A laser diffraction study on droplet diameters in two lubrication systems

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Laser-based techniques for particle-size measurements become widely used, as they are non-intrusive measuring methods. As droplet distribution becomes of higher and higher importance in heat exchange processes, two-phase flow pressure drops, pipe corrosion, manufacturing processes and research activities, online control of this distribution with laser diffraction systems is really helpful. Nevertheless, some discuss the accuracy of those systems and as their use is not always easy, a good understanding of the working principle of the laser and the application may be needed to correctly interpret the results.

The aim of this paper is to present a study of the usability of laser diffraction systems to measure droplets for a large range of working conditions. This will be illustrated, from a user point-of-view, by two applications where the droplet size distribution is of importance. The Aero-Thermo-Mechanics Department (ATM) of Université Libre de Bruxelles (ULB) is currently developing two different devices used in lubrication systems. The first one is a Minimum Quantity Cooling (MQC) airblast injector for machining purposes of metallic and non-metallic materials (Diakodimitris 2011). The second is an innovative device that separates and simultaneously pumps an oil-air mixture for aero-engine lubrication systems (Gruselle 2011). Oil droplet sizes are of a crucial importance in both applications. For MQC applications, the cooling effect depends on the droplet size distribution, which changes with the geometry of the injector, air/oil pressures and the fluid properties. For the second application, theoretical and experimental studies showed that the deoiling efficiency of the Pump and Separation System (PASS) is directly related to the droplet distribution in the inlet. At the outlet of the PASS, small droplets (< 3 µm) are measured. So, both applications need a good measurement methodology to obtain correct and reliable results. They both need a deep knowledge of the droplet size distribution to predict the performance of each lubrication system. Furthermore, droplet size distribution is one of the main input parameters for theoretical and computational fluid dynamics studies in those applications.

In this paper, droplet size measuring systems are presented, and a comparison between the results obtained with the Sympatec Helos-Vario/KR Laser Diffraction (LD) system and a Particle Dynamics Analysis (PDA) system are presented. They are in good agreement, even if the PDA slightly shifts the droplet distribution towards the larger droplets.

The innovative MQC and PASS systems will be presented with their respective test benches and working conditions. The measuring method developed to extract the droplets from the film of annular flows is discussed and the working conditions are presented in function of a parameter chosen to characterize the efficiency of using LD methods. Droplet distribution and Sauter Mean Diameter (SMD) results of both systems (spray and annular flows) were compared to semi-empirical models. In the boundaries of validity of this models, the prediction of droplet distribution was successfully compared to the experimental results (with SMD and Rosin-Rammler distributions (Lefebvre 1989)). Nevertheless, the difference between results and theoretical predictions, observed out of those boundaries, should lead to establish new semi-empirical models fitted on the experimental results.

A parameter was introduced to characterize the difference of ease of performing LD measurements. It compares the amount of liquid to measure on the measuring surface and on the gas flow. A lower limit of this parameter showed that the tests were reaching the limits of possibility of LD systems for small droplets, as the limit in working distance was reached. An upper limit was found and is defined by high liquid mass flux, where turbulence and droplet concentration led to hide small droplets. Spray applications, on the other end, represented by a mean value of this parameter showed easy and repeatable results. Some other applications should be tested in order to confirm this parameter as an interpretation of the facility of use of LD systems.

References

