Droplet deposition in radial turbines

Sebastian Schuster, Chair of Turbomachinery, University of Duisburg-Essen, Germany,
Friedrich-Karl Benra, Chair of Turbomachinery, University of Duisburg-Essen, Germany
Dieter Brillert, Chair of Turbomachinery, University of Duisburg-Essen, Germany
Hans Josef Dohmen, Chair of Turbomachinery, University of Duisburg-Essen, Germany

Long Abstract

Introduction

Radial turbines are used for waste energy recovery in the chemical industry. At the end of many of the processes a residual gas containing steam and gas arises. The thermal energy stored in this gas can be converted into mechanical work by using a radial turbine. During expansion the steam undergoes sub cooling and at a certain point a cloud of fine droplets begins to form. Usually a fraction of these droplets impinges at the blade surface and accumulates there. The mechanism of fine droplet deposition involves a broad spectrum of length and time scales. Droplets generated by steam condensation cover a diameter range of nano meter up to micro meter droplets. These different scales are very challenging when investigating the physical phenomena by CFD methods.

1. Methods

In this paper droplet deposition is calculated by incorporating turbulent fluctuations and Brownian motion into a Lagrange particle tracking algorithm [1] [2]. After introducing the nucleation/condensation approach [3] a validation using experimental results from Laval nozzles tests [4] is shown. A validation of the CFD code by means of deposition experiments in a straight tube [5], [6] (Fig. 1) and a curved duct [7] is presented as well. The calibration factor necessary to achieve the experimental results when using the k-ω-SST turbulence model is given. For a radial turbine design series the functional relation between the location of maximum sub cooling and the onset of droplet deposition is pointed out. Even though the validation of the numerical code is quite satisfactory some uncertainties arise from the nucleation modelling. This uncertainty will be addressed in the publication as well. The paper concludes with suggestions of how to increase the reliability of droplet deposition calculations in the background of condensation.

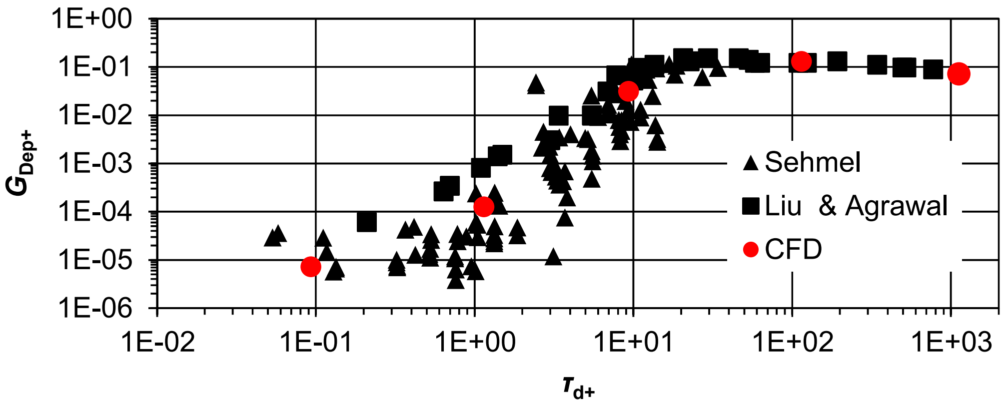

Figure 1. Validation – Deposition rate vs. particle relaxation time

References

[1] A. Guha. Transport and deposition of particles in turbulent and laminar flow. Annu. Rev. Fluid Mech. 2008, Bd. 40, S. 311 - 341.

[2] R. I. Crane. Droplet deposition in steam turbines. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science. 2004, Bd. 218, S. 859 – 870

[3] S. Schuster, F. – K. Benra, H. J. Dohmen, S. König and U. Martens. Investigation about the sensitivity of condensation calculations on model coefficients. Proceedings of the 15th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, ISROMAC - 15. 2014.

[4] M. J. Moore, P. T. Walter, R. I. Crane, R. I. and B. J. Davidson. Predicting the fog-drop size in wet-steam turbines. Inst Mech Engrs Wet Steam 4. 1973.

[5] G．A．Sehmel. Aerosol deposition from turbulent airstream in vertical conduits. AEC Research & Development Report. BNWL-578, 1968.

[6] B．Y．H．Liu and J. K. Agarwal. Experimental observation of aerosol deposition in turbulent flow. Aerosol Science, Pergamon Press. 1974, Bd. 5, S. 145 - 155.

[7] Z．Wu, and J. B. Young. The deposition of small particles from a turbulent air flow in a curved duct. International Journal of Multiphase Flow. 2012, Bd. 44, S. 34 - 47..