PDA measurement of particle dispersion in confined swirling air flows with and without recirculation

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Many industrial applications are based on the special characteristics of swirling flows, for instance the construction of a special kind of industrial burners. These so-called swirl burners take advantage of the high shear strain rates found within rotating flows ensuring a good mixing between air and fuel. If the swirling flow is combined with pipe expansion a recirculating zone will develop downstream of the flow expansion (see figure 1). This will lead to high residence times of the fuel particles within the burning zone. For these reasons swirl burners will reach low emissions and high efficiency.

In the design process of such burners, usually many experiments are needed. Simulations may be used to reduce the amount and costs of the experiments that have to be realized. Until now, most of the simulation techniques only use turbulent kinetic energy and turbulent dissipation for the calculation of the particulate phase. However, the streamline curvatures found in swirling flows can only be reproduced by reynolds stress turbulence models (RST). Thus, it would be reasonable to use the information calculated by RST models in the simulation of the disperse phase. For an improvement of these models reference data is needed, which will be generated by the experiments described here.

The experimental setup and the geometry of the swirling zone are designed following the experiments of Sommerfeld and Qiu (1993). In addition to the main measurement section the test rig consists of a cleaning section containing a cyclone and a bag filter as well as a screw conveyer connected to the cyclone. This setup allows a recycling of the used tracer particles and disperse phase (see figure 2). The rotation of the air flow is caused by a swirl generator working on the basis of the movable block principle (see figure 3) (Blomeyer, 1999). With this configuration it is possible to reach higher swirl numbers than in the original experiments, where a swirl generator working with adjustable guiding vanes was used. Theoretically, swirl numbers up to two are possible.

Two configurations were examined: a simple tube with constant diameter and a tube expansion with an expansion ratio of 3.125. The investigation of the straight tube should yield further knowledge about particle dispersion in swirling flows in general. The results gained from the geometry including the pipe expansion will be used as reference data in the following development of turbulence models. In both experiments the used particles are added via a small central tube (d_i=8mm) to measure also the behaviour of a single dust rope as accurate as possible. In order to access the influence of the disperse phase on the flow patters, the gas velocity will be measured using tracer particles. Two kinds of measurement techniques will be applied: at first the swirling flow will be measured by a phase doppler anemometry (PDA), in comparison with the experiments done by Sommerfeld and Qiu (1993). In a second stage the flow will be measured by particle image velocimetry (PIV) to gain further data.

The proposed report will describe the experimental facility and present first results of the measurements.

Literature:

Blomeyer, M. (1999) Entwicklung von Auslegungskriterien für die Mischzone einer luftgestuften Gasturbinen-Ringbrennkammer, Diss., TU Darmstadt

Sommerfeld, M.; Qui, H.-H. (1993) Characterization of particle-laden, confined swirling flows by phase-doppler anemometry and numerical calculation, Int. J. Multiphase Flow, Vol. 19, pp 1093-1127

