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Supersonic Spray Advanced Modelling SSAM

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INTRODUCTION

New required standards and tolerances come along with an increasing demand of enhanced surface properties, making a new generation of coating technologies necessary and capable of applying high quality layers of advanced materials onto substrates of other metals or alloys. A novel deposition technology is Cold Spray (CS). This method deposits particles in a solid-state manner and therefore avoids the unwanted effects of high temperature technologies. High pressure gas is accelerated in a converging-diverging supersonic nozzle to velocities in the order of 1000 ms^{-1}. The coating material is injected as powder into the nozzle and accelerated by the gas flow. As the powder particles strike against a substrate placed at a distance from the nozzle exit, they deform plastically and bond with the substrate material. The efficiency of this process strongly depends on the impact velocity of the particles. Due to physical complexity, the standard of numerical methods is not tailored for all the present local flow situations and investigations often focus on specific aspects of the flow field independently. In reality however, the different aspects of gas and particle dynamics influence each other. In order to develop a high-quality simulation tool for reliable estimations of the particle impact conditions, a more sophisticated, coupled and adaptable approach must be chosen. As the final goal of this project, an advanced numerical model will give insight in the events during the particle acceleration and therefore cost-efficiently provide valuable information for the deposition process. Because the model must incorporate all relevant phenomena, this project takes a fundamental approach. Instead of basing the model development solely on mathematical assumptions and a subsequent experimental validation, we take the challenge to gather experimental knowledge of the particle behaviour inside the nozzle at first and use this a-priori data for the numerical representation of the actual measurable processes.

