Hybrid AI and CFD Approach for Simulating Droplet Impacts in Thermal Coatings

M2 Internship subject, 5-6 months

Subject

Suspension plasma spraying (SPS) is an emerging industrial process, particularly for the creation of ceramic coatings capable of withstanding the very high temperatures and mechanical stresses inside an aircraft engine for a long time (thermal barrier). For the aeronautics industry, it is classified as a special process whose output elements can only be verified by monitoring or post-measurement, and whose deficiencies therefore only become apparent once the product is in use. The SPS process creates thermal barriers by injecting and melting ceramic powder into a plasma. The plasma flow accelerates the particles, and the molten droplets are then crushed onto a substrate. They spread out and solidify rapidly successively to form the coating.

Millions of particles are involved in this process. The structure of the coating is a function of the operating conditions, from the plasma torch to the droplet impact conditions (shape, velocity, temperature, and substrate roughness). A dense or columnar structure may occur, which influences the final thermomechanical properties of the material. A full CFD simulation of the entire process is beyond reach due to limitations in the number of particles that can be simulated. Therefore, we propose a three-step approach, consisting of CFD simulations at the droplet scale combined with a stochastic approach [1], enriched by AI at the coating scale:

• The stochastic approach aims to represent realistic spray conditions (spatial, temporal, radius, velocity, and temperature distributions of the particles).

• Simulations of droplet impacts using the CFD code Notus [2] aim to populate an image database representing the topology of various instantaneous sprayed surfaces.

• A neural network-based image processing AI aims to surpass CFD simulations by representing large impact surfaces and amounts of particles. The AI tool's results can be verified and refined through additional CFD simulations.

The aim of the internship focuses on the AI component of the project, beginning with a bibliography of available image analysis AI tools, Python programming of the selected method, the creation of a 2D database of droplets impacting a flat substrate, and the verification of the proposed approach.

Skills

Python, Fortran, AI, Image Processing, Computational Fluid Mechanics.

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References

[1] M. Xue et al 2008, A stochastic coating model to predit the microstructure of plasma sparyed zirconia coatings, *Modelling Simul. Mater. Sci. Eng.*, 16 065006.
[2] Notus CFD code, https://notus-cfd.org