PhD course of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

Università degli Studi di Padova

Annual report

Name and surname: **Francesca Valentini**
Cycle and a.a.: **39° cycle, 2023-2024**
Supervisor: **Simone Mancin**

- **Research activity carried out during the year**

During the first year of my PhD, I primarily focused on two projects: the LoCoMoSa project and the development of high-performance heat sinks filled with Phase Change Materials (PCM).
The main portion of my work revolved around the LoCoMoSa project (Low-Cost Molten Salt Thermal Energy Storage for Industrial Processes). This project aims to demonstrate a cost-effective thermal energy storage (TES) system designed for industrial heat storage, operating at temperatures between 120-450 °C. The TES system comprises two molten salt tanks, an electric heater, and a steam generator, with NaOH molten salt serving both as the thermal storage medium and as the working fluid in the steam generator. The molten salt is stored at 700°C in the hot tank and 400°C in the cold tank.
My role in the LoCoMoSa project was to design an innovative steam generator to be produced by additive manufacturing technology. The initial task was to research existing steam generator designs and previous thermal storage projects to establish the starting point of the design. Several candidates were considered, but ultimately, the kettle reboiler was selected as the favorite design. Following this, I focused on developing innovative boiling-enhancing geometries using topology optimization (TO) algorithms. This required an in-depth study and the development of a suitable model, for which I used COMSOL Multiphysics ® software. By the end of the academic year, I had proposed three preliminary geometries aimed at enhancing heat transfer efficiency. However, further work is needed to refine the TO model. The main challenges in this work were both understanding the implications of working with NaOH as a high-temperature molten salt, which enters the steam generator at approximately 600°C, and developing a TO model tailored to this application. Given the limited similar cases in the literature and the constraints of commercial software, advancing this model has been particularly difficult. The next step involves some future collaboration with Purdue University, which possesses a more advanced algorithm that could be beneficial to our research.
The second project involves developing high-performance heat sinks filled with PCM and experimentally assessing the efficiency of four proposed 3D-printed prototypes. These heat sinks are intended to function as passive cooling devices capable of withstanding power spikes from high-performance electrical appliances. Their design comprises fins on top, and a hollow portion filled with PCM and various conductivity-enhancing geometries to compensate for the PCM's low thermal conductivity. The proposed geometries include an empty control model, one with pin fins, one with gyroids, and a yet-to-be-designed TO version. After calibrating the experimental setup and determining the ideal experimental conditions, two of these geometries were already tested. The main challenge in this project is creating a suitable TO model for the heat sink design.

- **List of attended courses and passed exams**
  - Thermo-fluid dynamic in 3D printed channels
  - Coupled electrical-thermal-structural Finite Element Analyses
  - Experimental measurements in thermal fluid dynamics

- **List of attended conferences, workshops and schools, with mention of the presented talks**
  - Summer School Metal Additive Manufacturing, Associazione Italiana di Metallurgia AIM, Bertinoro - 30 June, 1-2-3 July 2024. No Talk was presented.

- **List of published papers/proceedings**

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- **Thesis title (even temporary)**

Innovative Design and Optimization of Thermal Energy Storage Systems and High-Performance Heat Sinks Using Additive Manufacturing and Topology Optimization Techniques.

Date, 05/09/2024 **Signature…**

Seen, the supervisor.