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Experimental investigation of droplet flow in wire mesh demisters: comparing plastic and metallic types

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ABSTRACT

This study reports experimental results for the performance of wire mesh demister as a function of broad ranges of operating conditions. Various parameters such as air velocity (6–10 m/s), packing density (50–200 kg/m^3), wire diameter (0.3–1.9 mm), size of the mesh, and different materials of construction have been studied. Further betterment by the use of different materials or geometry modifications was investigated. A feasibility study was done in order to check the possibility of substitution of the plastic demister instead of a metallic one. The experiments were carried out to measure the performance of demister for an air-water system and evaluated by pressure drop and separation efficiency in different geometries and materials of wire mesh demister. Two empirical correlations were developed as a function of the design parameters for the separation efficiency and dry pressure drop. These correlations are sufficiently accurate for practical calculations and demister design. The outcomes show that the separation efficiency of plastic demister with big mesh was more than the separation efficiency of stainless steel wire mesh demister for an equal pressure drop. Consequently, plastic demister can be used as an alternative, by lower cost.

Keywords: Wire mesh demister; Plastic demister; Separation efficiency; Pressure drop; Packing density

1. Introduction

Effective separation of gas and liquid is a primary requirement for efficient industrial processing. Mist eliminator devices, also called demister, are used in many chemical engineering and industrial applications to trap the droplets. There are two main kinds of mist eliminators: the vane pack and the wire mesh demister. The main difference between these two types is the range of droplet diameter that each one can collect efficiently. The vane pack type is designed to collect droplets bigger than the wire mesh type. Different construction materials for the wires include metal, fiberglass, and plastics. New polymers such as polypropylene or polyethylene have been made available in wire form, which routinely provides longer service lives of the traditional materials. Plastic screens are suitable in corrosive media with low pressure drop in industrial applications. Wire mesh mist eliminators can be installed either horizontally for vertical gas flow or vertically for horizontal gas flow.

In the most general sense, wire mesh mist eliminator is a simple porous blanket of metal or plastic wire retains liquid droplets entrained by the gas phase. Demisters are widely used in gas–liquid separation in a range of industrial processes including egestion, absorption, and distillation. They are important components in thermal desalination plants such as multi-stage flash (MSF) and multi-effect distillation

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(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. The demister performance was evaluated by droplet separation efficiency, gas pressure drop of wet demister, and flooding, and loading velocities. The main features of wire mesh mist eliminators are low pressure drop, high separation efficiency, reasonable capital cost, and minimum tendency for flooding, high capacity, small size, and long service life [1].

Previous studies on demisters can be divided into two main areas: experimental work and numerical simulation.

Wire mesh mist eliminators, eliminate droplets by impingement on the wire surface. There are three different mechanisms for capturing the entrained droplets by the wire mesh pad. These are diffusion, interception, and inertial impaction. 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. These variables were measured as a function of vapor velocity (0.98–7.5 m/s), packing density (80.31–208.16 kg/m^3), pad thickness (100–200 mm), wire diameter (0.2–0.32 mm), and diameter of captured droplets (1–5 mm).

Rahimi and Abbaspour [3] 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.

Setekleiv et al. [4] studied holdup distribution, pressure drop, separation efficiencies, and droplet separation characteristics of six different wire mesh pads experimentally. One of the mesh pads was tested with and without a small gas bypass at the wall. The liquid holdup was recorded at minimum of five locations inside the pads. The holdup distribution in the mesh pads were tested for time dependency. Separation efficiencies and droplet size distribution for the empty column were also investigated.

Janajreh et al. [5] presented a numerical simulation of the water vapor flow in an MSF flash chamber along with the pressure drop across the demister using uniform initial vapor velocity at vapor inlet. The demister is considered as a porous medium and the flow is a single water vapor phase.

Kouhikamali et al. [6] investigated the effects of geometry and operating conditions on the pressure drop and separation efficiency of wire mesh mist eliminator numerically. The effects of various variables such as vapor velocity (1–20 m/s), packing density (100–250 kg/m^3), demister thickness (200–300 cm), wire diameter (0.1–0.3 mm), the 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.

El-Dessouky and Al Marshad [7] studied the impact of various parameters on the dry pressure drop of wire mesh demister using three different materials of construction experimentally. The materials tested were the date palm fiber, industrial wire stainless steel 316 L, and *Luffa aegyptiaca* fiber. They also find empirical correlations for the dry pressure drop of these materials.

The basic concept and main features of the wire mesh and vane mist eliminator have been discussed in a limited number of publications. Examples can be found in the studies by Helsør and Svendsen [8], Ghetti [9], Pak et al. [10], Galletti et al. [11], and Zhao et al. [12].

Narimani and Shahhoseini [13] studied the efficiency of vane type mist eliminator using computational fluid dynamics. Their simulation results showed that there was a conceivable dependency of separation efficiency on the gas velocity and geometrical parameters of vanes.

Venkatesan et al. [14] presented the numerical investigations of vane demisters using a computational fluid dynamics tool to validate the presently adopted computational methodology. A vane demister profile identified from literature, on which experimental data is available, is chosen and water particles at the rated flow rate and distribution are injected. Various options within the solver are numerically tested to recommend an appropriate combination of solver settings.

Koopman et al. [15] investigated the predictive power of analytical models for the droplet separation efficiency of vane separators and compares the experimental results of two different vane separator geometries. The ability to predict the separation efficiency of vane separators simplifies their design process, especially when analytical research allows the identification of the most important physical and geometrical parameters and can quantify their contribution.

Liu et al. [16] proposed a novel compound demister that combines an upstream tube bank and downstream wave plates which is used for application in MSF desalination process. Both experiments and numerical simulations were carried out to evaluate the performance of the proposed compound demister. The mechanisms of droplet re-entrainment in the compound demister were also discussed.

This paper issues the performance of wire mesh demister for an air-water system experimentally. Three plastic types of demister with different size of mesh were used which has not been reported in the literature. The demisters used were layered type and made of stainless steel wire and high density polyethylene (HDPE). A large number of previous experimental investigations have been done in horizontal configuration for vertical gas flow. Our setup operates in a vertical configuration for horizontal gas flow, because many industries use separators in this configuration. Separation efficiency and pressure drop of wire mesh demister under various operating conditions were investigated.

2. Experimental apparatus and testing procedure

The experimental model of the wire mesh demister unit was designed and manufactured to give a good basis for the measurements. The rig was designed to test horizontal orientation (Fig. 1). The experiments were performed at ambient pressure and air was used as the flow medium in which droplets of water were entrained.

Fig. 2 displays the overall schematic diagram of the experimental set up for horizontal airflow which includes the system components.

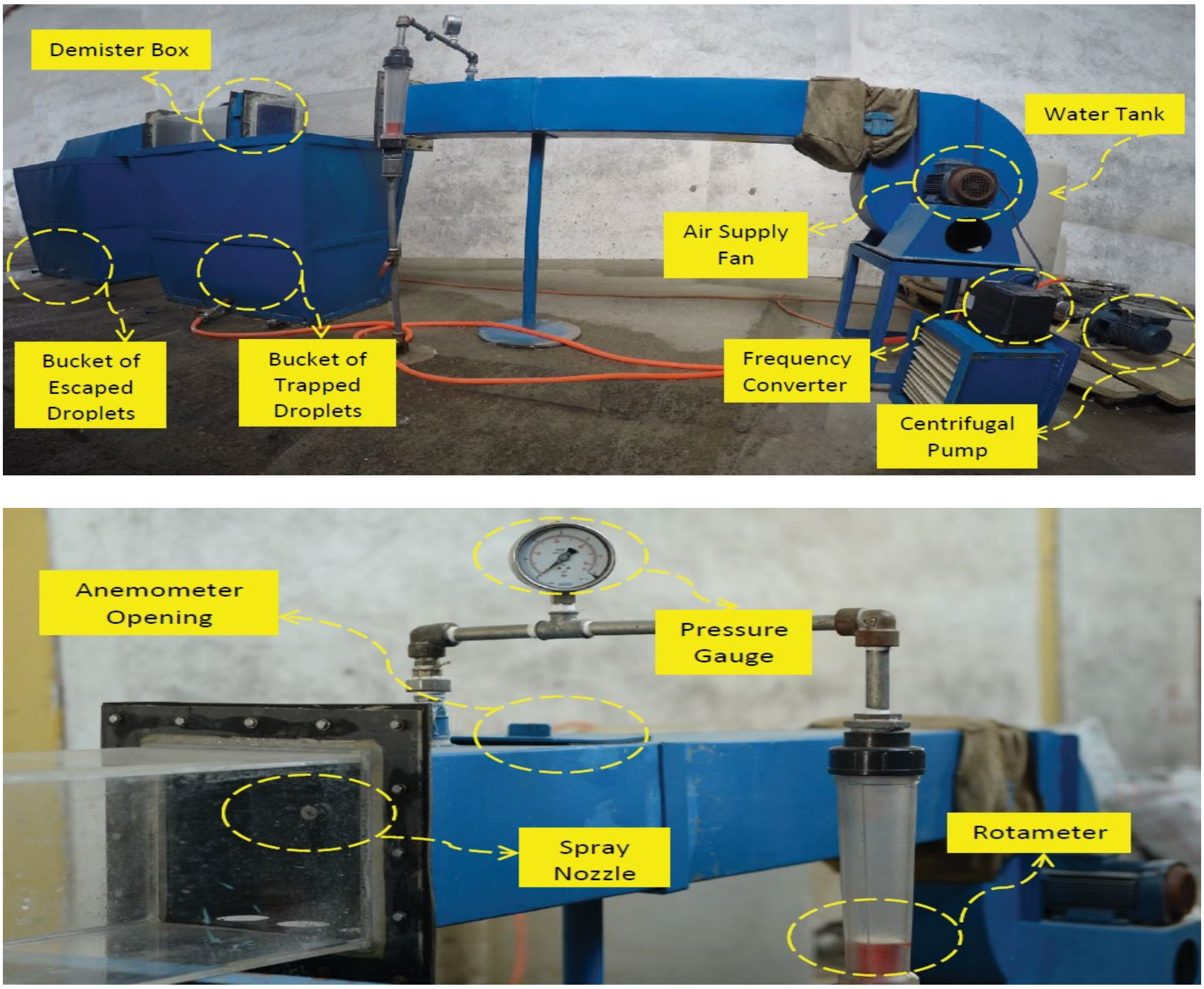

Fig. 1. Pictorial view of experimental rig and system components.

