



Effects of wavelength and number of bends on the performance of zigzag demisters with drainage channels



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ABSTRACT

In this paper, the effects of number of bends and bend wavelength on droplet removal efficiency and pressure drop of a zigzag demister with drainage channels have been numerically investigated. A combination of Eulerian-Lagrangian method with eddy interaction model (EIM) has been used for the simulation of the droplet dispersion in turbulent gas flow. The droplet collection efficiency has been calculated and compared with available experimental data to show the validity of the simulation. The Reynolds stress transport model (RSTM) was applied to model the turbulent airflow. The results show that applying more bends in the demister reduces the filtration size of the demister but it can increase the pressure drop significantly. On the other hand, the demisters with small dimensionless bend wavelength have more pressure losses and higher droplet removal efficiencies.

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1. Introduction

Zigzag (Wave-plate) demisters are widely used to remove the liquid droplets from the gas streams in industrial processes. The main reasons for using the demisters are protection of the downstream equipment, recovery of used liquid and reduction of the total cost. The need for cost effectiveness and pollution control has also generated great interest in the study of the wave-plate demisters performance.

In a wave-plate demister, gas droplet flow passes through a series of channels that have sharp bends. Droplets cannot follow the gas flow streamlines due to their inertia and strike the channel walls. The drainage channels are used at positions where the deposited liquid may accumulate and re-entrainment from the liquid film may occur. In this way, higher collection efficiency is obtained but is accompanied by more pressure drop across the demister.

Performance of a demister is determined by its collection efficiency and gas flow pressure loss. For environmental protection and the minimization of the makeup water, the collection efficiency should be high in the demisters of the cooling towers. On the other hand, the pressure loss should be low to reduce the required fan power. A compromise between these goals is necessary in an actual design. Computer simulations of the airflow and droplet transport and deposition in such a device help the designers to find the best geometry of the demister.

Bürkholz [1] proposed a simple theoretical model for calculation of the demister efficiency. However, there are some deficiencies with this theory. For example, the effects of the wavelength are not taken into account in the Bürkholz theory. On the other hand, the equation is valid only for simple wave plate demisters without drainage channels.

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Nomenclature

b	depth of the demister (m)
C_D	drag coefficient
C_L	eddy lifetime constant
d_p	particle diameter (m)
F_D	coefficient in Drag force acceleration (1/s)
F_x	additional acceleration (N)
k	turbulent kinetic energy (m^2/s^2)
L	length of wave plate (mm)
L_{DC}	length of drainage channel (mm)
W_{DC}	width of drainage channel (mm)
L_e	eddy length scale (m)
$\dot{m}_{liquid}$	liquid film mass flow rate (kg/s)
n	number of bends
Re_g	gas Reynolds number
Re_p	particle Reynolds number
Re_r	relative Reynolds number
R_{ij}	Reynolds stress tensor (m^2/s^2)
S	channel width (mm)
S_φ	source term in transport equation
T_L	integral time scale (s)
t	time (s)
t_{cross}	eddy crossing time (s)
u	bulk velocity of the gas flow (m/s)
$\bar{u}$	average gas velocity (m/s)
u'	gas fluctuating velocity component (m/s)
u_p	droplet velocity component (m/s)
α	bend angel (deg.)
Γ_φ	diffusion coefficient in transport equation
ε	dissipation rate (m^2/s^3)
η	droplet removal efficiency (%)
η_B	droplet removal efficiency for one bend (%)
λ	bend wavelength (mm)
μ_t	turbulent dynamic viscosity(Pa.s)
ρ_g	gas density (kg/m^3)
ρ_p	particle density (kg/m^3)
σ_k	turbulent Prandtl numbers for k
σ_ε	turbulent Prandtl numbers for ε
τ_p	droplet relaxation time (s)
φ	general variable in transport equation

The trajectory of the individual droplets is calculated from a Lagrangian equation of motion. Low concentration of the droplets is assumed in the simulations. Therefore, it is not necessary to re-compute the primary gas flow allowing for the influence of droplets. A combination of eddy interaction model (EIM) and Reynolds averaged Navier Stokes (RANS) equations has been used extensively to model the droplets dispersion in complex turbulent flows.

The eddy interaction model (EIM) developed by Gosman and Ioannides [2] is one of the simplest and most frequently used methods for the simulation of turbulent particle dispersion. In the EIM, each droplet undergoes a series of interactions with eddies. A droplet interacts with an individual eddy so long as the particle remains within that eddy. During each interaction, the eddy velocity remains constant.

As mentioned before, assuming one-way coupling, the effects of droplets on the airflow is neglected and the gas flow is assumed steady. Eddies are characterized by their velocity, size and lifetime. The basic EIM assumes isotropic turbulence in order to calculate instantaneous eddy velocities from mean flow quantities.

Graham [3] studied the performance of variants of the eddy interaction model of Gosman and Ioannides [2]. In that study, each model had a different combination of randomly sampled eddy length and time scales. Random time scales for eddies are used in a different way in commercial software and used in the present study. The option of random calculation of eddy lifetime yields a more realistic description of the particles dispersion in turbulent flows.

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