PhD thesis position - 2022

TITLE	**Modelling the physical mechanisms in suspension plasma processing**
Summary and description:	***Abstract*** Plasma spraying of suspensions allows obtaining coatings with fine and varied microstructures addressing applications which emerge at the industrial level as for example, thermal barriers of new generation for aeronautics. In this process, the liquid suspension containing the submicronic particles of the material to be deposited is injected into a thermal plasma jet to be fragmented, evaporated releasing the submicronic particles which are then accelerated and melted and will impact and spread on the part to be coated to form the deposit. The control of the process requires the understanding of the mechanisms that govern the treatment of the suspension and the construction of the coating. This understanding requires the simulation of the process from the generation of the plasma jet, its interaction with the suspension, the impact of the particles/droplets on the substrate and the construction of the deposit. The IRCER and TREFLE laboratories of I2M have joined together to address this issue, which is of great interest to Safran and Oerlikon, international leaders respectively in the production of coatings for aeronautical parts and in the manufacture of spraying equipment. Modeling work on the plasma jet generation, its turbulent development and the construction of the deposit has already begun. The work of this PhD will consist in modeling the hydrodynamic fragmentation of the suspension due to shear stresses applied by the gas flow as well as the behavior of the fine particles within a drop of suspension whose carrier liquid evaporates, deforms and recirculates by taking into account the diffusion and the forces on/between particles, so as to make it possible to predict the number of particles resulting, their size and even their shape, a drop possibly leading to the birth of several aggregates. **Description** **Background and objectives:** The plasma spraying of suspension allows obtaining coatings with fine and varied microstructures (columnar, dense, ...) answering the requirements of applications which emerge at the industrial level as for example, thermal barriers of new generation for the aeronautics or solid electrolytes of fuel cells. In this process, the liquid suspension containing the submicronic particles of the material to be deposited is injected into a thermal plasma jet to be fragmented and evaporated, releasing the submicronic particles which are then accelerated and melted and will impact and spread on the part to be coated to form a deposit. Its microstructure, and therefore its properties of use, depend on a large number of operating parameters related to the plasma torch, the suspension, the substrate and the torch-substrate kinematics♦. ♦: V. Rat, C. Chazelas, S. Goutier, A. Keromnes, A. Vardelle, In-Flight Mechanisms in Suspension Plasma Spraying: Issues and Perspectives, , J. Therm. Spray Technol. **31**, pages 699–715 (2022)

Also, the complexity of this process requires many tests to achieve a coating with controlled properties on a part of complex shape, which hinders its adoption by the industry. The mastery of the process requires the understanding of the mechanisms that govern the treatment of the suspension and the construction of the coating. This understanding requires the simulation of the process from the generation of the plasma jet, its interaction with the suspension, the impact of the particles/droplets on the substrate and the construction of the deposit.

The proposed study is linked to the Selenite project co-financed by the CNRS. Selenite project is led by the Institute of Research for Ceramics IRCER (France), the Institute of Mechanics and Engineering (I2M) of Bordeaux (France), the companies Safran (2nd aeronautical equipment manufacturer, leader for the realization of deposits on aeronautical parts) and Oerlikon (first world manufacturer of plasma torches and integrated industrial projection systems).

At IRCER, the Selenite project focuses on 1) the modeling of the plasma jet generation by the electric arc thanks to a MagnetoHydoDynamic approach (Code_Saturne) of the Sinplex plasma torch developed by the Oerlikon company, 2) the development of the turbulent jet in ambient air, 3) the primary and secondary fragmentation of the suspension by the plasma jet, 4) its kinematic, thermal and physical treatment by a global approach (Ansys_Fluent code). The TREFLE laboratory of the institute I2M models the formation of the deposit on the substrate from the results of previous models developed thanks to the Notus code.

Description of the work: The work of the PhD student will focus on a detailed description of the plasma-liquid input interactions. This description is essential to obtain a reliable simulation of the treatment of a suspension in plasma. It aims at understanding and modeling the thermal, hydrodynamic and physical treatment of suspension drops. The developed model will have to consider:

- the hydrodynamic fragmentation of the suspension due to gas flow shearing;
- the behavior of fine particles within a suspension drop whose carrier liquid evaporates, deforms and recirculates, taking into account the diffusion and the forces on/between particles.

This will allow predicting, depending on the operating conditions and thus on the treatment of the suspension within the plasma jet, the shape and morphology of the solid phase resulting from this evaporation, its size and eventually the particle size distribution; a drop can lead to several solid particles resulting from the agglomeration of submicronic particles. The developed model should allow establishing a law of evaporation of the drops of suspensions in a plasma environment as a function of the original load in solid particles and their size. The results of the model will eventually be integrated into the Ansys-Fluent fluid mechanics code which simulates the behavior of a large number of drops injected into a plasma jet with different temperatures and velocities taking into account the modification of the plasma gas properties by the evaporation of the liquid.

This thesis, co-supervised by IRCER and I2M, will take place mainly at IRCER and in close collaboration with i) IRCER researchers who are working on the experimental observation of the treatment of suspensions in the plasma jet and ii) collaborators from SAFRAN and Oerlikon who are industrializing the process of plasma spraying of suspensions and iii) the PhD students and post-docs of the on-going Aventurine project. The TREFLE department of the I2M will bring its expertise in terms of modeling of the physical phenomena and their numerical aspects and will ensure the adequacy of the results with the model of construction of the deposit which it is being developed.

	Role and skills of the PhD student • Develop and implement numerical models to represent the physics governing the interactions between the suspension drop and the plasma: Eulerian two-phase approach (gas/liquid), Lagrangian approach (behavior of the particles in suspension in the drop), • Implement numerical schemes adapted to these models. • To feed the database developed in the IRCER/Oerlikon project and to ensure a harmonious exchange of data flows with the other calculation codes used in this project (Fluent and Notus). Knowledge and experience in modeling, numerical methods, programming and physics, good physical sense, ability to communicate with partners
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