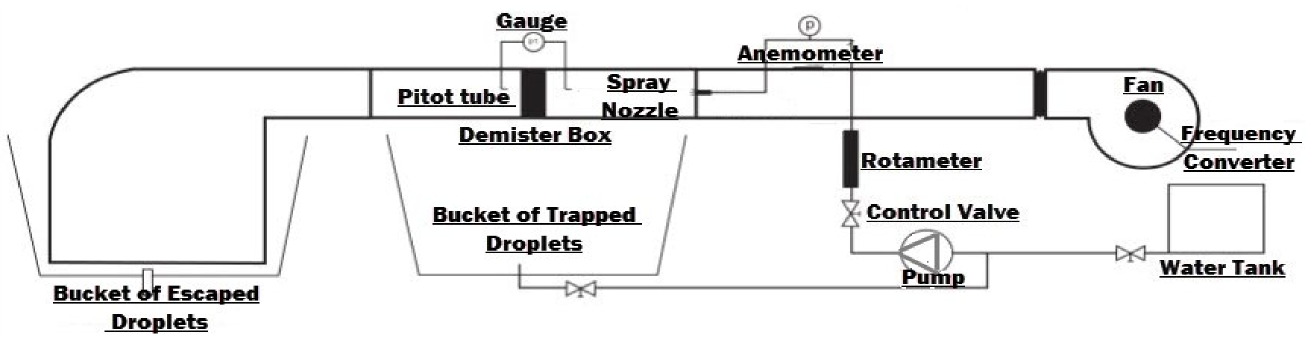

Fig. 2. Schematic diagram of experimental rig for horizontal airflow.

The system includes a galvanized carbon steel channel, a Plexiglas channel, an air blower supply, a water circulating pump, the wire mesh demister, a nozzle for droplet distribution, an inverter (frequency converter) and a water tank. The Plexiglas rectangular cross-section channel has a 250 mm × 250 mm and 700 mm length. It is fitted with several connections for measuring the air velocity and measuring the pressure drop across the wire mesh screens inside the channel. The channel was made of several parts connected by flanges and packings in order to improve sealing. The Plexiglas section is fastened very well to channel by a stocky layer of silicon rubber. The system was held at the required height by fixing the bottom support. The air was fed through a horizontal channel and the water was fed through a spray nozzle in the upstream and the middle of the channel (Fig. 3).

It should be noted that there is no any relationship between the maximum droplet diameter determined by the needle inside diameter and the particle size distribution and the mean particle diameter. The placing of the spray nozzle, regarding the wire mesh screen section, is important to avoid spurious effects. If the spray nozzle is placed too close, only a part of the mesh screen section will be utilized and if it is placed too far away, a major fraction of water can hit the wall before the mesh screen section. The water droplets are spread in a cone formation, which agrees with data from the manufacturer. The density of the continuous phase together with the effect of gravity is the most crucial factor in scattering behavior. Higher density seems to decrease the spread and the gravity pulls down the water droplets faster. The placing of the nozzle becomes a compromise between largest possible spread and to prevent water from floating along the walls. If a considerably part of the water floats along the wall it will become a major source of error and a small spread will not utilize the whole cross-section of the mesh screens.

A 0.75 kW centrifugal blower (Model: Motogen 1,450 rpm, 50 Hz) was used to supply the necessary airflow, equipped with a frequency converter (Model No: Delta C 2000) to allow for adjustment of its rotational speed and control the electrical power of the centrifugal blower so that different gas velocities could be obtained for various conditions. Air velocity was measured by the calibrated handheld anemometer (Model No: LT Lutron LM-81 AM). Water entering the channel was pumped by a 3.2 kW centrifugal pump (Model: Pentax, H = 34 m, Q = 30 m^3/h) and fed through a spray nozzle. The water droplets were carried over by air stream flowing towards the screens. The flow of water was measured with a rotating flow meter (Model No: Alpha IS 400), with an accuracy of 1% of full scale. A pressure gauge (Model No: WIKA EN-837), with an accuracy of 0.1% of full scale was used to measure the pressure of water entering the nozzle.

The wire mesh screens were all mounted inside a demister box with a width of 100 mm, which is a transparent section, to allow visual inspection of screen operation. The water which penetrated the wire mesh screens was collected, and by turning a valve, water could be returned to the water tank (about 500 L) and recycled to the spray nozzle. Water escaping the wire mesh screens inside the channel was collected in a scaled bucket for measuring the outflow rate of water escaped through the wire mesh screens and provides data to calculate the separation efficiency. The most routinely used stack and duct gas flow measuring techniques are based on the use of pitot tubes. Pitot tube flow measurements are required by many sampling methods to characterize duct flows. Pitot tube measurements are also used to enable isokinetic sampling to be achieved and verified. The pressure drop near the entrance and the exit of the wire mesh screen was measured using a pitot tube (Model: Magnehelic), having an accuracy of 0.1% of the total range. Measurements were made for air velocities between 6 and 10 m/s at a constant water flow rate. It is clear that wire mesh screens may need a running time to reach steady-state operation. The steady condition was considered since the outflow rate of escaped droplets through the demisters in the test box does not change by time and is fixed during the measurement. It means if a data of outflow rate of escaped droplets was recorded, after lapse the same data should be recorded as before. Wire mesh demisters come in many different forms. A typical mesh screen is made up of wires of a particular diameter interweaving together to form a perforated planar structure with a desirable mesh opening size. A total of four different classes of geometries and materials of mesh screen was considered and tested which are shown in Fig. 4. They were all located 950 mm in front of the spray nozzle. The mesh screens were varied in geometrical characteristics and made of standard metal or standard plastic materials.

The wire mesh demister is the heart of the experimental unit. The Schematic view of a wire mesh screen is shown in Fig. 5 and geometric properties of the screens are given in Table 1.

The demister box has a width of 100 mm and the wire diameter ranges from 0.3 to 1.9 mm. The screens are made of stainless steel or HDPE plastic. Tested stainless steel

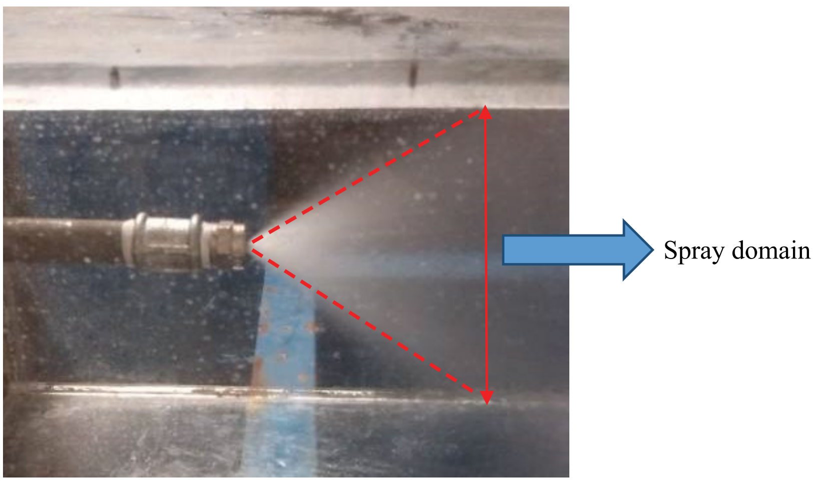

Fig. 3. Pictorial view of spray nozzle and domain.

