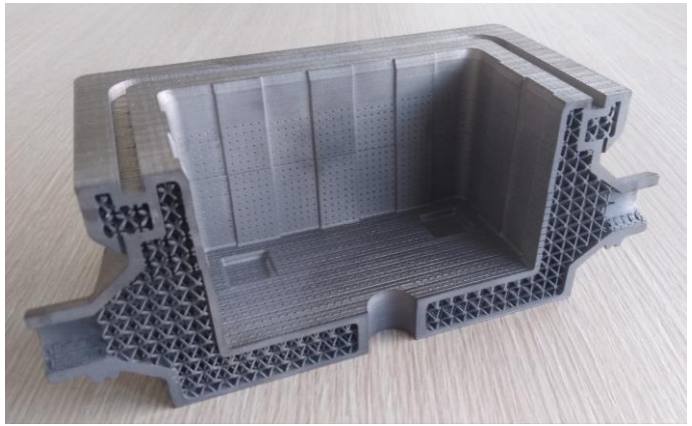


Replacing the steam chest with a light sandwich structure

The bulky Al alloy mould is replaced by a light sandwich structure composed of two thin sheets supported by an internal 3D lattice.

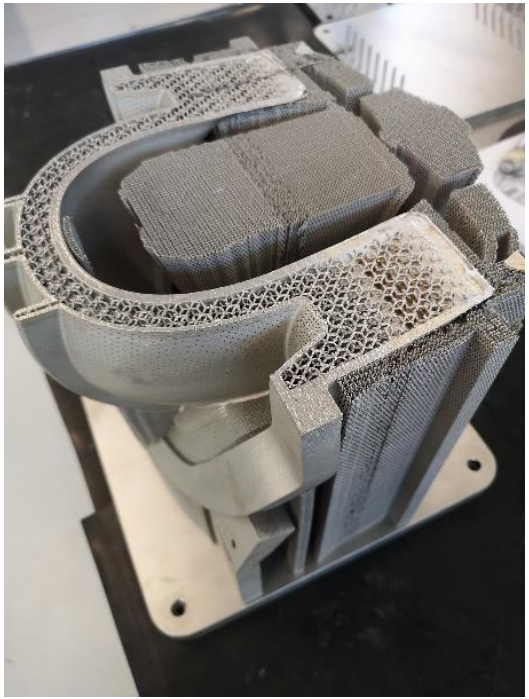
- ✓ The skin exposed to the EP beads is required to be as thin as possible to fasten the moulding cycles and to save energy.
- ✓ The volume contained within the two skin surfaces of the sandwich should also be limited to reduce the amount of steam and water required for the moulding cycles.
- ✓ The features of the 3D lattice must be defined considering a compromise between the need to reduce the mass subjected to the thermal cycles and the strength against the structural loads
- ✓ Highly conductive Al is not required anymore, other alloys with superior properties can replace it
- ✓ A controlled flow of the steam and water inside the chamber has to be assured by computational fluid dynamics analysis





