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ORIGINAL ARTICLE

Investigating pressure drop across wire mesh mist eliminators in bubble column

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Abstract 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. These parameters include: specific surface area (236–868 m^2/m^3), void fraction (97–99%), wire diameter (0.14–0.28 mm), packing density (130–240 kg/m^3), and superficial gas velocity (0.109–0.118 m/s). All demisters were 15 cm in diameter with 10 cm pad thickness, made from 316L stainless steel layered type. Experiments were carried out using air–water system at ambient temperature and atmospheric pressure. The measurements of the pressure drop were done using a U-tube manometer device. The pressure drop across the demister pad is a combination of dry and wet pressure drops. In this work, the experimental investigations 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. A good agreement was obtained between the measured values and the correlation predictions with ±15% accuracy.

1. Introduction

In many operations in the petrochemical, oil production and thermal desalination plants, it is frequently necessary to remove fine droplets of liquid from process and waste gas or vapor streams. Liquid separation is required to recover valuable products, improve product purity, increase throughput capacity, protect down stream equipment from corrosive or scaling liquids, avoid undesired reactions in the reactors overhead lines, and to improve emissions control. Mist eliminators are devices that can remove entrained liquid from gas flow effectively. As the rate of a spontaneous separation process is often

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Nomenclature

A	Bubble column cross sectional area (m^2)
A_s	Specific surface area (m^2/m^3)
D_w	Demister wire diameter (mm)
f	Friction factor (–)
H	Thickness of the demister mesh pad (m)
Q_g	Volumetric flow rate (m^3/s)
V_g	Superficial gas velocity (m/s)
K	Velocity constant (depending on application) (m/s)
g	Gravitational constant (9.81 m/s^2) (m/s^2)
Re	Reynold's Number (–)

Greek Letters

Δp	Pressure drop across the demister (cm H_2O)
Δp_{dry}	Dry Pressure drop (cm H_2O)
ε	Void fraction (–)
ρ_g	Gas density (kg/m^3)
ρ_l	Liquid density (kg/m^3)
ρ_p	Packing Density (kg/m^3)
μ_g	Gas Viscosity (kg/ms)

economically and operatively desirable, mist eliminators are generally employed to accelerate this step and to increase throughput capacity. For example, in thermal desalinations plants, the droplets must be removed before vapor condensation over condenser tubes. If the mist eliminator doesn't separate efficiently the entrained water droplets, reduction of distilled water quality and formation of scale on the outer surface of the condenser tubes occurs. The last effect is very harmful because it reduces the heat transfer coefficient and enhances the corrosion of the tube material (Souders and Brown, 1934; Fabian and Cusack, 1993; Fabian and Hennessy, 1993).

Another example is the two phase bubble column reactors. Bubble columns have been widely used in industry because of their simple construction and operation. Important applications include hydrogenation, oxidation, polymerization, Fischer–Tropsch synthesis, ozonolysis, carbonylation, carboxylation, alkylation reactions as well as for petroleum processes. Other important application area of bubble columns is their use as bioreactors in which microorganisms are utilized in order to produce industrially valuable products, such as enzymes, proteins, antibiotics, etc. In the bubble column, the gas is introduced in the form of bubbles into a pool of liquid via a distributor. The mass transfer and hence the reaction takes place between the gas bubbles and the liquid. The gas stream leaving the liquid pool entrains droplets of liquid with it, which must be removed before it exits the reactor. Failure to do so will cause the reaction to continue in the exit streamlines. In polymerization reactions for example, the entrainment will cause plugging of the exit streams and overhead lines.

Many mist eliminators have been developed with various efficiency and cost. Mist eliminators belong to one of the ollowing groups: settling tank, fiber filtering candles, electrostatic precipitators, cyclones, impingement van separators and wire mesh. Each of these devices operates under different principle and is applied for the removal of the droplets with a specific size range and effective separation performance. When selecting a mist eliminator, careful considerations should be given to performance parameters and one must weigh several important factors so as to ensure a cost effective installation (Bell and Strauss, 1973; York, 1954). The important performance parameters of liquid separators are capacity, pressure drop, droplet removal efficiency and plugging tendency. These parameters are all interrelated and should be considered together when comparing the performance of alternative mist eliminators (Brunazzi and Paglianti, 2001). Operating pressure is expressible as an energy expense so low pressure drop is required. Pressure drop is primarily a function of superficial gas velocity, mist loading and the mist's physical properties, such as density and viscosity. If the entrained droplets contain solids, susceptibility of the separator to plugging by solids shall be considered. Additionally, it is needed to evaluate whether the mist eliminator can be installed inside the existing equipment, or if needs a standalone vessel instead (easy of manufacture and installation are preferred). Concerning the material of construction, the availability of materials that are compatible with the process is also an important factor. The medium and structural support materials must be durable enough to withstand process conditions and provide an acceptable service life. Table 1 shows equipment selection according to some performance parameters.

The knitted wire mesh mist eliminator, commonly specified as the ''demister'', is one of these devices which has a widespread application in many industrial plants. It is a simple porous blanket of metal or plastic wire that retains the liquid droplet. It has gained extensive industrial recognition as low pressure drop, high separation efficiency, reasonable capital cost, minimum tendency for flooding, high capacity, and small size. It probably outnumbers all other types of mist eliminators combined specially in petrochemical industries. The wire mesh entrainment separator is installed without difficulty in process equipments, such as scrubbers, evaporators and distillation columns. Although knitted wire mesh has been used by industry for broad ranges of entrainment elimination operations, the volume of fundamental work published regarding their performance characteristics is scant. The work of Satsangee (Satsangee, 1948) was concerned primarily with wire mesh as column packing and contacting media and not specifically entrainment elimination. The detailed investigation studied wire mesh as an entrainment separator in an evaporator handling salt solution and defined the efficiency, pressure drop, and capacity of knitted wire structure.

As generally used, knitted wire mesh mist eliminator consists of a bed, usually 10.16–15.24 cm deep, of fine diameter wires interlocked by a knitting to form a wire mesh pad with a high free volume, usually between 97% and 99%. The separation process in the wire mesh mist eliminator includes three steps; first 'inertia impaction' of the liquid droplet on the surface of wire. The way in which the mist wets the collecting medium determines whether the liquid will coalesce in a drop wise -or film wise- fashion; a characteristic that influences operating pressure drop (Plant and Fairs, 1963). Mists that coalesce into droplets lead to lower pressure drops. The second