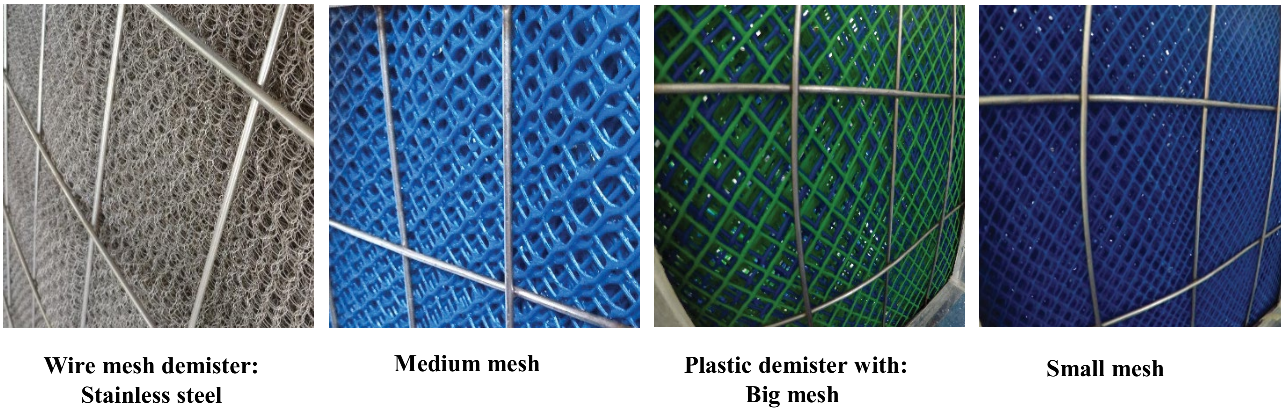

Fig. 4. Four different classes of wire mesh screen.

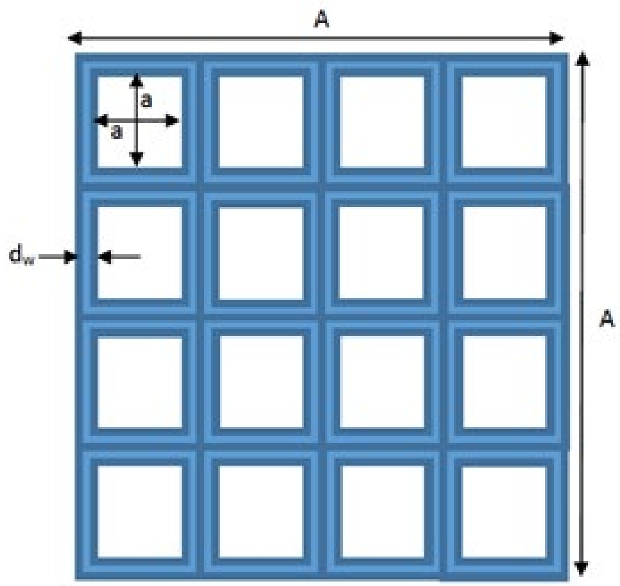

Fig. 5. Schematic view of a wire mesh screen.

wire mesh demister is used in most industrial desalination plants and is one of the common types. The stainless steel wire was combed and flattened to give a double layer. Several of the double-layered wires are used to form the demister, where the appropriate number is chosen to give the desired packing density. The screen is placed into a cubic box and central support inside the channel. The mesh screen was sized to be 30 mm larger than the channel inside diameter to minimize bypassing of the air.

Demisters are usually specified by means of their specific surface area, porosity, and packing density. Packing density (ρ_p) of screens was considered as an important parameter which is very interesting. This parameter is defined as:

$$\rho_p = \frac{\text{Mass of wire}}{\text{Volume of demister}} \tag{1}$$

The packing densities of the demister screen used in the experiments were selected within the ranges 50–200 kg/m^3. All experimental measurements were taken at steady-state conditions. The water valve was opened and the water was admitted into the channel and fed through a spray nozzle. The flow rate of water was controlled using a valve to achieve 0.95 m^3/h required flow. The air velocities inside the channel were selected within the range from 6 to 10 m/s. The lower limit is determined by the minimum air velocity for water entrainment. Data were recorded for each test after steady-state conditions had been maintained for at least 10 min. The amount of escaped water droplets through the wire mesh screens had been measured and repeated at least three times for each test then the average value was calculated. All demisters are 280 mm × 280 mm, and made of stainless steel or a plastic polymer. A digital camera was used to capture film and image. This camera was waterproof and could be installed before or after the demister box (Model: Go Pro HERO 4). Films and images captured by the camera help to see some phenomena like Re-entrainment, liquid film formation, droplets collision with wires, escaped

Table 1
Geometrical and physical characteristics of the tested wire mesh screen

	Stainless steel wire mesh demister	Plastic demister with big mesh	Plastic demister with medium mesh	Plastic demister with small mesh
Mesh dimension {$a \times a$ (mm)}	7.8 × 7.8	17.5 × 17.5	10.9 × 10.9	6.6 × 6.6
Screen dimension {$A \times A$ (mm)}	280 × 280	280 × 280	280 × 280	280 × 280
Wire diameter {d_w (mm)}	0.3	1.9	1.5	1
Screen weight (g)	30	22	22	25

droplets, and trapped droplets. The experimental measurements were made as a function of the air velocity, packing density, demister screen geometry, and material. Collected data were used to analyze the system performance and to calculate the separation efficiency and the pressure drop for the dry demister. All experiments were carried out at an ambient temperature and atmospheric pressure (T = 25°C and P = 1 atm). All parameters from the rig, such as flow rates, velocities, differential pressures, and accumulated water on the scaled bucket, were recorded on an excel file that calculates automatically the separation efficiency and pressure drop of the experiments. All parameters were logged and when logging was finished, the average of all parameters was automatically written to a file and stored on the hard drive. Collected data were discarded and the experiment was repeated, if the result was in error by more than 5%.

3. Results and discussion

Data required to evaluate a wire mesh demister system include the droplet separation efficiency and dry pressure drop. These two parameters are evaluated simultaneously. In this research, separation efficiency and pressure drop were calculated to give us the exact comparison in the same operating conditions. These results facilitate decision making whether to use plastic mesh demister with lower cost instead of stainless steel mesh demister or not. The separation efficiency of demister can be presented either as fractional removal or as fractional penetration. The summation of the removal and penetration efficiencies is equal to unity. Broadly, the experimental separation efficiencies have been computed from the measured water volumetric flow rate balances. In fact, separation efficiency is a measure of the fraction of droplets in the air trapped by the wire mesh demister and is given by:

$$\eta = \frac{Q_{in} - Q_{out}}{Q_{in}} \times 100 \qquad (2)$$

where η is separation efficiency, Q_{in} and Q_{out} are the volumetric flow rate of entrained water droplets by the air and escaped water volumetric flow rate through the demister, respectively. The difference between Q_{in} and Q_{out} represents the volumetric flow rate of trapped water droplets by the wire mesh demister. Also, the dry pressure drop is the sum of the head loss incurred as the air travels through the mesh screens, as well as that due to the resistance to trapped liquids. The dry demister refers to the condition at which the mesh screen is free of water droplets.

3.1. Effect of air velocity

Figs. 6a–c illustrate the percentage of separation efficiency as a function of packing density in different air velocities. Four sets of data are presented that correspond to three different velocities of the air. As displayed, all experiments carried out for different types of demister indicate a similar trend, where the efficiency is high at a lower air velocity (6 m/s). For plastic demister with big mesh the separation efficiency reaches to 100% (maximum efficiency) at the conditions of 200 kg/m^3 packing density and 6 m/s air velocity. For similar conditions, 8 and 10 m/s air velocities give 98% and 96%, respectively, so they have close efficiencies as for 6 m/s air velocity. The same experiments were carried out for the other types of demister (plastic demister with medium mesh, stainless steel wire mesh demister, and plastic demister with small mesh), to obtain the separation efficiency and all data are available.

At 6 m/s air velocity, the size of the droplets passing to reach the demister will increase, because smaller water droplets will coalesce and form larger water droplets. Since the large droplets have less chance to be entrained in the air flowing inside the screens, a larger section of them will be trapped by collision with the wires and the liquid droplets trapped by the demister screens gradually increases (Fig. 7a). It is clear that the inertial forces of larger droplets decreasing the tendency of these droplets to follow the path of the air stream lines. But, when the air velocity becomes higher, it is a recognized fact that the free drainage of the demister is blocked by the air, and liquid holdup or overload on the wires of the demister will occur. In such circumstances, the droplets are trapped, but the velocity of the air provides adequate energy to tear off and re-entrain droplets. It is in the context of re-entrainment that separation efficiency is directly proportional to the surface tension of the water. As the surface tension increases, so it requires greater kinetic energy to break the bond between droplets and the target, and the droplets collect and coalesce until drainage. At sufficiently high velocities (10 m/s and higher air velocities), the effect of surface tension is overcome by the pressure of the air, and at least some of the liquid film enveloping the wires is swept to the front layer of the demister. So, separation efficiency diminishes with further increase in air velocity. As a matter of fact, for higher velocities, most of the droplets accumulated in the demister screens are separated from the wires by the pressure of the air and are entrained again in the air flowing inside the demister screens as re-entrainment (Fig. 7b).

Moreover, at air velocities higher than 6 m/s, the re-entrained liquid droplets can re-collide on the surfaces of subsequent wires. This may lead to the atomization of the water droplets by the force of the impact. Consequently, an atomized mist of droplets is generated, which is difficult to re-trap by subsequent screens of demister. This may clarify the reduction in the separation efficiency at high air velocities. It is observed that the separation efficiency decreases with increasing the air velocity from 6 to 10 m/s. Re-entrainment may be defined as entrainment that is initially removed by the demister, and eventually escaped being torn from the wires of the demister.