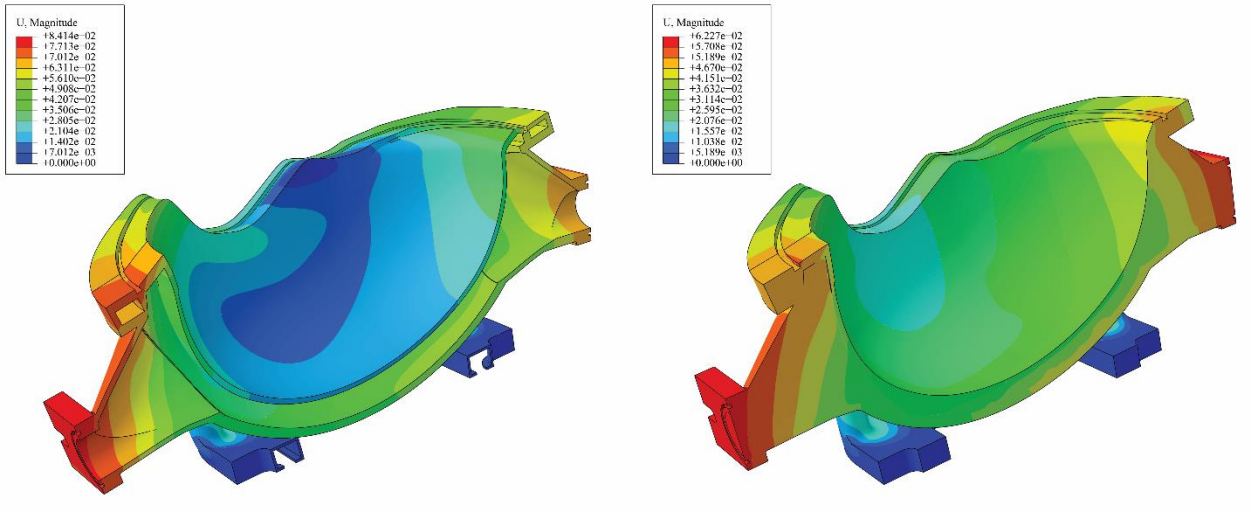
Case-study: moulds for EP helmets

Innovative moulds for polypropylene climbing helmets have been designed and manufactured by L-PBF implementing some of the above opportunities



Moulds for EP helmets: their design

FEM calculations have been carried out to verify the strength of the mould and its compliance under the steam pressure load

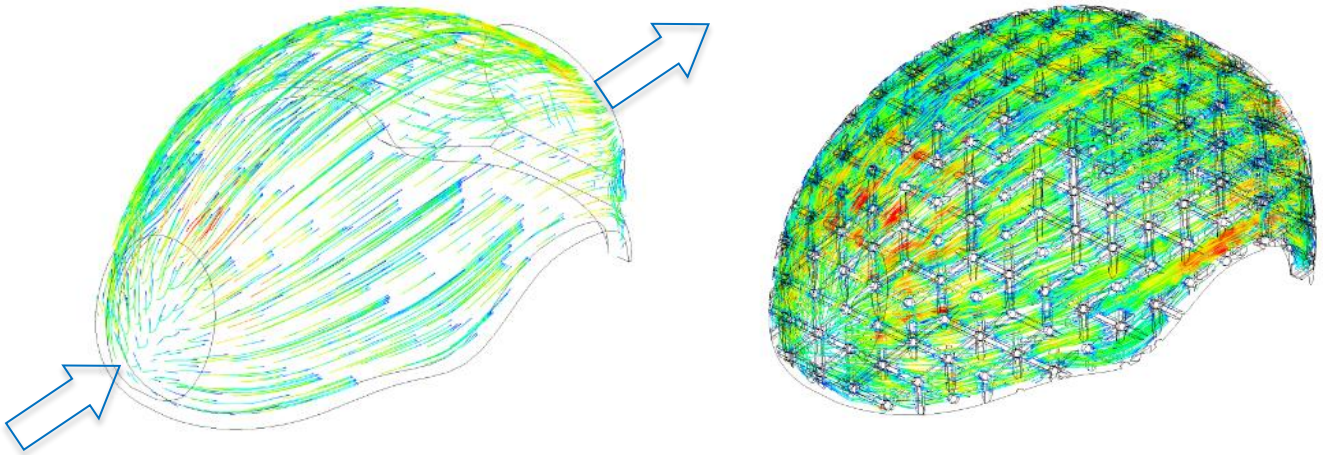


FEM simulation of the deformed female mould. Model without lattice structure in the conveying chamber (left) and with an equivalent material simulating its mechanical behaviour (right).

Moulds for EP helmets: their design

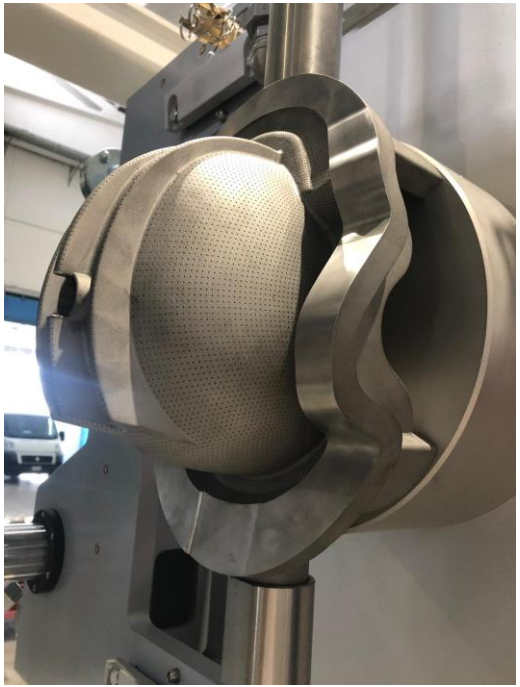
Computational fluid dynamics (CFD) analysis was performed to evaluate the expected flow of water and steam in the conveying chamber.