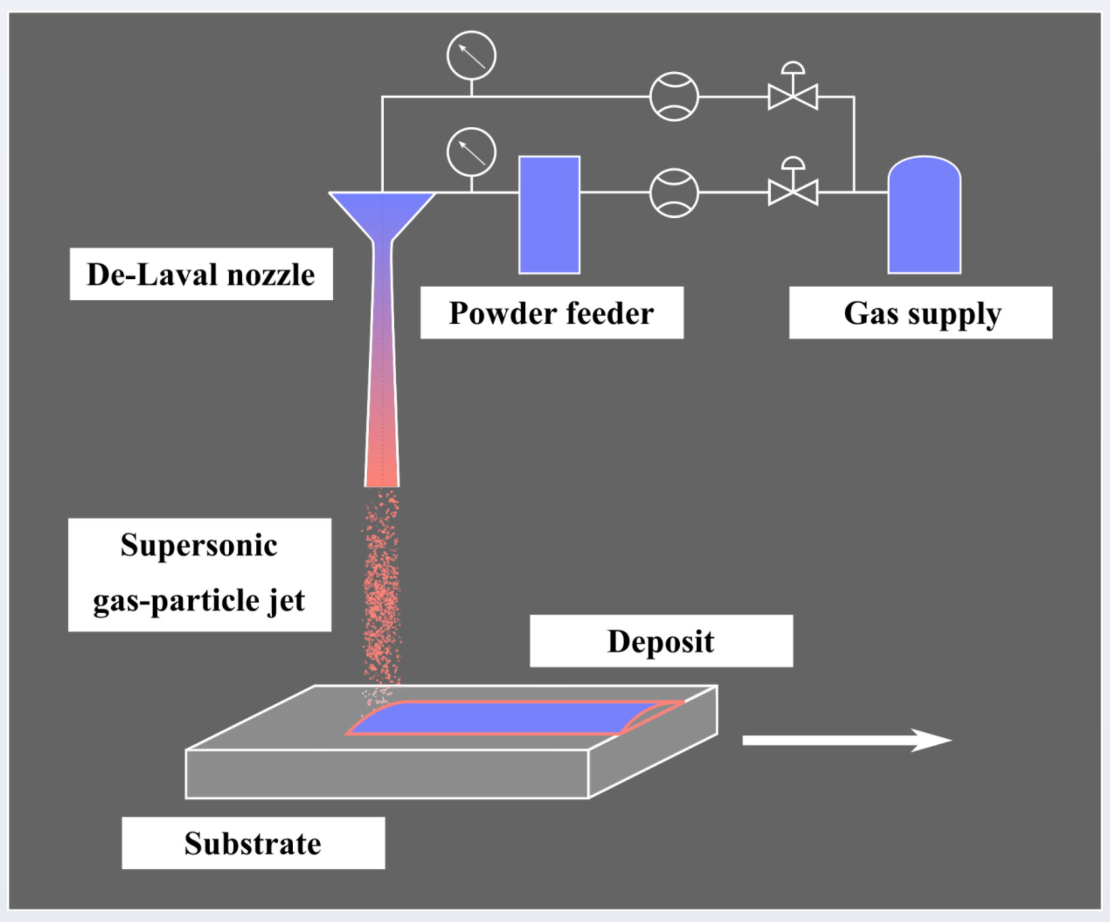


Fig. 01 – Cold Spray process

COMPUTATIONAL APPROACH

An Eulerian computational fluid dynamics (CDF) approach is applied to the gas phase. Reynolds averaged Navier–Stokes equations for mass, momentum, and energy are solved for a steady state as given on the left below.

The dispersed phase of solid particles is usually tracked in a Lagrangian reference frame based on the force balance as shown on the right underneath. In standard-methods, the particle is decoupled from the particles.

If this coupling is additionally introduced, closer agreement to experimental data is possible. Exemplary velocity results of such coupled simulations are shown for a 2D-axisymmetric calculation (Fig.02) and a 3D application (Fig.03) below for both the gas and the dispersed phase. However, this type of extended model is still extremely case-dependent. In order to achieve more general validity, the modelling principles need to be challenged. The main reasons for this are connected to the little knowledge of the actual particle laden flow within the nozzle.