Figs. 8a–c depicts the pressure drop across the demister as a function of packing density in different air velocities. Total experimental results for different demisters display that the pressure drop expresses the augmentation as the air velocity is increased. For plastic demister with small mesh, the maximum pressure drop obtained was 470 Pa at 200 kg/m^3 packing density, and 10 m/s air velocity. Also, in similar conditions at 200 kg/m^3 packing density, and 10 m/s air velocity, pressure drop obtained were 360 and 440 Pa for plastic demisters with big and medium mesh, respectively. The minimum pressure drop determined for the

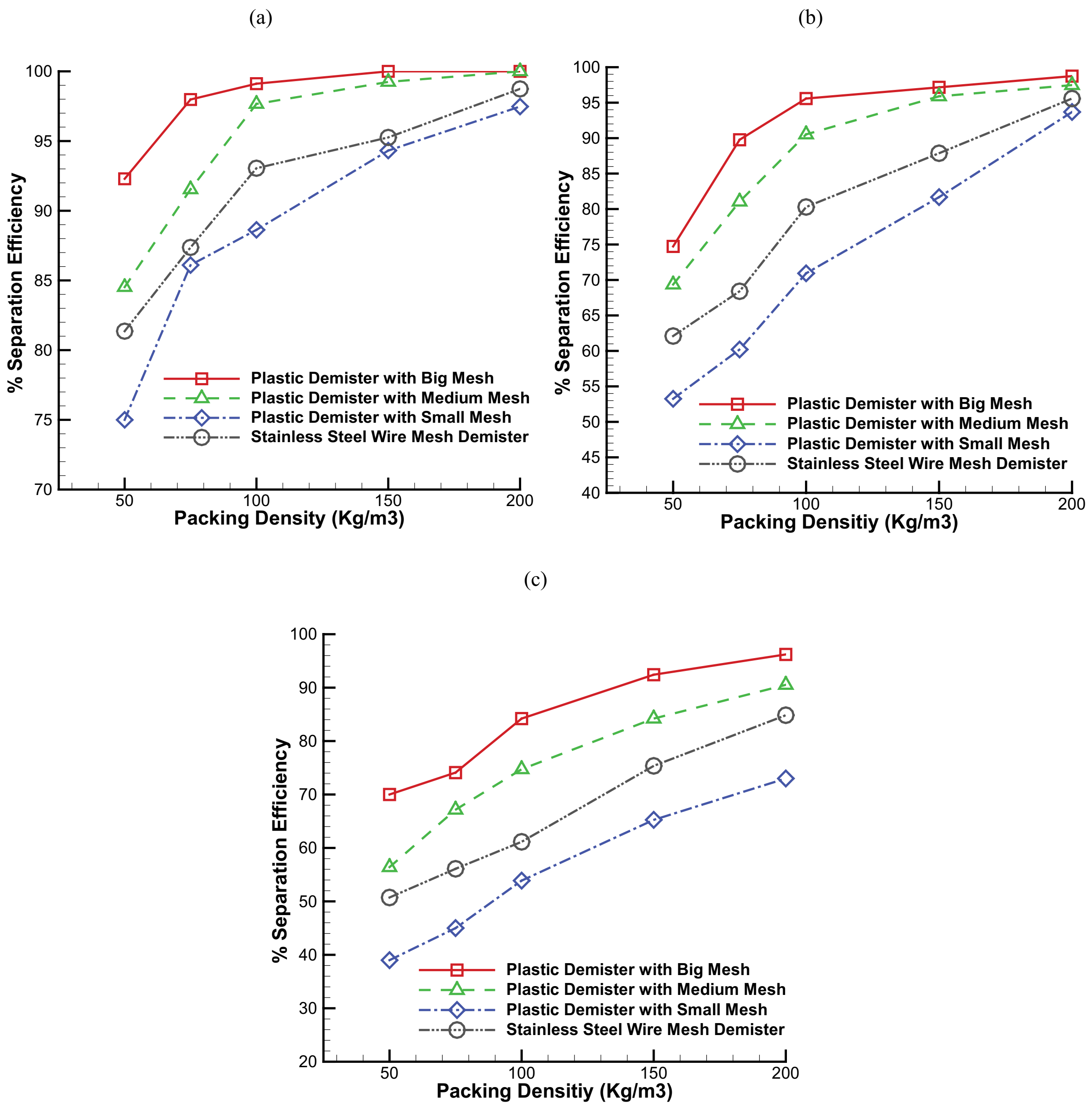

Fig. 6. Effect of air velocity on the separation efficiency at different packing densities: (a) 6 m/s, (b) 8 m/s, and (c) 10 m/s.

stainless steel wire mesh demister was 29 Pa at 50 kg/m^3 packing density, and 6 m/s air velocity. It is obvious that the plastic demister with big mesh has the lowest pressure drop and the plastic demister with small mesh has the highest pressure drop between plastic wire mesh demisters based on provided data. Also, the plastic demister with medium mesh is, respectively, between big and small mesh in terms of pressure drop.

3.2. Effect of packing density

The packing density can be expressed as the mass of the wire over the total volume of the demister. The increment of the packing density is related to the decrement of the free space area available for the flow. The diminution of the free space area available for the flow leads to an increase the number of entrained droplets that collide the wires and the amount of trapped droplets. Augmentation of the separation efficiency with the increase of the demister packing density as illustrated in Figs. 9a–d can be caused by the mentioned phenomenon. Also, the effect of the packing density on the separation efficiency is more conspicuous at low air velocity. Because at higher air velocities, both liquid holdup and droplet re-entrainment is increased and lead to a decrease in separation efficiency. Four different demisters made of metal and plastic were tested at different packing

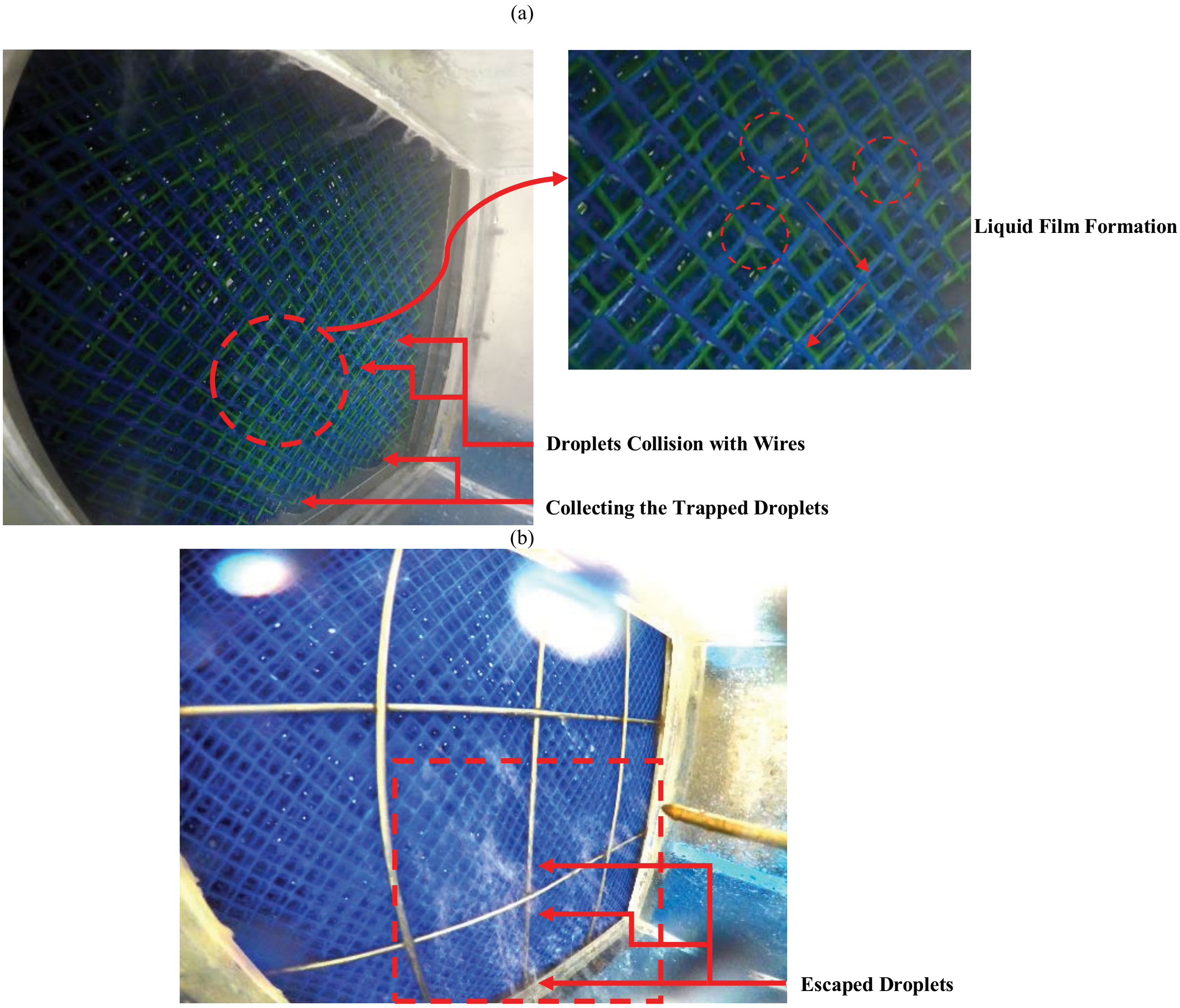

Fig. 7. Images captured with a waterproof camera (Go Pro Hero 4): (a) liquid film formation and trapped droplets and (b) re-entrained liquid and escaped droplets.

densities. For the plastic demister with big mesh, the maximum efficiency obtained was 100% at 200 kg/m^3 packing density, and 6 m/s air velocity and the minimum efficiency acquired was 70% at 50 kg/m^3 packing density, and 10 m/s air velocity. The minimum efficiency determined for the plastic demister with small mesh was 39% at 50 kg/m^3 packing density, and 10 m/s air velocity. Also, in similar conditions at 50 kg/m^3 packing density, and 10 m/s air velocity, efficiencies obtained were 50% and 56% for stainless steel wire mesh demister and plastic demister with medium mesh respectively. It is obvious that the plastic demister with big mesh has the highest efficiency and the plastic demister with small mesh has the lowest efficiency based on provided data.

