Applied Thermal Engineering 67 (2014) 214–222

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Numerical study of performance of wire mesh mist eliminator

R. Kouhikamali*, S.M.A. Noori Rahim Abadi, M. Hassani

Department of Mechanical Engineering, Faculty of Engineering, University of Guilan, Rasht, Iran

HIGHLIGHTS

- The performance of wire mesh mist eliminator is investigated numerically.
- Separation efficiency increases with the increase of the droplet size.
- Separation efficiency increases with the increase of packing thickness and density.
- There is an optimum vapor velocity range of $8 < V_{\mathrm{vapor}} < 10$ m/s.
- Pressure drop along the demister increases with increase of vapor velocity.

ARTICLE INFO

Article history:
Received 31 October 2013
Accepted 28 February 2014
Available online 21 March 2014

Keywords:
Wire mesh
Droplet separation
Pressure drop
Numerical simulation

ABSTRACT

In this paper the effects of geometry and operating conditions on the pressure drop and separation efficiency of wire mesh mist eliminator have been investigated numerically. The effects of various variables such as vapor velocity (1–20 m/s), packing density (100–250 kg/m^3), demister thickness (300–200 cm), wire diameter (0.1–0.3 mm), diameter of captured droplets (1–3 mm) and the geometry of wires on droplet separation efficiency and vapor pressure drop of demister have been studied in order to evaluate the demister performance. The results show the increase of separation efficiency with increasing the diameter of water droplets, vapor velocity, packing thickness and density while increasing wire diameter decreases the performance.

1. Introduction

Wire mesh mist eliminator is a simple porous blanket of metal or plastic wire that retains liquid droplets entrained by the gas phase. There are several devices which are offered to industry for separating the entrained liquid droplets, and each of which are effective over their own particular range of mist size. Mist eliminators can be summarized into the following groups: settling tanks, fiber filtering candles, electrostatic precipitators, cyclones, impingement van separators, and wire mesh. Demisters are widely used in gas–liquid separation in a range of industrial processes including evaporation, absorption, and distillation. They are important components in thermal desalination plants such as Multi Stage Flash (MSF) and Multi Effect Distillation (MED). In these plants, demisters are desired to have low pressure drop, and high mist removal efficiency. In addition, they should have high flooding resistance whilst having high capacity [1].

The separation process in the wire mesh mist eliminator includes three steps; the first is “inertia impaction” of the liquid droplets on the surface of wire. As the gas phase flows past the surface or around wires in the mesh pad, the streamlines get deflected, but the kinetic energy of the liquid droplets associated with the gas stream may be too high to follow the streamline of the gas, so they impinged on the wires. The second stage in the separation process is the coalescence of the droplets impinging on the surface of the wires. In the third step, droplets detach from the pad.

The wire mesh demister performance depends on several design variables such as supporting grids free passage, wire diameter, vapor velocity, packing density, pad thickness and material of construction. Due to the flexibility of the wire mesh, the supporting grids should have high-free-passage to reduce premature flooding.

The basic concept and main features of the wire mesh mist eliminator have been discussed in a limited number of publications. El- Dessouky et al. [2] conducted a comprehensive experimental study to measure the performance of wire mesh mist eliminator. The demister performance was evaluated by droplet separation efficiency, vapor pressure drop of wet demister, and flooding and loading velocities. Using CFD, Pak et al. [3] simulated a laminar fluid

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* Corresponding author. Tel.: +98 131 6690276; fax: +98 131 6690273.
E-mail address: kouhikamali@guilan.ac.ir (R. Kouhikamali).

http://dx.doi.org/10.1016/j.applthermaleng.2014.02.073
1359-4311/

Nomenclature

u	x-component velocity of vapor (m/s)
v	y-component velocity of vapor (m/s)
x	horizontal direction (m)
y	vertical direction (m)
M_{in}	mass of incoming droplets (kg)
M_{out}	mass of outgoing droplets (kg)
Re	Reynolds number
F_D	frag force (N)
F	summation of forces on a droplet (N)
C_D	drag coefficient
d_p	droplet diameter (m)
t	time (S)
g	gravity (m/s^2)
L_p	packing thickness (m)