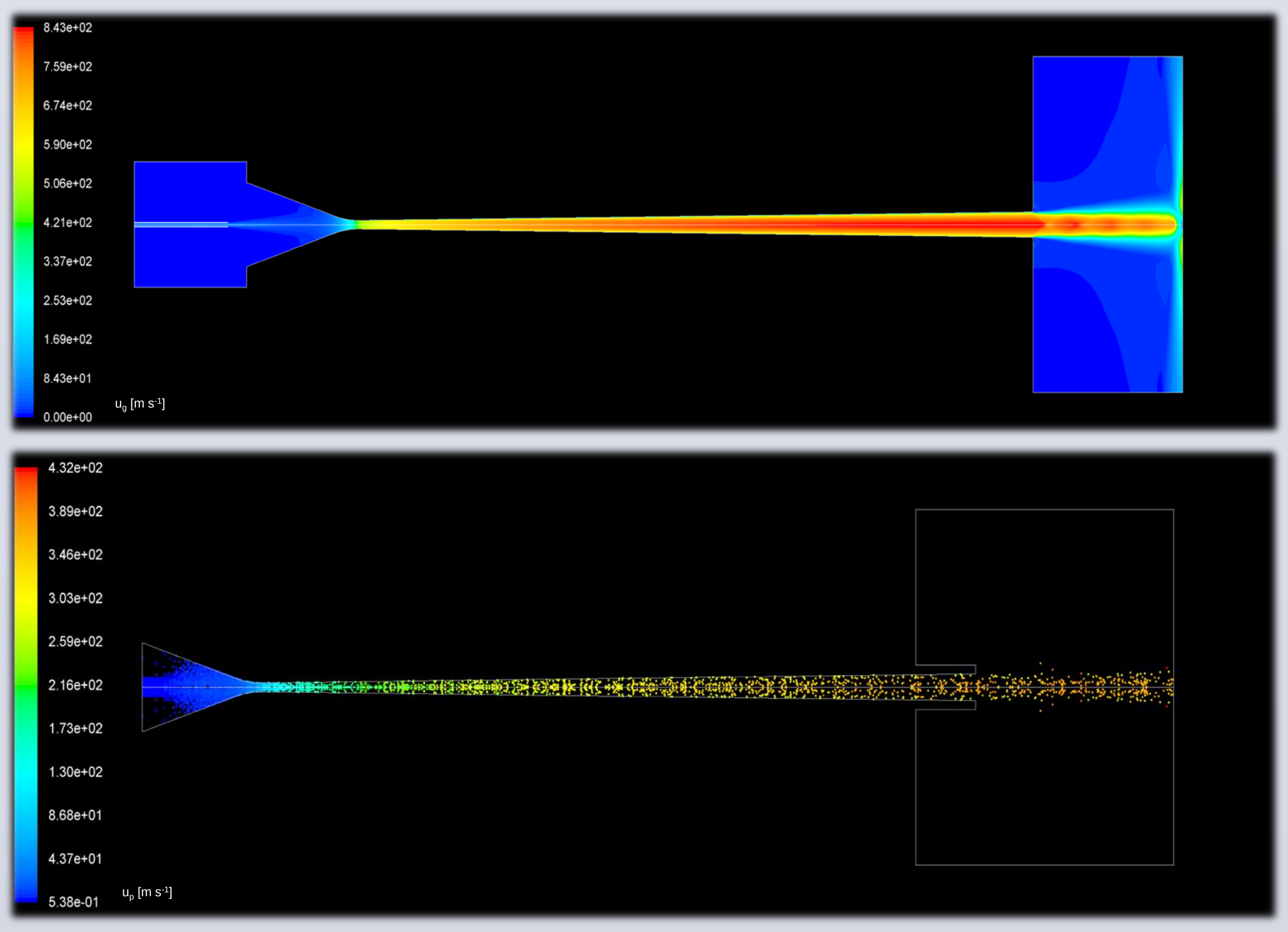


Fig. 02 – 2D simulation results for gas and particle velociy

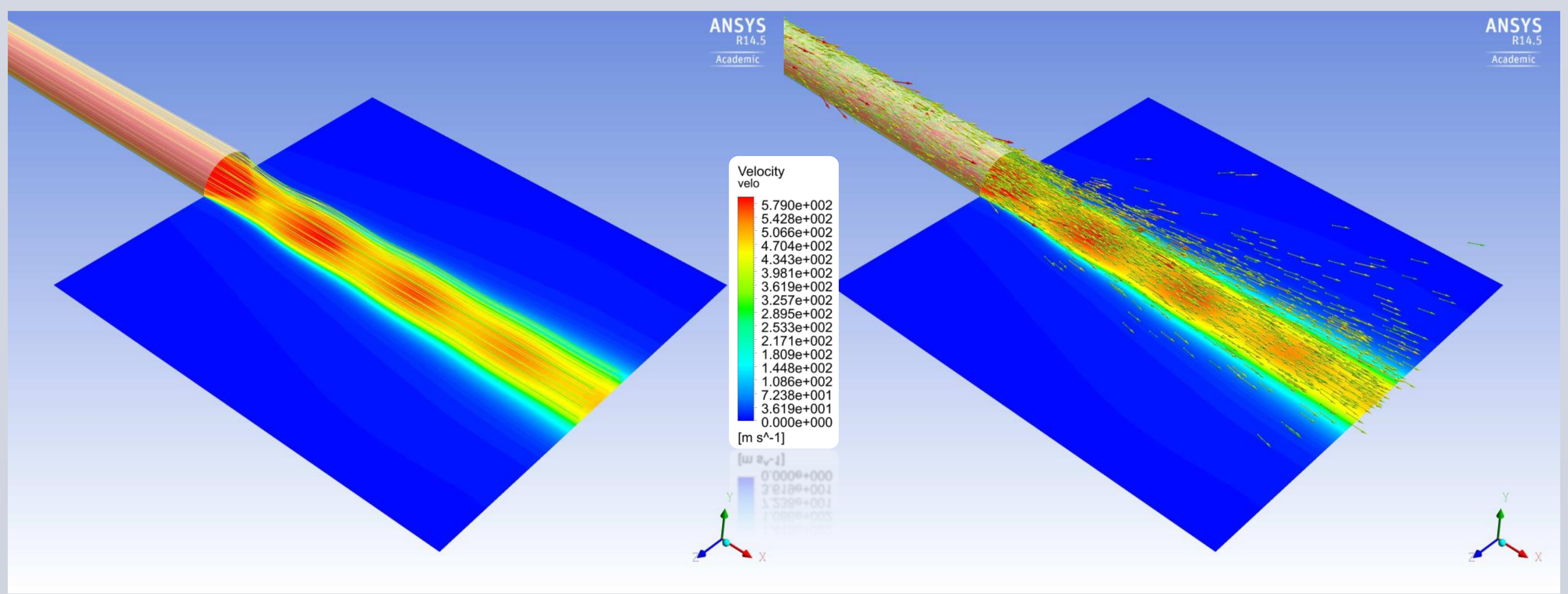


Fig. 03 – 3D simulation results in the nozzle exit and jet for gas and particle velociy

EXPERIMENTATION

In order to measure the velocity of particles in the flow, a technique called Particle Image Velocimetry (PIV) is used. It is an optical method and, in case of CS, the feedstock powder can be measured directly. The particles are illuminated by two subsequent laser pulses which are formed to a light sheet in the plane of measurement. A camera system captures two images of the scattered light respectively. These images are processed by a cross–correlation algorithm, deducing the displacement. At lower particle image densities, it is possible to identify single particles. By knowledge of the inter–pulse time, the displacement data can be interpreted as velocity information. Fig.04 displays the experimental set-up and in Fig.05 an expample image is shown of a high speed particle flow. The right part shows the identified single particle vectors corresponding to the velocity. Average particle velocity measurements for several CS materials are presented in Fig.06, in which the reciprocal influences between the two phases can be identified. The average velocity decreases with increasing particle feed rate. Hereby, the more particle mass needs to be accelerated the more the mean gas velocity reduces and loses some of its potential to accelerate the particles. Moreover, the particles disperse and decelerate differently within the jet, depending on the parameters, as can be seen in Fig.07. Here, two materials (a) and (b) are shown at increasing particle feed. For example, due to longer characteristic reaction time, the second material decelerates less along the jet and the velocity profiles disintegrate less.