Also, the plastic demister with medium mesh and stainless steel wire mesh demister are, respectively, between plastic demisters with big and small mesh in terms of efficiency.

Although the pressure drop across a properly sized mesh screen is never more than a few centimeters of water, but the pressure drop is an important design consideration in certain applications. The pressure drop is often small due to the large free space area available for the flow even at higher velocities. It rises almost proportional to the packing density.

Variations in the pressure drop as a function of air velocities are shown in Figs. 10a–d in different packing densities. Four different types of wire mesh demisters were tested. As clearly seen, the pressure drop enhances with the increase of the packing density. It should be noted that the measured pressure drop trend for all types of demister are similar to each other. In a similar packing density and air velocity, the stainless steel wire mesh demister has the minimum and the plastic demister with small mesh has the maximum pressure drop. As the liquid holdup gradually increases, the free space areas available for the airflow reduces and lead to a rapid rise in the flow resistance. Based on acquired results, the effect of the packing density on dry pressure drop is obvious at higher air velocity for all types of demister.

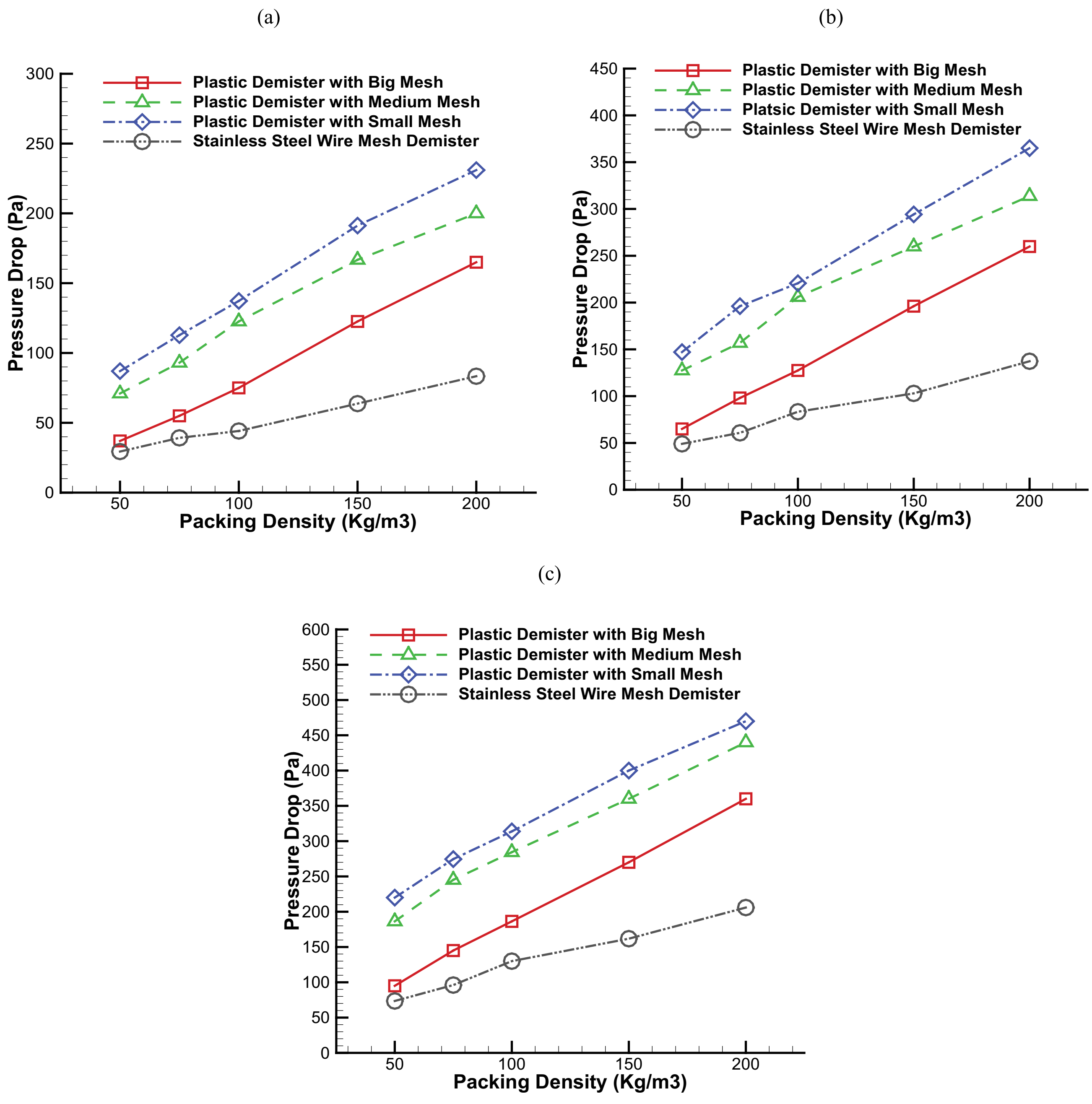

Fig. 8. Effect of air velocity on the pressure drop at different packing densities: (a) 6 m/s, (b) 8 m/s, and (c) 10 m/s.

3.3. Comparison separation efficiency against pressure drop

For further understanding and in order to have a better comparison, several experiments have been conducted to determine whether the plastic demister can be used to replace the metallic demister or not. It is obvious that metallic demisters are much more costly compared to plastic demisters.

Figs. 11a–c presents the percentage of separation efficiency enhancement as a function of packing density in different air velocities for three models of plastic demister compared to stainless steel wire mesh demister. The percentage of separation efficiency enhancement is defined as:

$$\text{Separation efficiency enhancement}(\%) = \frac{\text{Separation efficiency}_{\text{Plastic}} - \text{Separation efficiency}_{\text{Stainless Steel}}}{\text{Separation efficiency}_{\text{Stainless Steel}}} \times 100 \quad (3)$$