- ✓ The lattice array was modified to improve the flow in some critical regions.



Flow pattern with empty chamber (left) and with chamber filled with the 3D lattice (right).

Moulds for EP helmets: the working moulds



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Alessiohitech is an Italian leading company in the development of solutions for

EPS
Expanded
Polystyrene

EPP
Expanded
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ETPU
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Thermoplastic
Poly-urethane

For more than thirty-five years, the brand Alessio has been known as one of the most innovative companies in the foam industries.

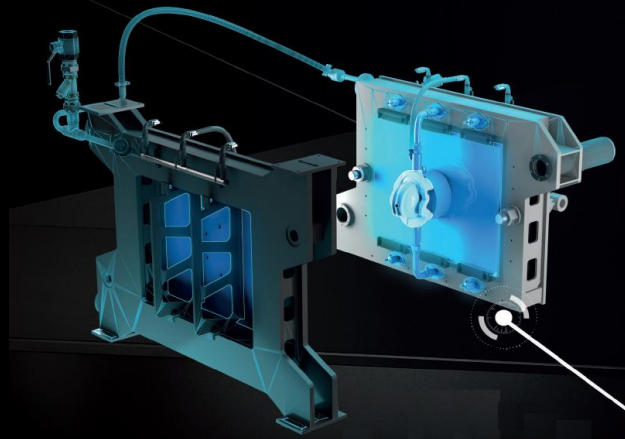
ALESSIOHITECH

ZERO®

The new generation of molding. Beyond savings.

Processing

ZERO® molds have been designed to fit on Alessiohitech ***ELETTRICA***, the new series of electrical machinery created to enhance mold performance even further with a smart modular design.

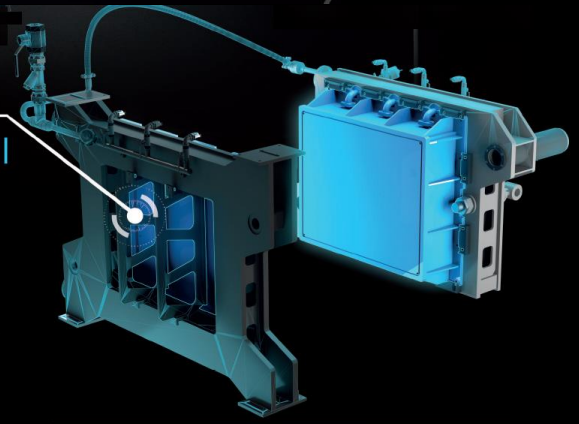


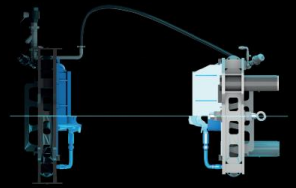
ZERO® SYSTEM CONFIGURATION

SUSTAINABILITY, production costs reduction and the higher flexibility required by the market inspired us to design the new PMP ***ELETTRICA*** with a modular structure. It allows the customer to use traditional mold and steam chambers as well as the new ZERO® molds on the same machine. New software with a re-designed steam and water system guarantees the total control of all process parameters, working to reduce the entire cost even further. The machine's software manages all the production output data as required by the industry 4.0.

STEAM CHAMBER CONFIGURATION

The modular system of ***ELETTRICA*** allows the operator to run standards molds simply by switching to "steam chamber" configuration.
Thanks to the electrical movement and the revised plant scheme of this high-end machine, also the performances of standard molds can be increased.





*Please note that ZERO mold technology is specifically designed to run on Alessiohitech **ELETTRICA** machineries and permits the production of a wide range of products, especially ones with complex configurations. For more information about this technology, the **ELETTRICA** range of machineries, or the compatibility of your current Alessiohitech machineries, do not hesitate to contact us at comm@alessiohitech.com*

