ROOM
-VENT
'90

Velocity field in the reaction area of semi-limited radial flow

L. Laskowski
Polish Academy of Science
Institute of Fundamental Technological Research
Warsaw, Poland

B2

VELOCITY FIELD IN THE REACTION AREA OF SEMI-LIMITED RADIAL FLOW

L. Laskowski
Polish Academy of Science
Institute of Fundamental Technological Research
Warsaw, Poland

SUMMARY

The purpose of this paper is to present the empirical results of model tests on the velocity distribution in a room with a single ceiling air outlet. The main zone of weak non-isothermal radial flow were characterized and statistical estimation of the velocity field in the zone of secondary motions were given. The basic advantages of using additional grid of blades in a ring slot of a plate air diffusor were shown.

Introduction

A characteristic feature of a movement of radial flow in a symmetrical velocity field. Due to Coanda's-effect expansion of teh flow takes place along the ceiling and, if the kinetic energy is large enough, also along the walls and the floor (fig.1). Observations have shown that a change of direction of the flow leads in effect to formation of an overpressure area and partial energy conversion. This is usually accompanied by appearance of local whirls. However, these phenomena disturb the flow continuity conditions and hence after a change of direction the flow width is smaller than that before the barrier.

Bacause of a turbulent mixing and induction properties the main flow carries away on its path a considerable amount of ambient air. In result, the volume of the moving air is several times greater than the amount of the leaving air and the picture of the movement is as follows:

- the initial flow takes place still within a narrow area in the vicinity of the partitions surrounding the room;
- a major part of the room lies within the zone of the secondary movements with small enough velocity.

An attempt of an analytical description of the air velocity field within the zone of a semi-limited radial air flow has been undertaken by Waschke (1) in his doctoral thesis. On the basis of a semi-empirical theory of turbulence and the principles of dimensional analysis he has proposed a function which gives the relation between the distribution of local velocities and the conditions of a turbulent air movement and configura-