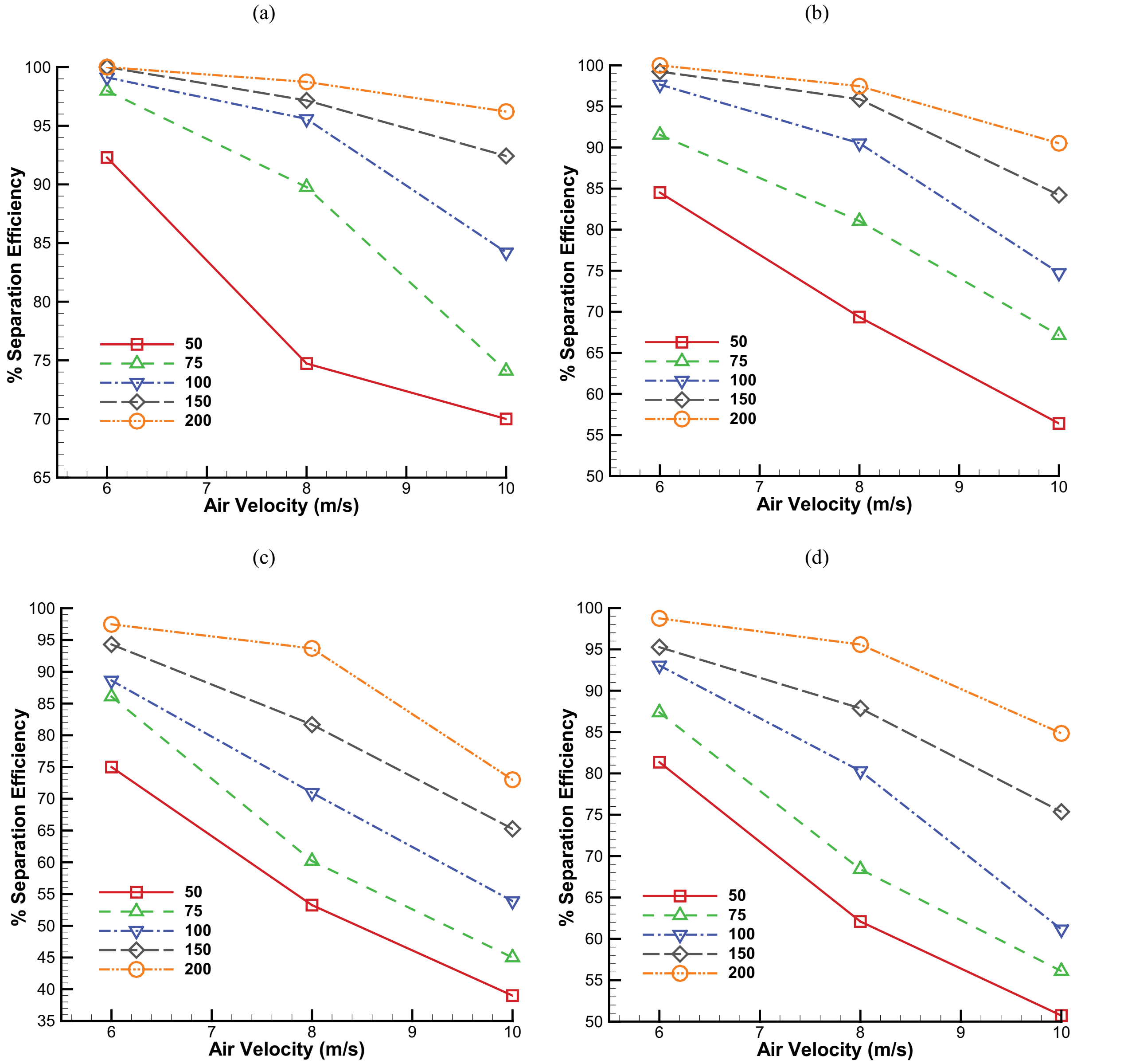

Fig. 9. Effect of packing density on the separation efficiency at different air velocity: plastic demister with (a) big, (b) medium, (c) small mesh, and (d) stainless steel wire mesh demister.

These figures illustrate that in the same packing density, plastic demister with big and medium mesh have a higher separation efficiency than the stainless steel wire mesh demister and, therefore, the percentage of separation efficiency enhancement is positive as defined in Eq. (3). Also, plastic demister with small mesh has a lower separation efficiency than the stainless steel wire mesh demister, and accordingly, the percentage of separation efficiency enhancement is negative as defined in Eq. (3). Furthermore, as can be seen in Figs. 11a–c, with increasing the packing density in plastic demister with big and medium mesh, the percentage of separation efficiency enhancement has downward trend and this behavior is similar in 6, 8, and 10 m/s air velocities. But, in plastic demister with small mesh, with increasing the packing density, the percentage of separation efficiency enhancement has upward trend. As a result, at higher packing densities (about 200 kg/m^3), separation efficiency of plastic demister with small mesh is close to separation efficiency of stainless steel wire mesh demister under low velocity (<8 m/s) conditions, and in this situation use of plastic demister with small mesh can be reasonable. Also, at lower packing densities, use of plastic demisters with big and medium mesh are much more economical than stainless steel wire mesh demister. Another result is that with increasing air velocity for all types of plastic demisters, the percentage of separation efficiency enhancement increases in the same packing density. For example, in plastic demister with big mesh, and 50 kg/m^3 packing density, the percentage of separation efficiency enhancement in 6, 8, and 10 m/s air velocities are 13.4%, 20.3%, and 38%, respectively.

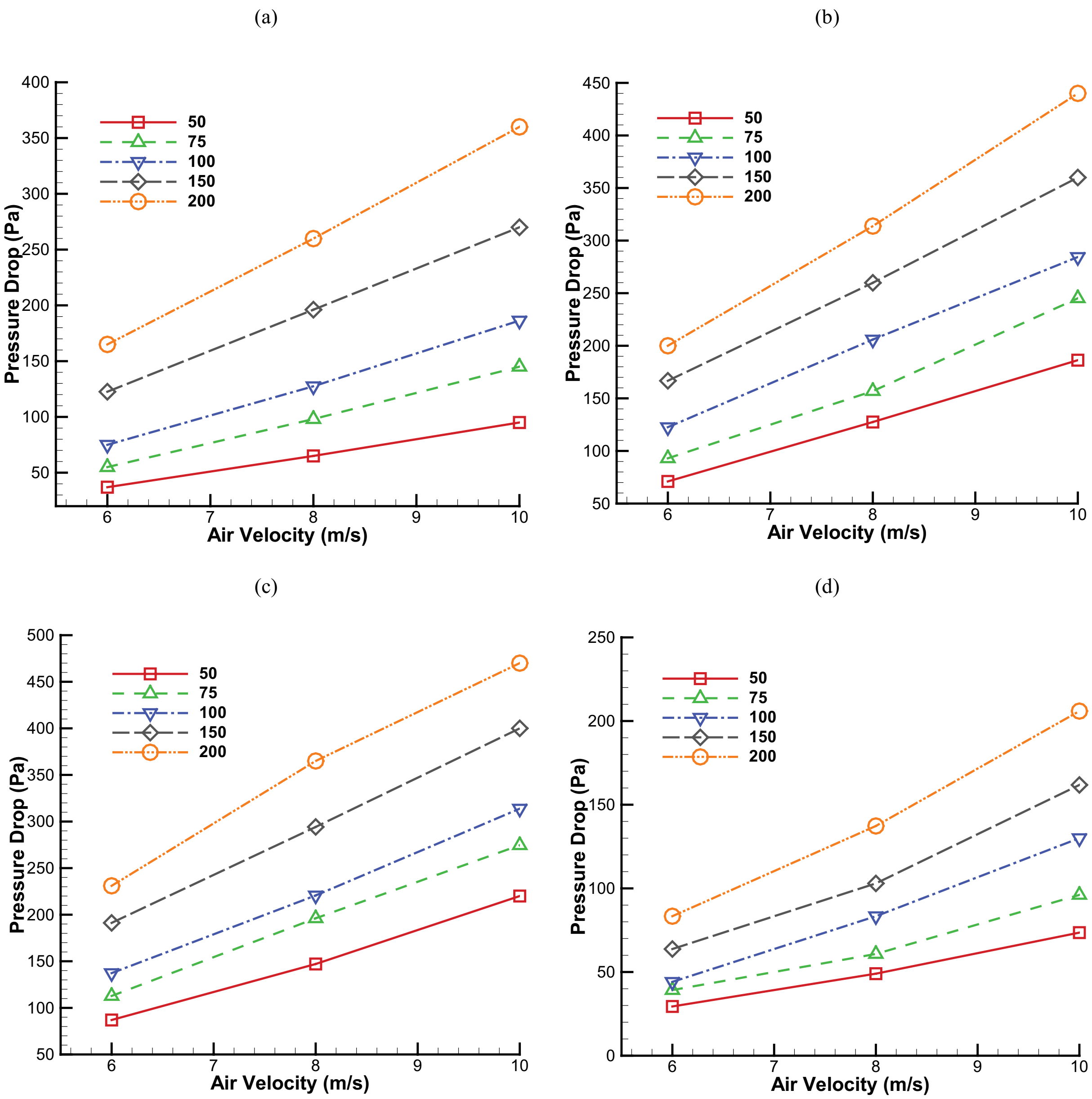

Fig. 10. Effect of packing density on the pressure drop at different air velocity: plastic demister with (a) big, (b) medium, (c) small mesh, and (d) stainless steel wire mesh demister.

Figs. 11a–c displays the percentage of pressure drop increment of plastic demisters compared to stainless steel wire mesh demister. The percentage of pressure drop increment is defined as:

$$\text{Pressure drop increment}(\%) = \frac{\text{Pressure drop}_{\text{Plastic}} - \text{Pressure drop}_{\text{Stainless Steel}}}{\text{Pressure drop}_{\text{Stainless Steel}}} \times 100 \quad (4)$$

As displayed, at all packing densities, the pressure drop of the plastic demister with small mesh is the highest and the pressure drop of the plastic demister with big mesh is the lowest. Fig. 11 shows that using the plastic demister with small mesh can increase the pressure drop up to about 200%, but for plastic demister with big mesh, the pressure drop increment is between 40% and 90%.

For a more illustrative comparison and conclusion, separation efficiency of the plastic, and metallic demisters used in this study, were investigated at the same pressure drop, as indicated in Table 2. In order to reach to an equal pressure drop, different packing densities have been used.

