Supersonic Spray Advanced Modelling – SSAM

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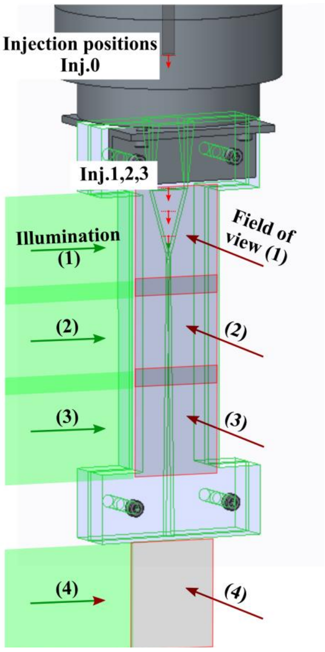
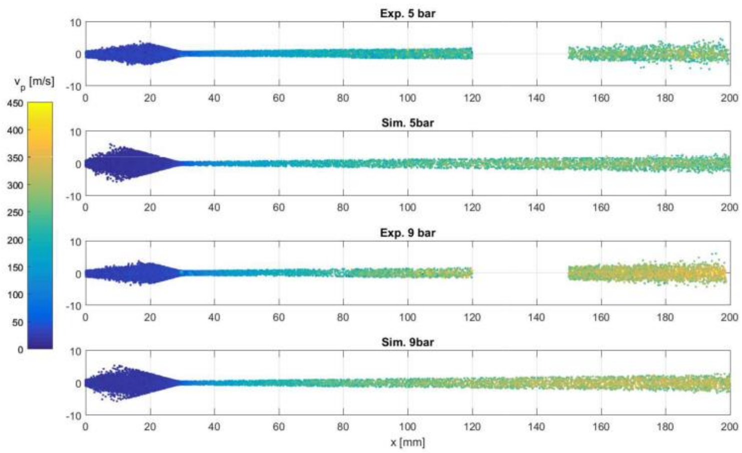
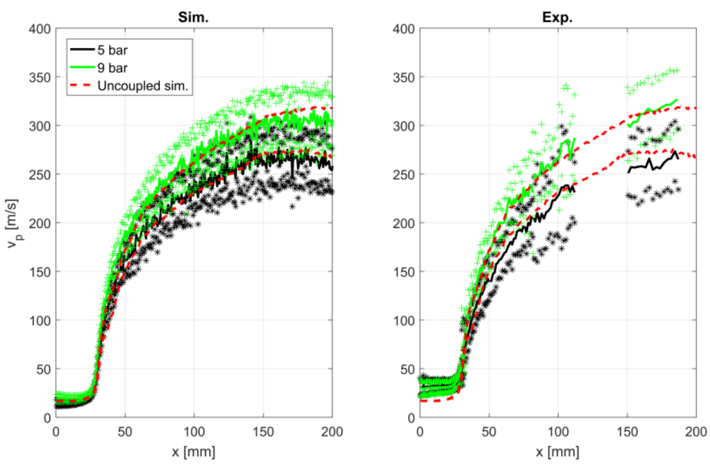
Cold Spray (CS) is a unique process for surface coating formation and additive manufacturing: material powders are accelerated by an expanding process gas in a supersonic nozzle and deposited via high-speed impact onto a substrate. Due to such high speeds, the temperatures are kept low in comparison to other additive techniques, i.e. below the melting point, which leads to distinguished benefits, from good material properties to the newly-enabled combination of otherwise incompatible and temperature-sensitive materials. The essence of this process is the gas-particle flow that defines the required high velocities upon impact. Although some aspects can be simulated with established computer models, not with general validity or with the assessment of advanced features that become increasingly important to understand: the particle spray spot, clogging of the nozzles, or the effect of high particle loading of the gas. *Supersonic Spray Advanced Modelling (SSAM)*, led by Dr. Rocco Lupoi, is a project focussing on amending these simulations, such that - in the long term - particle impact statistics and hence spray spot and process efficiency can be included in the list of predictable quantities.