Greek symbols

η	separation efficiency
μ	molecular viscosity (Pa s)
τ	shear tension (N/m^2)
ρ_p	packing density (kg/m^3)
ρ	density (kg/m^3)
k	turbulent kinetic energy (m^2/s^2)
ε	turbulent dissipation rate (m^2/s^3)

flow in porous tubes, a mode of cross flow filtration tubular membrane. He found that increasing the *Re* number by increasing the inlet axial velocity resulted in a decrease in the mass boundary layer, increases the wall filtration velocity and a gain in the performance of a tubular membrane is observed. Wang and James [4] investigated the collection efficiency of two wave-plate demisters by numerically simulating the flow field and droplet motion and compared the results with experimental work of Phillips and Deakin [5]. Their results showed that large discrepancies exist between the numerically predicted and the measured efficiencies over a range of droplet sizes. Galletti et al. [6] used CFD to develop Eulerian–Lagrangian models of two wave-plate mist eliminators with considering drainage channels. The resulted pressure drop was found to be in satisfactory agreement with the available measurements [7].

Rahimi and Abbaspour [8] predicated pressure drop in a mist pad by using numerical simulation. They compared the obtained numerical result with the available experimental data and empirical model of El-Dessouky et al. [2]. Their CFD results predicted the wire mesh mist eliminator pressure drop within 21% deviation from the empirical model. Unfortunately, the effects of operating and geometry conditions on the performance of wire mesh mist eliminators have not been studied numerically.

Zhao et al. [9] conducted a numerical simulation of a demister vane with various geometries and operating conditions in order to study the separation efficiency using FLUENT 6.1. Their results showed that not only the vane spacing and flue gas velocity, but also vane height (including height of curve and upright region) and vane turning angles have a greater influence on the separation efficiency. Abdullah et al. [10–11] studied the effects of design parameters on pressure drop across the wire mesh mist eliminators were experimentally investigated in 15 cm bubble column. The pressure drop across the demister pad was evaluated as a function of wide ranges of operating and design parameters. They showed that the dry pressure drop is nil. The wet pressure drop was found to increase with increasing the demister specific surface area, packing density, and superficial gas velocity. In contrast, it was found to increase with decreasing the demister void fraction and wire diameter. The pressure drop is correlated empirically as a function of the design parameters. Setekleiv et al. [12] investigated the holdup distribution and pressure drop of five different wire-mesh pads experimentally. Their results showed variations in the holdup profile of the pads depending on geometry, surface area, gas velocity and measuring height. Their data also showed that there is a strong correlation between surface area of the mesh pad and the flooding point.

Narimani and Shahhoseini [13] studied the efficiency of vane type mist eliminator using computational fluid dynamic (CFD. Their simulation results showed that there was a conceivable dependency of separation efficiency on the gas velocity and geometrical parameters of vanes. The results also revealed that in the 20 mm of vane spacing the highest separation efficiency could be achieved when the air velocity and vane angle were 5 m/s and 60°, respectively.

This paper studies separation efficiency and pressure drop of wire mesh mist eliminator under various operating and geometry conditions. The results will be compared with experimental data. Eventually, the achieved results will be used to modify the demister of a real industrial MED-TVC plant.

2. Problem statement

Fig. 1 shows a front view of the flashing chamber in Multi Stage Flash (MSF) desalination which is considered for the current study. The flow through the demister is generally simulated in three different methods: porous jump, porous media, and direct simulation with staggered baffles. Porous jump is the model simulation for thin mesh bed that has a known velocity (pressure-drop) characteristic. Thickness of the demister is not shown but it is demonstrated as a line and the thickness is defined in the boundary conditions of the porous jump. It is essential to have a 1D over simplification model for the demister. Porous media accounts for demister thickness and hence viscous and inertial losses based on experimental data are predicted. A better level of accuracy is

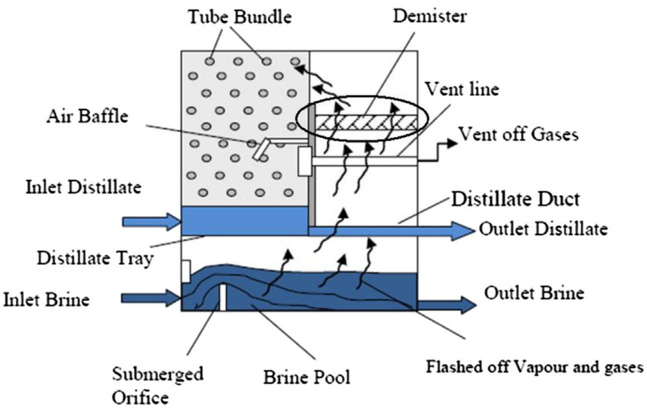

Fig. 1. Schematic of an MSF chamber.