REACH OF AIRFLOW FROM THE TEXTILE DIFFUSERS

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ABSTRACT

The textile diffuser is a duct and a distribution element at the same time. The flow of air distributed into a room by means of a textile diffuser is influenced first by the longitudinal flow inside the diffuser, second by properties and finishing of the fabric, by the size of openings primarily. This way the outlet velocity and direction of air can be modified in synergy with positive pressure. The subsequent diffusion of the air depends on the concrete allocation of the openings, parallel action of the airflow from them and differences in temperatures. There are methods of achieving a maximal airflow reach or, on the contrary, draught-free distribution. The intensity of action of each factor can be presented and quantified by generalization of measurements and experiments. An equal airflow will be distributed in a radically different way if various positive pressures, sizes, spacing and positions of the openings are combined. Differences in temperatures have fundamental influence. Several combinations are illustrated by graphs and animations, computer software and complex calculation provide generalized form. Compared to designing of metal or plastic distribution elements a different designer's approach is required if designing textile diffusers.

CIRCULATION INSIDE OF DIFFUSER

The airflow from a textile diffuser is influenced by the longitudinal flow inside the diffuser. The resulting effect is usually undesirable and there are methods to eliminate it. However, for various technical and economic reasons, the majority of duct manufacturers do not employ them so it is necessary to acquaint ourselves with them.

The velocity and direction of the airflow from the diffuser through an opening are determined by two perpendicular elements. The first is the longitudinal flow inside the diffuser and the second is a vector component of the outlet flow perpendicular to the diffuser. If longitudinal flow exceeds perpendicular flow, the outlet flow diffuses alongside the diffuser, which is an undesirable effect. Further along the diffuser, the longitudinal flow drops in intensity and the flow gradually becomes more perpendicular until it reaches the end cap where it becomes completely perpendicular. The individual outlet vectors can be added together as they meet. However, it is possible and practical to keep the deflection from perpendicular to less than 30 degrees. In fact, 30 degrees should be the maximum deflection allowed. Fig. 1 shows the relationship between the longitudinal velocity/perpendicular velocity ratio and deflection from perpendicular. Bigger openings provide smaller deflection.

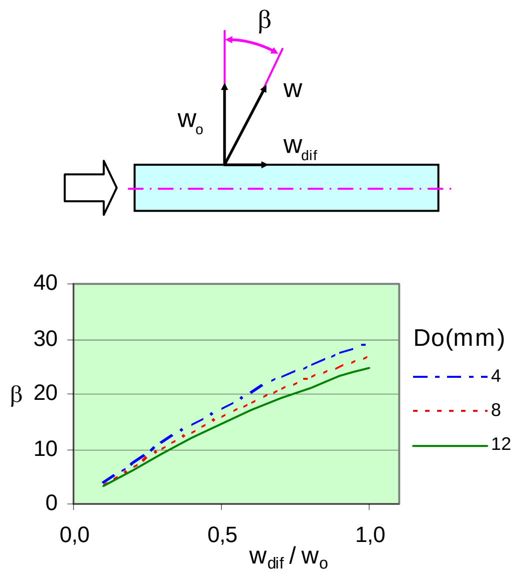


Fig. 1: Deflection of the airflow through an opening from perpendicular.

STATIC AND TOTAL PRESSURE

A simple rule of thumb says the higher the pressure inside the diffuser, the higher the outlet velocity. Changes in the outlet velocity along the length of the duct should be kept within a certain range. A difference of up to 20% between the beginning and end of the duct is acceptable. Although "entirely" uniform outlet velocities (a difference of less than 5%) is possible in theory, it is uneconomical and difficult to realize from a technological perspective in practice.

As a textile air diffuser is both a duct and a diffuser, the air is distributed evenly along the length of the duct. The amount of air inside the diffuser decreases and the dynamic pressure drops accordingly. Its drop changes into static pressure, which rises towards the end cap. The outlet velocity is directly proportional to the root of static pressure and rises smoothly longitudinally up to the maximum value at the end cap. Combination of low static pressure and high inlet velocity causes the most significant irregularity. If a diffuser is dimensioned incorrectly (usually oversized), under-pressure can occur at its beginning. This part of the diffuser will not inflate properly and undulates as a result. Well-dimensioned diffusers induce about 10% outlet irregularity. The following figure 2 illustrates the typical course of static and dynamic pressure. The outlet coefficient μ is directly proportional to the static pressure and also depends on the positive pressure inside the diffuser.

