3D printing for energy applications: materials and devices

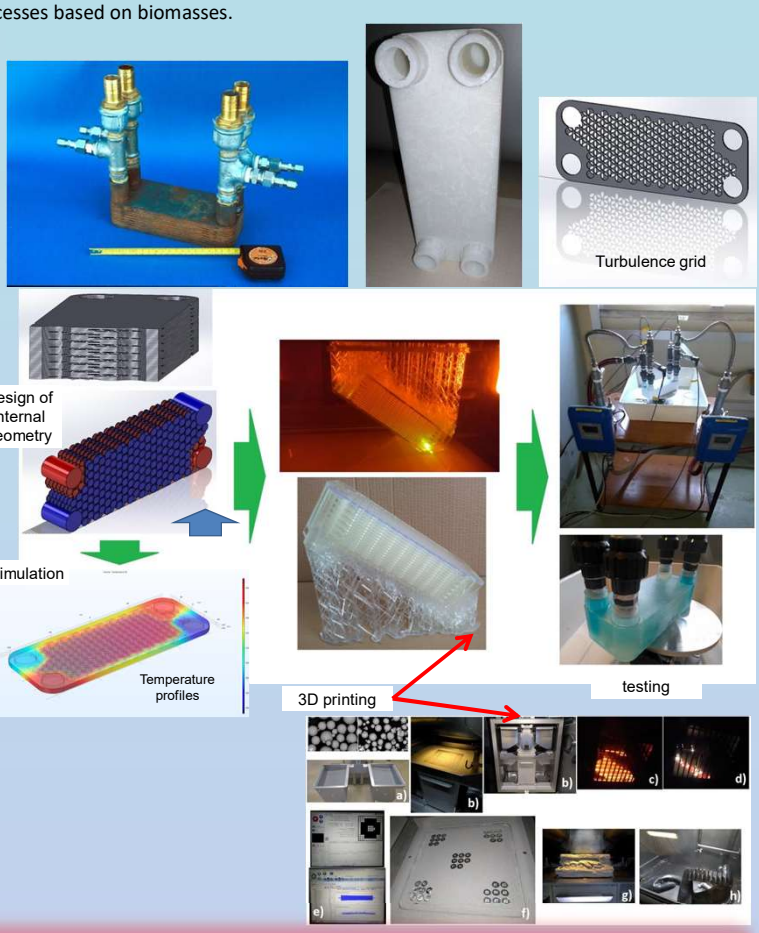
ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

ROME 8-10 OCTOBER 2021
Maker Faire
THE EUROPEAN EDITION

The project "Materiali di frontiera per usi energetici" is focused on different aspects of Additive Manufacturing (WP3 and WP4), mainly considering the possibility of integrating or substituting traditional manufacturing process, i.e. subtractive and foundry ones, for the realization of components for energy applications. A part of the activities are focused on development of metal composites 3D printing processes for metal alloy components, starting from polymer based composited, considering both the two aspects related to binders and charges. Moreover a plasma atomization machine, designed in ENEA, will be used to realize powders, even with customized composition, for AM processes, as charges for composites and slurries and for powder bed or direct deposition. One of the aims of the project, starting from previous activities, regards the realization by 3D printing of an heat exchanger, for its use in absorption machines for solar cooling and heating systems based on ammonia-water cycles and for household use. The realization of heat exchangers in polymeric composite materials with micro and nano charges, will be considered also for less severe conditions and for the optimization of the heat exchanger design before printing the heat exchanger in metal alloy. A new alloy was also designed and manufactured with properties suitable for use in highly alkaline environments, for the construction of heat exchangers using 3D printing. Another activity in the project is the optimization of 3D printable feedstocks for advanced ceramic components. Printable ceramic pastes, with optimized rheological properties, will be formulated for 3D printing based on material extrusion and in particular for Liquid Deposition Modeling (LDM) process. The printing strategy and thermal treatments will be optimized up to obtain sintered components, demonstrating the effectiveness of the 3D printing process. The advanced ceramic components will be properly designed as promising to improve the working temperature and the efficiency of energy production processes based on biomasses.

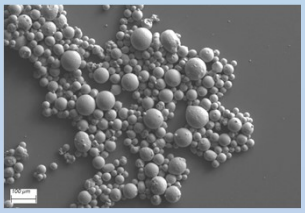
Additive Manufacturing for the Realization of Heat Exchangers: Case Study

ENEA carried on a R&D activity on absorption cycles for over 35 years. Among the several patented components developed and tested, one of them consisted of an original brazed plate-grid heat exchanger suitable for water ammonia cycles. Starting from this previous exchanger, a new research project is currently ongoing, aimed to the development of 3D printed exchangers. Heat exchangers are critical components in absorption machines working with water/ammonia solutions as they are subjected to corrosive environment. Brazing or diffusion bonding require long heat treatments. Moreover some materials or compounds as nickel and copper, used for brazing, are largely affected by corrosion. The research is focused on design of a new ferritic alloy and on the realization of heat exchangers with optimized internal geometry by 3D printing.



Materials and Methods

- Preliminary acrylic resin print with heat exchange and pressure drop tests.
- Computer Aided Design optimization by means of software simulating liquid flow and thermal behaviour .
- *Final realization in metal alloy by 3D printing with full performance tests.*
- After alloy design, gas atomization has been used for ferritic alloy powder production


SEM Image of Ferritic alloy produced by Gas Atomization

Advanced ceramics pastes as feedstocks for 3D printing and ceramics components for biomass power plants

➢ New ceramics feedstocks for advanced ceramics 3D printing

Development of new formulations of advanced ceramic pastes and preliminary testing for 3D printing extrusion techniques (LDM, Liquid Deposition Modeling).


Printable paste for advanced ceramics

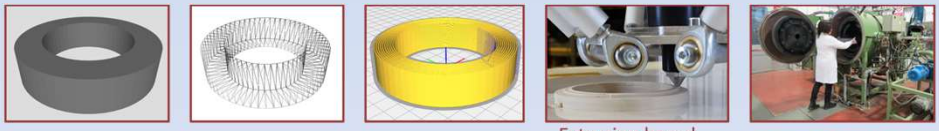

LDM printer Delta WASP 40100 Clay


Rheological behaviour tester

- **Characterization and rheological optimization of new printable ceramic pastes**
  - **Paste formulation** (liquid media, ceramic powder and rheological additives)
  - **Mixing/grinding methods**
- **Preliminary assessment for 3D printer working parameters and printing strategy**

➢ Development of 3D printing components in advanced ceramics

3D printing of pre-sintered ''green'' components up to **sintered advanced ceramics**.
Design of 3D printed ceramic components and fluid dynamics simulation.



WORKING DRAWINGS FOR CERAMIC 3D PRINTING
- 3D printing of components with reference feedstock
- Definition of the constraints for a Design for Additive Manufacturing (DfAM) aimed at LDM 3D printing

WORKING JOB (G-CODE)
- Slicing and 3D printing simulation

3D PRINTING OF GREEN COMPONENTS
- Printer working parameters (nozzle diameter, material extrusion and printing speed)

ADVANCED CERAMICS SINTERING
- High temperature thermal treatments setting up

Acknowledgments

The work is financed in the framework of Program Agreement with the Italian Ministry of Economic Development: PTR 2019-2021 Project "Materiali di frontiera per usi energetici" (CUP: I34I19005780001). INSTM, UNIBO, UNINA, UNIROMA1, UNISA, UNISalento collaborate in the project activities.

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