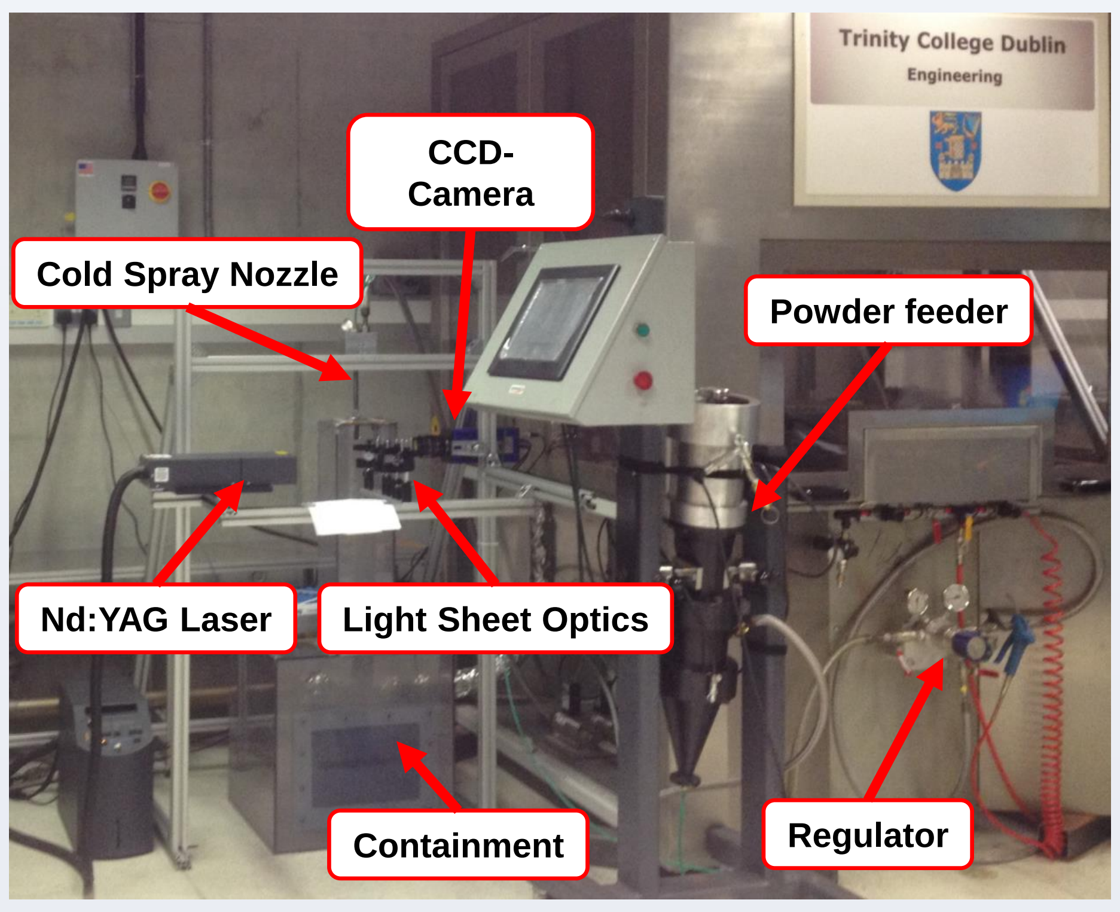


Fig. 04 – Initial experimental set-up

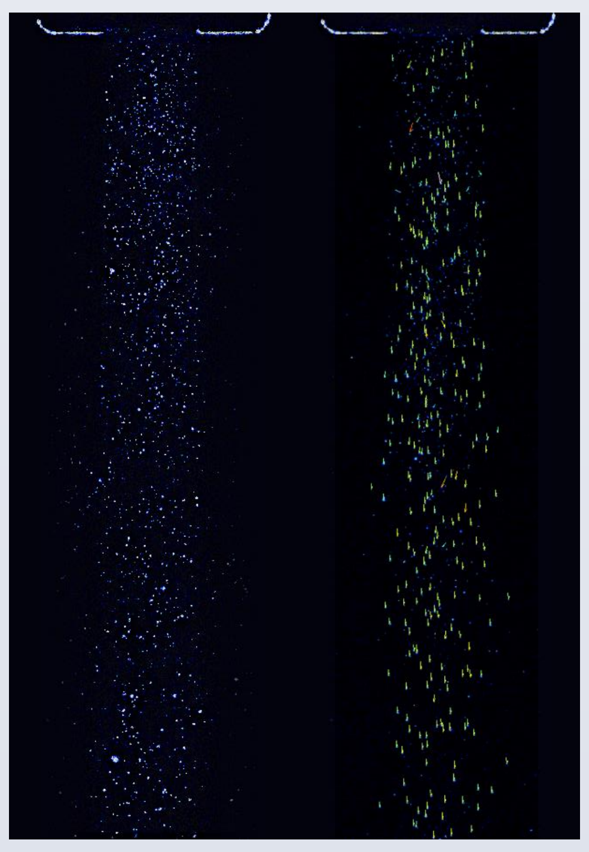


Fig. 05 – Particle velocity measurement

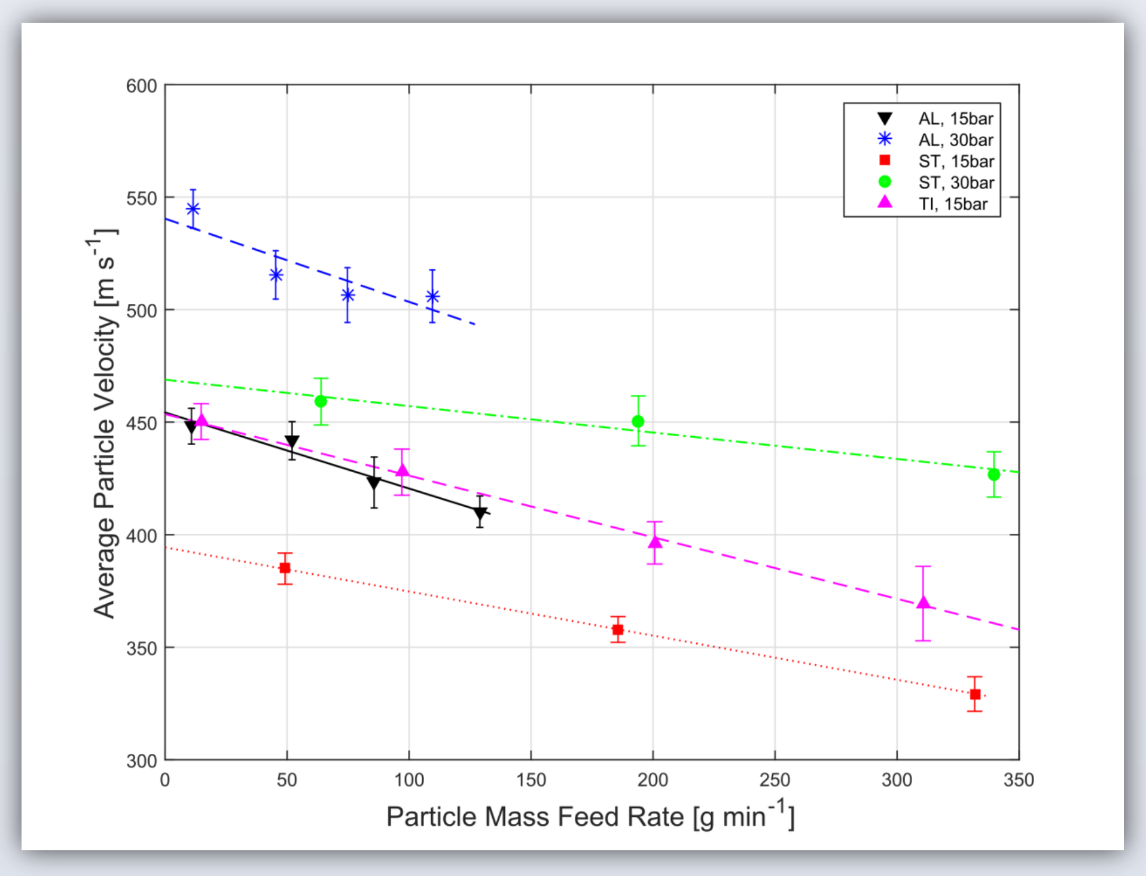
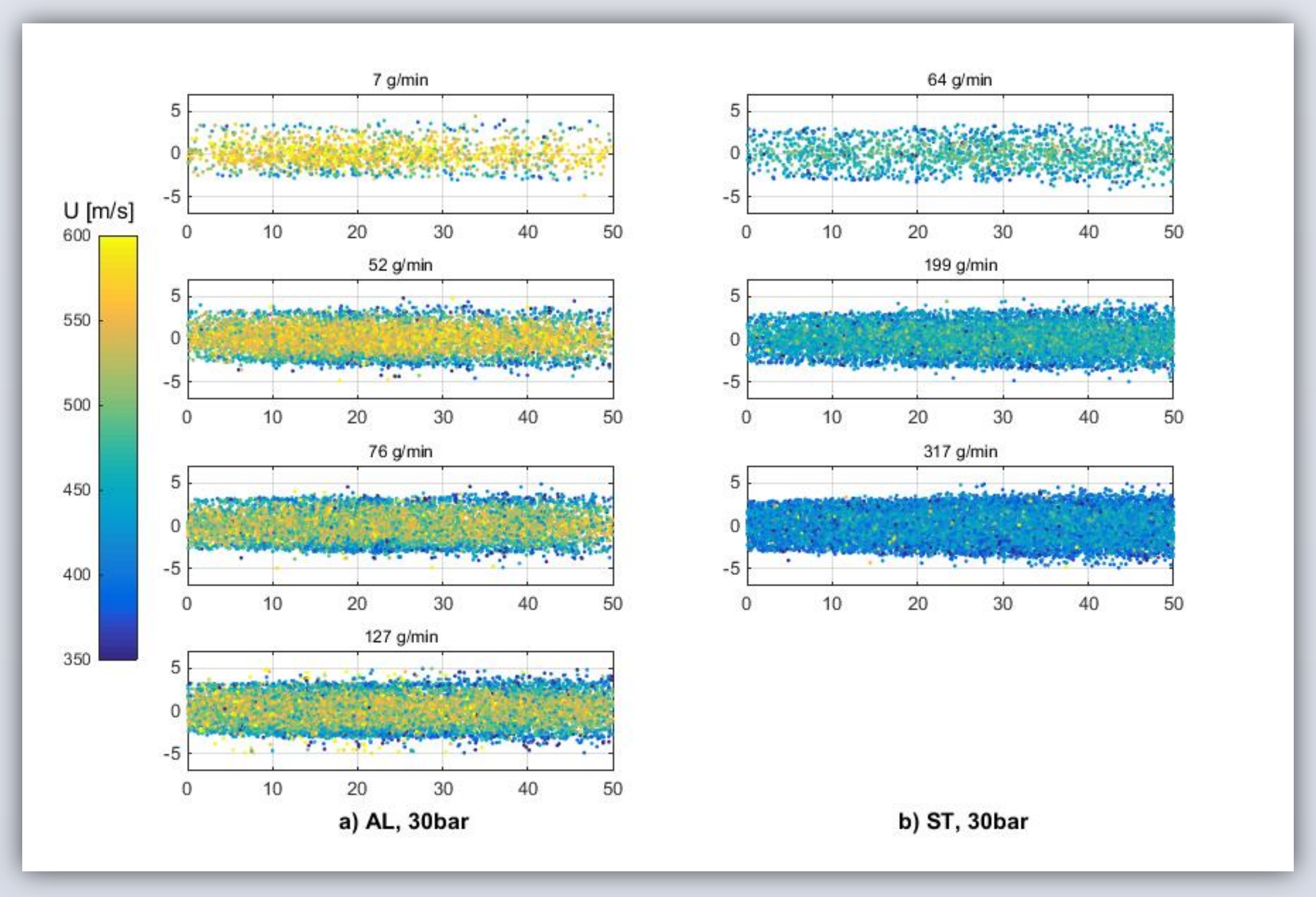


Fig. 06 – Average particle velocity

In order to fully understand all dependencies and phenomena, the investigations need to be extended to the whole flow field, in particular the acceleration inside the nozzle. The goal of this project is to study and model those interconnections, as yet neglected by researchers in the field of CS. This will lead to a generally valid and adaptable numerical model that can be applied to optimise the process, the spray spot and the efficiency.



a) AL, 30bar

b) ST, 30bar

Fig. 07 – Particle velocity profiles

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