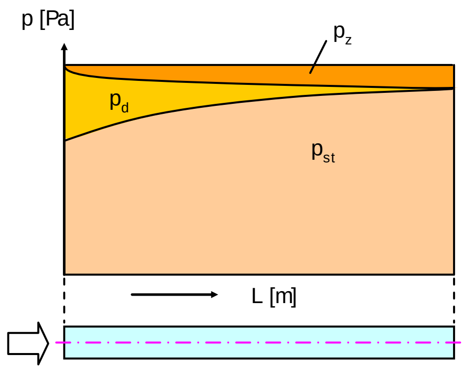


Fig. 2: The typical course of static and dynamic pressure inside the textile air diffuser.

MATERIAL

Textile air diffusers are made of various kinds of materials. The outlet airflow is influenced by the thickness of the material and by the shape of the opening rim created during the manufacturing process. Although the influence is relatively small, it should be known and manufacturers can acquire the necessary constants from tests. Their technological procedures must be capable of reaching identical values repeatedly. The value of the outlet coefficient μ indicating outlet acceleration caused by a flow contraction is expected somewhere between 0.6 and 0.9. Simple dependency on the weight of the material alone cannot be corroborated. The influence of the geometry of the opening rim given by the manufacturing process is more probable. Manufacturers perforate the material mechanically by means of a heated instrument or by means of a laser machine more and more often. The latter method provides high-quality openings.

DIMENSION OF OPENING

The size of the perforated area must not exceed maximum limits, up to which the diffuser will be properly inflated and retain its cylindrical shape. Two alternatives of air distribution based on the size of openings; tiny openings up to 1 millimeter; (so-called micro-perforation) and openings of regular-size from 4 to 50 millimeters (so-called perforation), can be specified on the condition that the maximum limit calculated from the positive pressure is not exceeded. The two ways of distributing the air are completely different. The air flowing from the tiny openings is affected by an interaction with the diffuser. It hugs the diffuser and flows alongside at first until it reaches a certain distance along the duct where it begins to deflect from the diffuser. The flow reaches a perpendicular direction at the end of the diffuser (see figure 3). Sometimes, such airflow is undesirable and should be avoided. Properly placed micro-perforated openings can solve this problem.

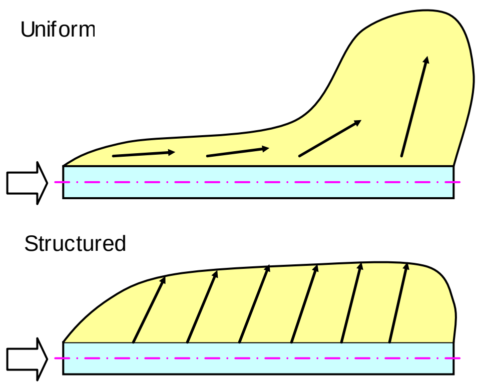


Fig. 3: Airflow from micro-perforated diffuser through different arrangements of openings

The air flowing through openings greater than 4 millimeters in diameter deflects uniformly even at the beginning of the diffuser. Naturally, bigger openings provide further reach of air flow. Figure 4 illustrates air flowing through openings 4, 8, and 12 millimeters in diameter. The outlet coefficient depends on the size of an opening. The larger the opening, the lower the value of the coefficient.

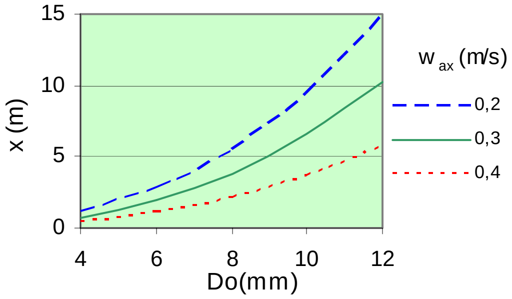


Fig. 4: Reach of air flow through openings of various diameters (always one row of openings)

PLACEMENT OF OPENINGS

Most often, the openings are arranged in rows, which creates a flat air flow directed from the diffuser longitudinal axis in the required direction. It is possible either to vary the spacing among individual openings or use several parallel rows, or place the openings in a certain location only. The alternative of several parallel rows is used frequently. Figure 5 illustrates the air flowing through different numbers of openings under unchanged static pressure. The air flow spreads and accelerates influenced by superposition of individual flows.

