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Review

Aerosol-mist coalescing filters – A review

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ABSTRACT

Fibrous filters and mist eliminators are widely used in a range of manufacturing and process industries worldwide to remove liquid mists from gas streams, thereby coalescing them to recover the bulk liquid and prevent emissions. The range of applications include compressed gas cleaning, engine crankcase ventilation, (liquefied) natural gas, propane (LPG) and hydrocarbon production and processing, cooling towers, machining and cutting processes and a range of other process engineering applications. Although research on mist filtration has been increasing since the late 1950s, and some of the fundamental physico-chemical processes were described as early as 1870, the scientific questions in the field are far from resolved. This is largely due to the complex kinetics of gas and fluid phases, and the wide range of possible filter geometric properties and surface energy. However, over the last 15 years, significant progress has been made in describing and modelling mist filter systems. Most models developed to date, are however empirically derived, and therefore only applicable to a narrow range of filter media and operating conditions. This paper reviews the state of current research, comparing currently available models for capture, saturation and pressure drop and discussing their applicability. Key gaps in the literature and necessary directions for future research are also given. The work also reviews published experimental data to-date, showing the range of media studied and summarising relationships which can be identified by collating results from all studies which provide sufficient data.

Contents

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Nomenclature

α	packing density
α_l	liquid packing density
α_{tube}	limit liquid packing density
α_{wet}	wet fibre packing density
γ	quality factor
$\gamma_{(100\text{nm})}$	quality factor specific to 100 nm diameter particles/droplets
$\gamma_{(1\mu\text{m})}$	quality factor specific to 1 μm diameter particles/droplets
ΔP	pressure drop
ΔP_l	Laplace excess pressure
ΔP_s	"pseudo"-steady state pressure drop
ΔP_0	pressure drop across a clean filter
ϵ_f	relative permittivity of the fibre
ϵ_0	relative permittivity of a vacuum
η_D	single fibre efficiency due to diffusion
η_{DR}	single fibre efficiency due to the combined effects of interception and diffusion
η_F	total single fibre efficiency
η_G	single fibre efficiency due to gravitational settling
η_I	single fibre efficiency due to impaction
η_R	single fibre efficiency due to interception
η_T	total filter efficiency
η_q	single fibre efficiency due to electrostatic attraction
θ_A	advancing contact angle
θ_R	receding contact angle
θ_e	equilibrium contact angle
λ	mean free path
μ_g	gas viscosity
μ_l	liquid viscosity
ρ_p	particle density
ρ_l	liquid density
σ	interfacial (surface) tension
σ_{LV}	liquid–vapour interfacial tension
σ_{SL}	solid–liquid interfacial tension
σ_{SV}	solid–vapour interfacial tension
Ω	filtration surface area
A_c	contact area
A_e	a filter geometry dependent constant
Bo	Bond number
Ca	capillary number
Ca_n	capillary number as defined by Liew and Conder [65]
C_c	Cunningham correction factor
C_d	diffusional efficiency correction factor
C'_d	diffusional efficiency correction factor
C_f	axial droplet drag coefficient
C_r	interception efficiency correction factor
C_T	transverse droplet drag coefficient
c_f	correction factor
D_p	droplet diffusion coefficient
Dr	Drainage rate term
d_d	droplet diameter
d_f	fibre diameter
d_{fwet}	wet fibre diameter
d_p	particle diameter
dZ	thickness of the filter layer, j, in flow direction
E	efficiency
F_f	drag force acting along a fibre
f	proportion of the fibre surface not covered by liquid
G_s	gravitational settling term
g	gravitational constant
h_t	film thickness
j	designates a theoretical layer within a filter
Kn	Knudsen number
Ku	Kuwabara hydrodynamic factor
K_1	a constant
k_B	Boltzmann constant
$\underline{k}$	damping coefficients tensor
m_{liq}	collected liquid mass
N_R	ratio of droplet diameter to fibre diameter
n_d	reduced droplet diameter
Pe	Peclet number
P_e	filter penetration
$P_{100\text{nm}}$	penetration of 100 nm diameter particles/droplets
$P_{1\mu\text{m}}$	penetration of 100 μm diameter particles/droplets
p	pressure
Q	volumetric flow rate
q	the charge on a particle
R_1, R_2	principle radii of curvature
Re	Reynolds number
Re_f	Reynolds number of a droplet on a fibre
r	radius
r_c	capillary radius
r_c	fibre radius
r_f	fibre radius
S	saturation
S_e	equilibrium saturation
S_p	spreading coefficient
S_t	Stokes number
T	temperature
t_f	droplet detachment time
U	droplet velocity
U_0	filtration velocity
u	velocity
u'	interstitial velocity (in a filter)
$\hat{u}$	average velocity field
u_0	gas velocity at the filter face
W	width of the test filter
x_d	distance between centroids of two droplets
Z	filter thickness
$\frac{\Delta P r_f^2}{4\alpha\mu u Z}$	dimensionless pressure drop parameter [107]

List of abbreviations

C	circular
Cyl.	cylindrical element
DEHS	di-ethyl-hexyl sebacate
DMP	deca-methyl-cyclo-penta siloxane
DOP	di-octyl phthalate
EtOH	ethanol
Glyc.	glycerol
H	horizontal
I	inclined
LPG	liquefied petroleum gas
MPPS	most penetrating particle size
OPC	optical particle counter
PE	polyester
PET	polyethylene terephphalate
PP	polypropylene
prop. glyc.	propylene glycol
R	rectangular
SFE	single fibre efficiency
SMPS	scanning mobility particle sizer
V	vertical