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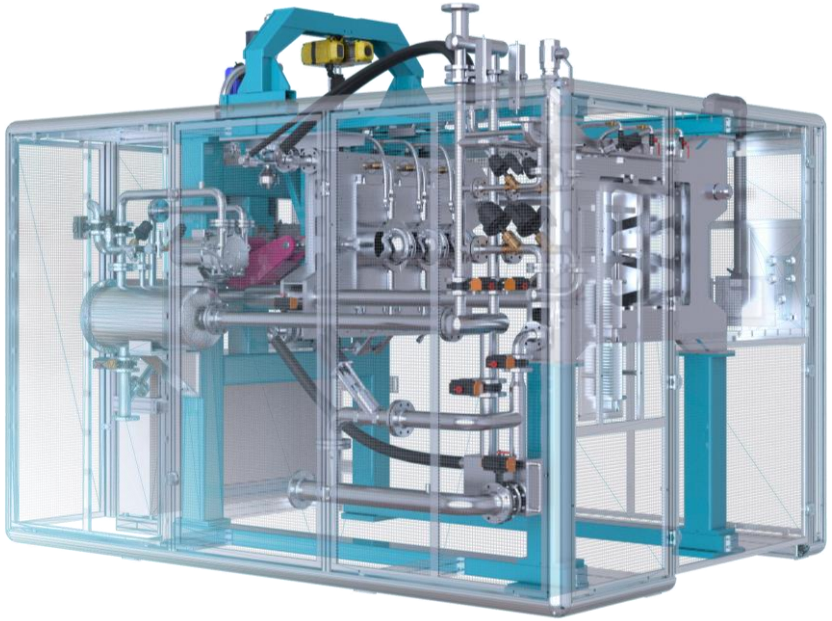
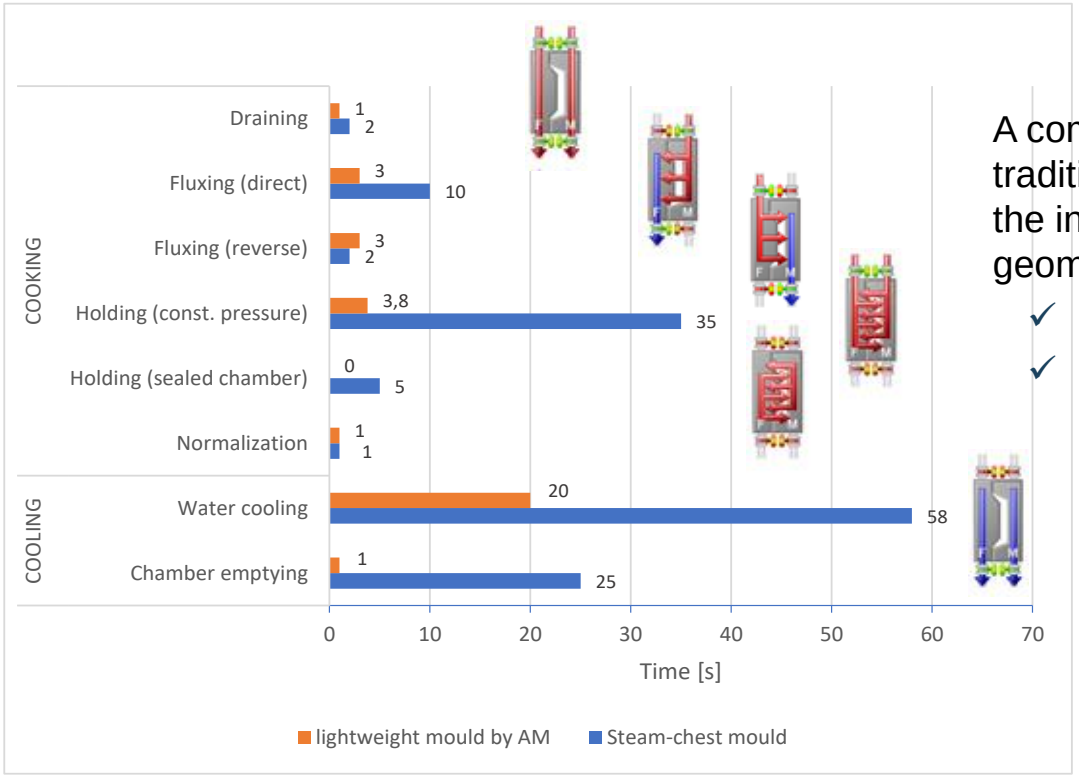
The innovative moulding system developed by Alessiohitech



Moulds for EP helmets: the performance of the innovative system



A comparison of the process data between a traditional stem-chest moulding machine and the innovative solution for the same helmet geometry led to:

- ✓ reduction of cycle time of 75%
- ✓ energy saving of about 80%

Conclusions

- ✓ New concepts were introduced for the design & manufacturing of moulds for EP exploiting opportunities offered by AM
- ✓ The innovative system developed by Alessiohitech Srl showed a remarkable improvement in energy savings and in cycle times with respect to the traditional chest moulding technology
- ✓ New tools for large mass production of EP products can conveniently be conceived, producing great advancement for environmental sustainability

Thanks for your kind attention !

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