Also, in Table 2 the percentage of separation efficiency enhancement in different air velocities for three types of

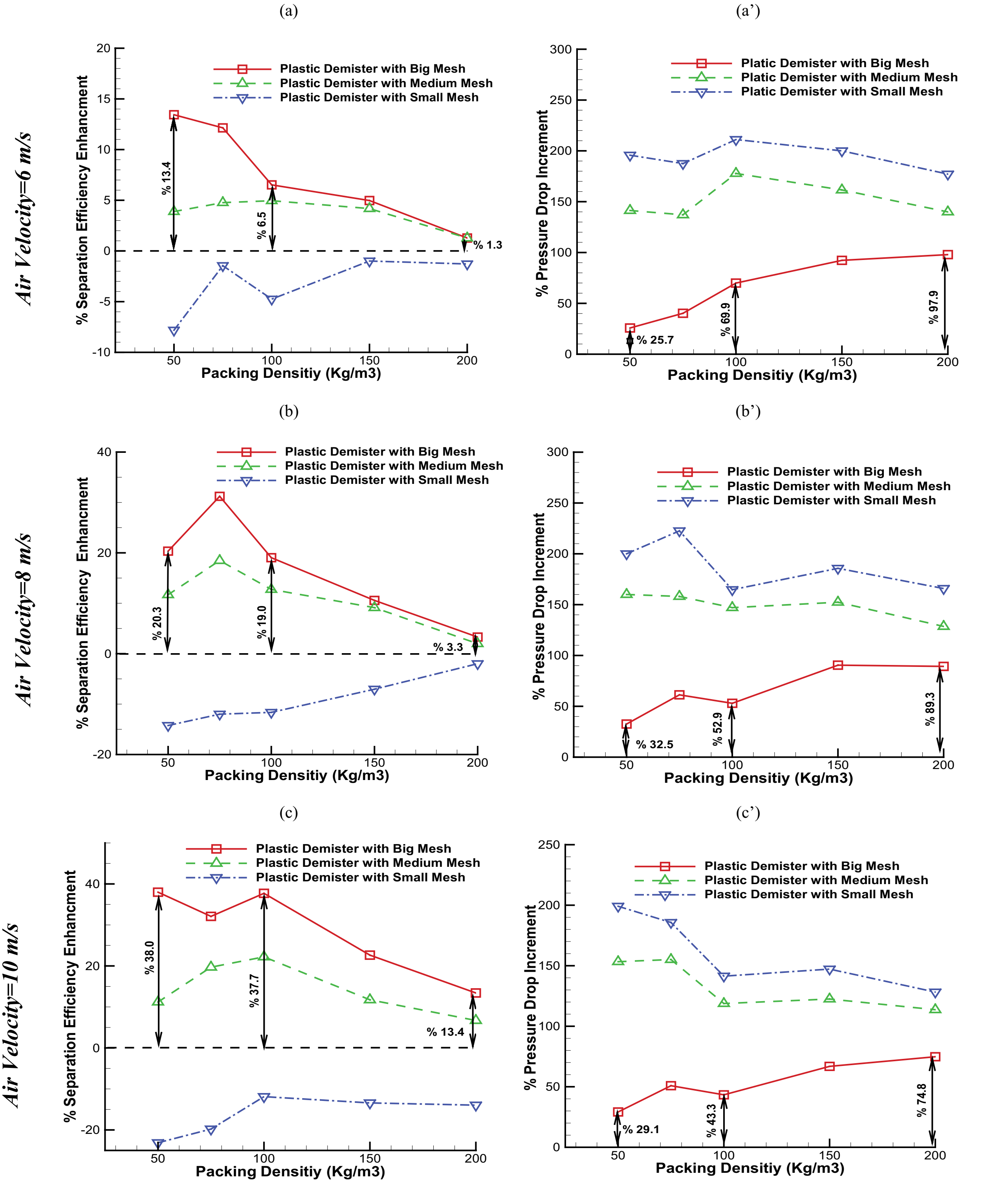

Fig. 11. Separation efficiency enhancement (a–c) and pressure drop increment (a'–c') as a function of packing density for plastic demisters compared to stainless steel wire mesh demister.

plastic demister compared to stainless steel wire mesh demister have been reported. Comparing: plastic demister with big, medium, and small mesh, the first one (i.e., plastic demister with big mesh) has better efficiencies in equal pressure drop. In other words, more droplets can be trapped by plastic demister with big mesh.

For equal pressure drop and the same air velocity, the plastic demister with big mesh has higher separation efficiency compared to stainless steel wire mesh demister and other plastic demisters, respectively. It can be concluded that using plastic demister with big mesh in these operating conditions is more efficient and has less capital cost. Also, it is necessary to use bigger opening mesh dimensions in order to facilitate cleaning of the demister and to obtain adequate mechanical strength and operational stability.

3.4. Correlation of the experimental data

In this section, considering the fact that the separation efficiency (η) and pressure drop (Δ*p*) in the demisters are affected by main design parameters: air velocity (ϑ) and packing density (ρ_p), two empirical correlation for predicting the separation efficiency and dry pressure drop are produced based on experimental results for four different types of demister. The considered ranges of the experimental variables were ϑ (6–10 m/s) and ρ_p (50–200 kg/m³) at standard environmental conditions (T = 25°C and P = 1 atm). Taking a regression fitting of the experimental data gives the following empirical correlations:

$$\eta = a\vartheta^b \rho_p^c \tag{5}$$

The value of coefficients in separation efficiency correlation for all types of tested demister are given in Table 3.

Eq. (5) is in-line with the experimental observation data where the separation efficiency is proportional to the increase of packing density, and decrease of air velocity. As indicated by this correlation, the power coefficient

Table 2
Comparison of performance characteristics of plastic demisters with stainless steel wire mesh demister

Demister type		Pressure drop (Pa)	Air velocity (m/s)	Packing density (kg/m³)	Weight (kg)	Separation efficiency (%)	Separation efficiency enhancement compared to stainless steel (%)
Plastic demister with:	Big mesh	80 Pa	6 m/s	103	0.64	98.5	+0.3
	Medium mesh			55	0.34	82.71	–15.7
	Small mesh			41	0.25	63.86	–35
Stainless steel wire mesh				204	1.27	98.2	–
Plastic demister with:	Big mesh	120 Pa	8 m/s	94	0.59	95.25	+3.1
	Medium mesh			48	0.3	68.35	–26
	Small mesh			37	0.23	47.47	–48.4
Stainless steel wire mesh				172	1.07	92.41	–
Plastic demister with:	Big mesh	200 Pa	10 m/s	106	0.67	83.97	+7.3
	Medium mesh			59	0.37	65.82	–15.9
	Small mesh			47	0.29	40.29	–48.5
Stainless steel wire mesh				196	1.23	78.3	–

Table 3
Value of coefficients in separation efficiency correlation

Demister type		Value of coefficients		
		a	*b*	*c*
Stainless steel wire mesh		83.5603	–0.6675	0.2792
Plastic demister with	Big mesh	83.19553	–0.3243	0.1618
	Medium mesh	76.05014	–0.4796	0.2354
	Small mesh	100.6932	–1.019	0.3715

Table 4
Value of coefficients in pressure drop correlation

Demister type		Value of coefficients		
		a	*b*	*c*
Stainless steel wire mesh		0.0565951	1.8482	0.7414
Plastic demister with	Big mesh	0.033159	1.7237	1.0144
	Medium mesh	0.25229	1.6995	0.6785
	Small mesh	0.427858	1.6068	0.6351

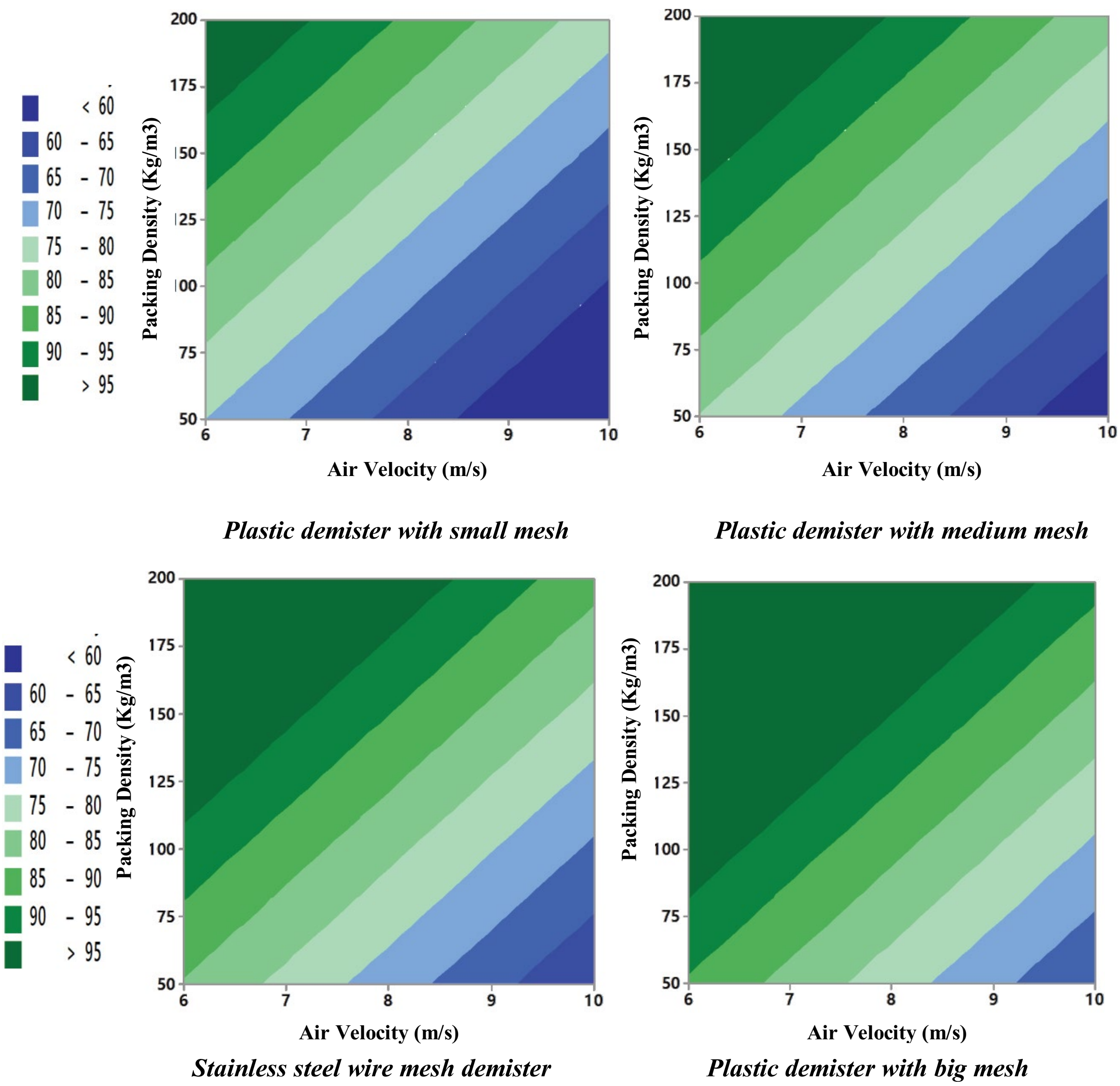

Fig. 12. Contour plots of separation efficiency vs. packing density and air velocity for different demisters.