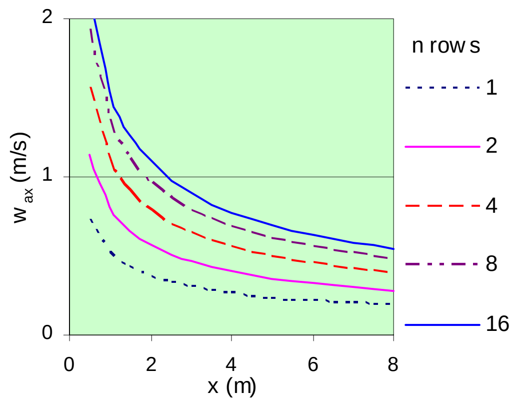


Figure 5: Velocity of the air stream at various distances from diffuser outlets as a function of the number of openings/rows, p_{st} = 100 Pa, Do = 4mm

TEMPERATURE DIFFERENCES

The influence of the operating temperature differences of the air stream and the indoor air as well as the temperature gradients along the diffused air mixing with the ambient air play an important role. This issue is very complicated because of the large number of possible arrangements of openings. The air distribution through permeable material affected by a range of temperature differentials is the simplest case. For this alternative, figure 6 illustrates the airflow with a delta T of 4 to 16 K. At higher temperature differences the exiting air stream does not expand at common constant angles; rather it contracts. In practice, it would be necessary to prevent it and assure the flow expansion, e.g. by means of directed perforation. The non-isothermal distribution flow by means of a row of openings is the most common application case. Thanks to the air density gradient, the stream of warm air bends upward, and that of the cold, downward. This case is illustrated in figure 7. The single row of openings with a diameter of 4 mm is oriented horizontally.

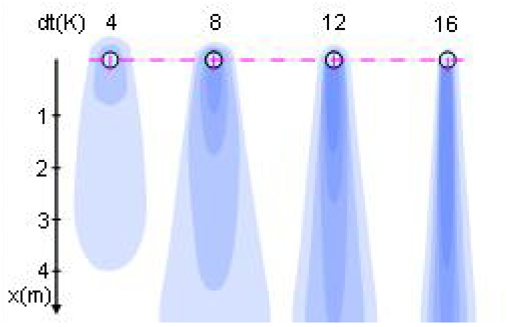
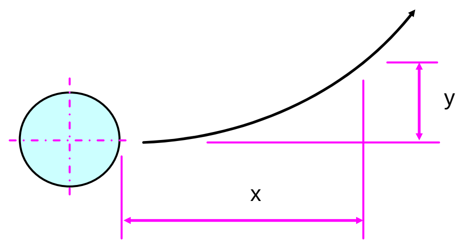


Figure 6: Flow distribution profiles for cold air exiting from a micro-perforated diffuser at various temperature differences.



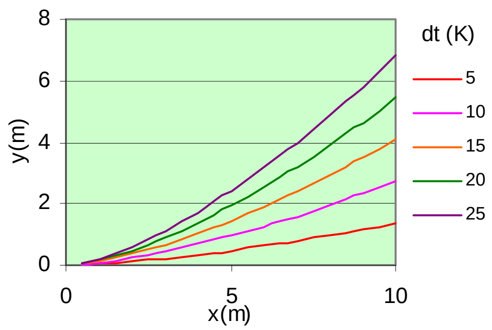


Figure 7: Deviation of horizontal streams due to temperature difference, (temperature of distributed air minus indoor temperature).

CONCLUSIONS

Six factors influencing the air flowing from the diffuser were described above. To make the issue simple, each factor was described separately. It is, however, much more complicated in practice because all the factors described act at the same time and influence each other. Their influences vary in intensity. Usually, one or two of them become predominant. Software, which contains all the necessary constants and considers the significance of the individual factors, provides results that correlate very well with the air distribution measurements.

REFERENCES

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NOMENCLATURE

x (m)	distance in the direction of the airflow
y (m)	distance in the direction perpendicular to the airflow
β (°)	angle of deflection of the airflow
D_o (mm)	diameter of perforation
L (m)	length
dt (K)	temperature difference
p_z (Pa)	pressure loss
p_{st} (Pa)	static pressure
p_d (Pa)	dynamic pressure
w_o (m/s)	outlet velocity
w_{dif} (m/s)	medium velocity of the airflow inside the diffuser
w_{ax} (m/s)	average velocity of the airflow in the distance x
n_{rows} (-)	number of rows