Transparent nozzle measurement

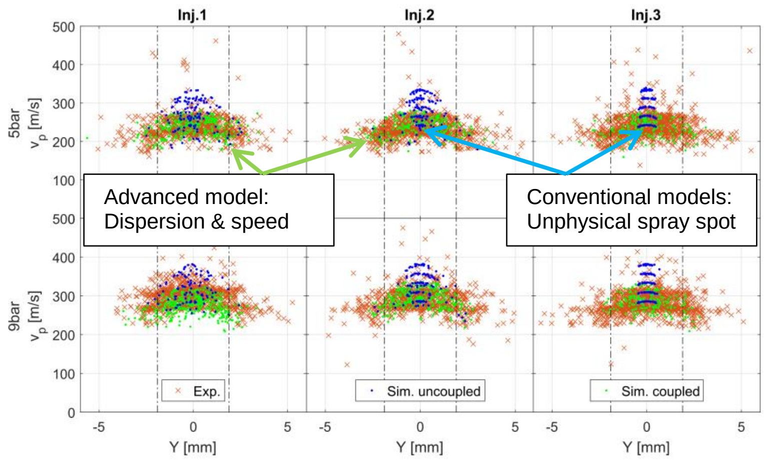
Early stages of the project applied conventional methods and tried to explain observed phenomena. The work has shown that the interactions of particles and gas are not yet fully understood and that the desired control over the particle stream requires that model assumptions are scrutinised. In order to provide entirely new means for validation, more direct measurements of the particles were concocted. This novel measurement tracks the particle position and speed optically within a transparent (quartz glass) version of the supersonic nozzle. This way, it was firstly possible to obtain data of the particle behaviour during nozzle-immanent acceleration and dispersion. This was done for various settings and the analysis finds firstly that the gas loses significant potential to accelerate particles when the particle mass is overly high. What was thereby entirely novel was the detection of additional volume-dependent particle-particle interactions, which play a decisive role, highlighting the importance of how “randomly” particles move and how that affects





the development of the particle phase all the way to the impact conditions. Another novelty was the use of this to advance the understanding of nozzle clogging: clogging at the throat and at the nozzle exit are subject to different mechanisms, and clogging risk analysis shows that almost all particles undergo interactions with the wall, which can be manipulated by injector location. This insight can be directly transferred to and amend many applications, but it helps more significantly, if it is used to create the new computer models needed to calculate such effects beforehand.

Such a new computational model based on the established already methods from earlier project stages was constructed in this project. It is a fully 3D-model of the CS nozzle and equipped with further advanced methods (full phase coupling, particle collisions and a tailored particle boundary condition). It is necessary to employ this advanced method to obtain adequate particle velocity predictions and the means to infer the spray spot. This is a matter of how particles disperse during their flight, and could be greatly amended over the state-of-the-art (to 10% error), but high-precision remains challenging due to the complexity of the statistical collisions. Further work on how particles bounce-off each other will increase the prediction standard even more.



With this modelling standard, it is possible to assess the low-speed mode of nozzle clogging, and the statistical distribution of particle speeds at the impact site – up until now, this was only possible for average information with much higher uncertainty. Within future studies, it will now be possible to quantify the particle impact angle in terms of the same statistics, and with it a computation of the spray efficiency – a leap step in the process analysis, which opens doors to finding possibilities to manipulate the spray beam.

With this distinguished outcome, the project significantly contributed to the thermal spray community and was accompanied by the rapid growth of the research team and expertise concentrated at the Science and Technology in Advanced Manufacturing group (STAM) in Trinity College Dublin. Dr. Lupoi has established a wide portfolio of additive manufacturing projects over the last 5 years, which led to significant scientific contributions and industrial collaborations, and current/future work will strengthen his nationally leading group in the European and global research community.

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