related to the air velocity is negative and the power coefficient related to the packing density is positive which indicates the positive influence of increment of the packing density on the increment of separation efficiency. Furthermore, the velocity power is negative which indicates the reverse effect of this parameter on separation efficiency. Besides, considering the absolute value of the coefficients, the most important parameter is air velocity.

The pressure drop is not easily calculated as it depends on the friction drag of the dry wires, coalesced liquid film, liquid hold up in the wet wires, and air velocity. In this work, the pressure drop across the dry demister is expressible as below, considering the investigated effective parameters.

$$\Delta p = a\vartheta^b \rho_p^c \tag{6}$$

The value of coefficients in pressure drop correlation for all types of tested demister are given in Table 4.

Eq. (6) is also in-line with the experimental observation data where the dry pressure drop is proportional to the increase of packing density, and air velocity. However, the effect of packing density is minor compared to the effect of air velocity.

To gain a better view, Fig. 12 illustrates contour plots of separation efficiency vs. packing density and air velocity for different demisters. As displayed, the separation efficiency has increased with increasing the packing density and decreasing the air velocity for all types of demister reviewed. Furthermore, the increment of separation efficiency in the plastic demister with big mesh is obvious compared to stainless steel wire mesh demister.

Fig. 13 shows contour plots of pressure drop vs. packing density and air velocity for different demisters. As displayed,

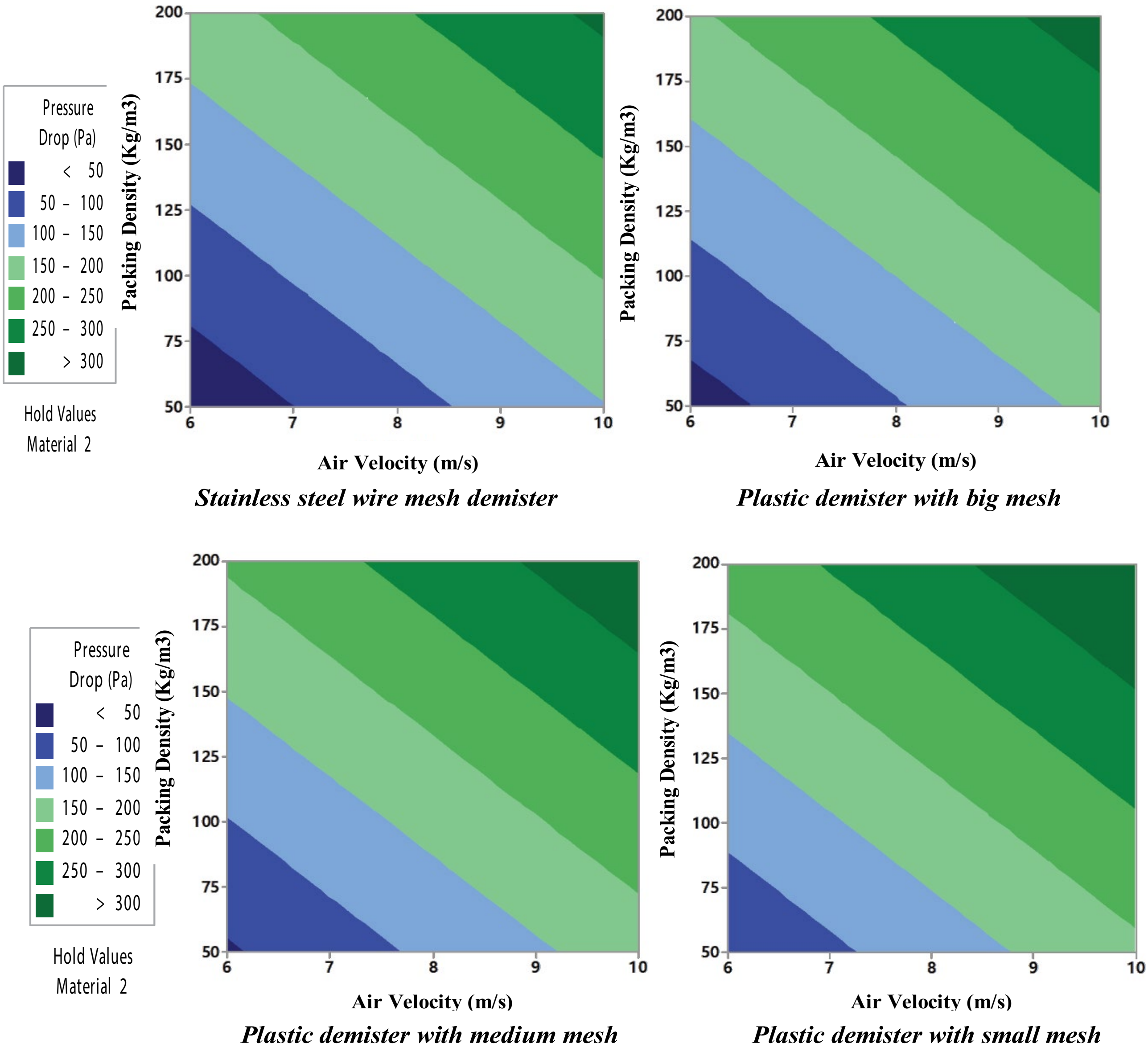

Fig. 13. Contour plots of pressure drop vs. packing density and air velocity for different demisters.

the pressure drop increases with increasing the air velocity and packing density. Also, it can be seen clearly that the plastic demister with big mesh and stainless steel wire mesh demister have less pressure drop compared to other demisters.

Based on these plots, the maximum amount of separation efficiency for plastic demister with big mesh and stainless steel wire mesh demister is occurred in minimum amount of air velocity and maximum amount of packing density. Also, the minimum amount of pressure drop is occurred in minimum amount of air velocity and packing density.

4. Conclusions

Reduction in costs and further improvement in performance of wire mesh demister were the most important points of attention in this work. Modifications or changing materials of demister can also be a significant item of expenditure. Moreover, demister separation efficiency is often a bottleneck in the production, so that separation efficiency improvements can increase the production capacity. Theoretical models devoted to simulation of the performance of wire mesh demister are not adequate for modification in an industrial unit. It has been the aim of this research to compare the separation efficiency of wire mesh demister with different materials of construction and geometries. Separation efficiencies were calculated in the same pressure drop for each demister to ensure that which one has higher performance compared to others. In fact, several experiments have been conducted to determine whether the plastic wire mesh demister can be used to replace metallic one or not. It is obvious that metallic demisters are much more costly compared to plastic demisters. Two empirical correlations obtained for predicting the separation efficiency and pressure drop with accepted accuracy. The obtained results are as follows.

Normally, the pressure drop for the dry demisters is low and enhances with an increase of both, air velocity and packing density. Also, the separation efficiency augments with the increase of packing density and in constant packing density, separation efficiency diminishes with the increase of air velocity.

Achieved results clearly show that, in similar operating conditions (equal water flow rate and air velocity), the plastic demister with big mesh has equivalent or higher separation efficiency for equal pressure drop compared to stainless steel wire mesh demister. Therefore, use of plastic demister instead of metallic demister is more economical and advisable in a real industrial plant.

Plastic demister with big mesh is expected to become the ideal substitute of stainless steel wire mesh demister for its advantages such as resistance to corrosion, excellent separation efficiency, and low capital cost. On the other hand, use of plastic demister with big mesh facilitates demister cleaning and gives the demister sufficient mechanical strength. Hopefully, the results presented in this paper will contribute to an improvement in demister performance.

Symbols

Q	—	Volumetric flow rate, m^3/s
ρ_p	—	Packing density, Kg/m^3
η	—	Separation efficiency, %
Δp	—	Pressure drop, Pa
ϑ	—	Air velocity, m/s
A	—	Screen dimension, mm
a	—	Mesh dimension, mm
d_w	—	Wire diameter, mm

Subscripts

in	—	Entrained water droplet by air
out	—	Captured water droplet by demister

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