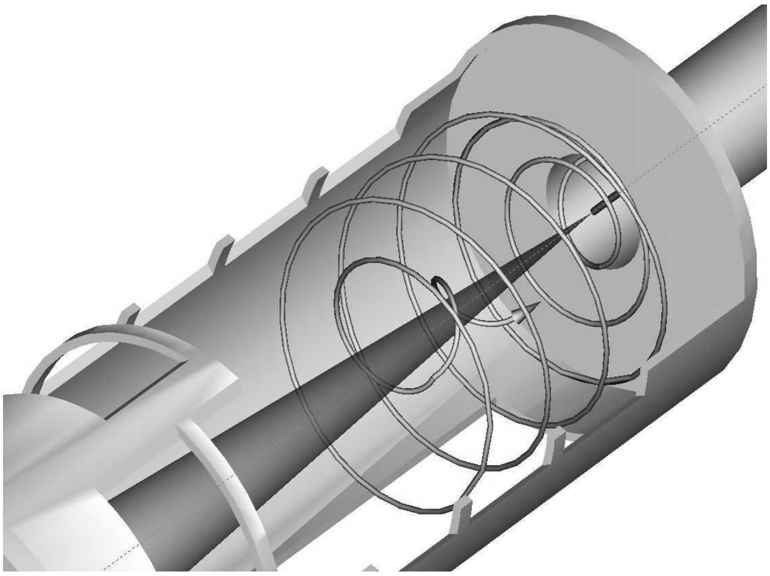

Figure 1: Recirculation zone in a widening tube

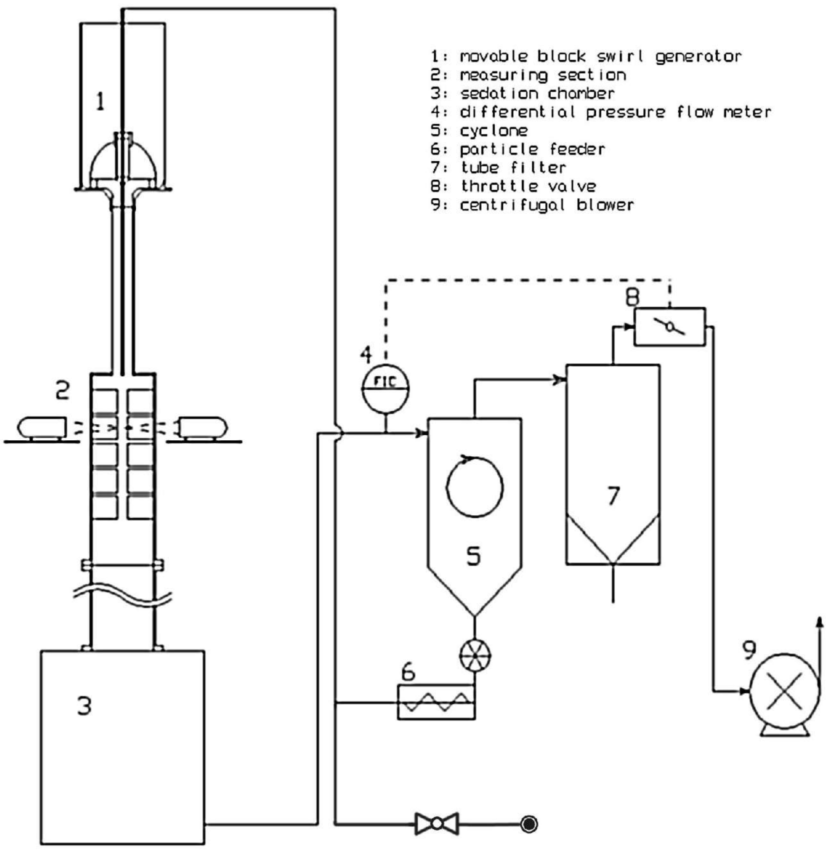

Figure 2: Flow chart of experimental facility

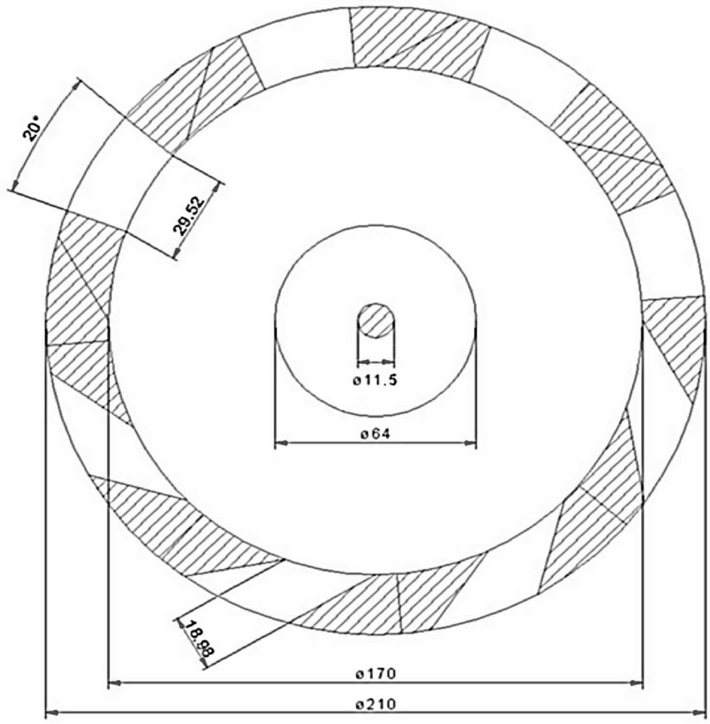

Figure 3: Geomerty of the swirl generator