PhD Position

Surrogate Models and Multi-Objective Optimization for the Cold Spray Process

Supervisors:

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Scientific context

Cold Spray processes present complex optimization challenges due to the multi-physics interactions between process parameters (gas temperature, pressure, spray velocity, nozzle-to-substrate distance) and the final coating properties. Since experimentation is costly in terms of both time and resources, it is essential to be able to predict promising configurations to explore. This thesis focuses on building surrogate models to predict coating qualities as a function of input parameters, and on developing multi-objective optimization methods to identify the most promising configurations.

Objectives

The candidate will develop an integrated approach built on two main methodological pillars.

1. Building intelligent surrogate models

• Development of machine-learning-based surrogate models integrating experimental data and, where applicable, data from numerical simulations.

• Exploration of various modeling approaches: Gaussian Processes (including heteroscedastic variants to capture uncertainty from different data sources), neural networks, or hybrid methods.

• Multi-source data processing and analysis:

– Exploratory analysis and preprocessing of heterogeneous data (in-situ instrumentation, post-deposition characterization, and possibly simulations).

– Extraction and selection of physically guided, relevant features to improve model performance and interpretability.

– Management of dimensionality and sparsity of experimental data.

– Definition of relevant and measurable quality criteria for coating evaluation (composition, microstructure, porosity, deposition efficiency).

2. Constrained multi-objective optimization

• Development and adaptation of multi-objective optimization algorithms suited to expensive black-box functions.

• Exploration of multi-objective Bayesian optimization approaches leveraging the developed surrogate models.

• Investigation of metaheuristics suited to this context (evolutionary algorithms, swarm optimization, etc.).

• Management of trade-offs between conflicting objectives (e.g., mechanical properties vs. process efficiency vs. energy cost).

• Sequential sampling strategies for adaptive updating of surrogate models.

Collaboration

This work is part of a larger project in which numerical simulation aspects of the process will be developed by other collaborators. The candidate will interact with these teams, in particular to:

• integrate simulation results as complementary data sources for the surrogate models;

• provide recommendations of optimal configurations to be tested experimentally or through simulation;

• validate the predictions of the surrogate models.

Expected impact

The tools developed will:

• accelerate the discovery of optimal process parameters for various application objectives;

• significantly reduce the number of required physical experiments;

• improve the understanding of relationships between input parameters and coating properties;

• provide a generic methodology transferable to other additive manufacturing processes.

Candidate profile

Master's degree (or equivalent) in Computer Science or Applied Mathematics, with skills in optimization and/or machine learning. An interest in industrial applications and interdisciplinary work will be appreciated.

Application

Please send by email or through the ADUM platform (https://www.adum.fr/):

• a detailed CV;

• academic transcripts;

• the master's thesis report (if available).

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Keywords: surrogate models, multi-objective optimization, Bayesian optimization, machine learning, Gaussian processes, metaheuristics, Cold Spray, additive manufacturing.