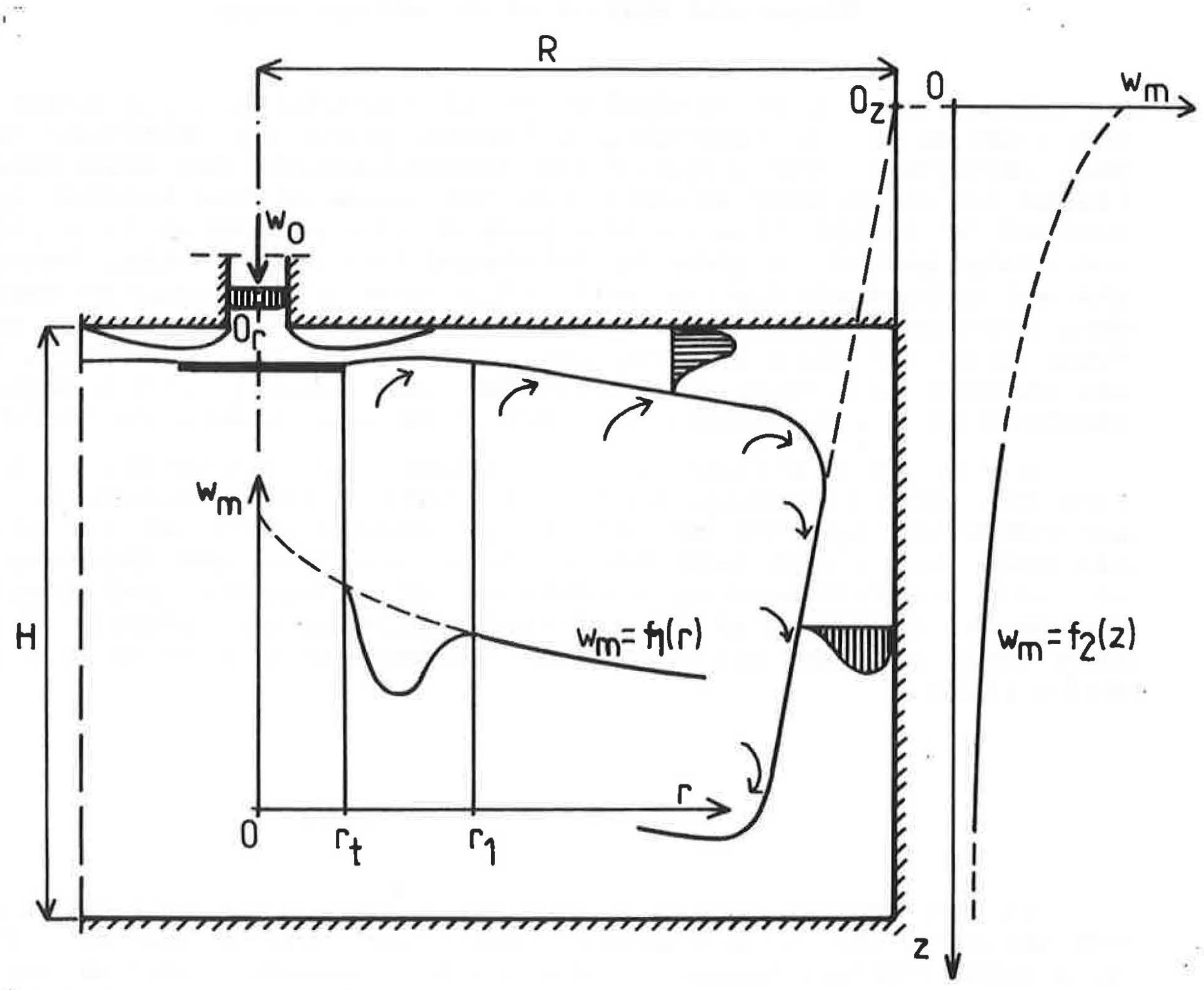

Fig. 1. Expansion of radial flow in the limited area

tion of dimensions of the room under consideration:

$$\frac{w.H}{\nu_\varepsilon} = f\left[\frac{s}{H}, \frac{w_o.H}{\nu_\varepsilon}, \frac{R}{H}\right] \quad (1)$$

The results of experimental investigations have confirmed the existance in isothermal conditions of the anticipated relationship, but they have not led to its precise formulation. Hence, we may suppose that the characteristics of the velocity field is also dependent upon some additional factors which introduce random effects to the description, these being additionally intensified by the influence of the temperature field in non-isothermal conditions.

In view of the above mentioned, the empirical characteristics of the velocity field in work (2) has been supplemented by parameters of statistical analysis relating to the conditions encountered within the range of secondary circulating air movements.

Scope and Method of Investigations

Measurements of distribution of velocities in a model of the room with one centrally situated plate air diffusor have been performed. The scope of the investigations has been established so as to make evident the influence of the initial turbulence of radial flow on the path of its expansion in a limited space and to be able to determine the relationship between the velocity distribution within the zone of the induced secondary movements and the conditions of outflow of air from a diffusor provided with a turbulence amplifier. This amplification was ensured by a ring slot provided additionally with a regular palisade with alternately variable free outlet area ratio (3).

A case of distribution of a weakly non-isothermal leaving flow has been investigated representative for ventilation and air-conditioning. The method of approximate physical modelling has been used which requires a stable air flow and maintenance of local self-modelling conditions of kinematic and thermal phenomena. Criteria of statistical estimate of velocity field have been assumed acc. to the recommendations given in the works (4,5).

Results of Investigations

It has been proved that the relationship between the maximum velocity in the successive cross sections of the main zone of a semi-limited radial flow and the distance from the vertical axis of symmetry of the plate air diffusor has a character of a power function with exponent independent of area ratio of free outlet from a ring slot. On the basis of the obtained results of investigations it has been proved by means of the method of the straight line of the least squares that for ε=0,3-1,0:

$$\frac{w_m}{w_n} = 2,29 . \varepsilon^{1,43} \left(\frac{r}{r_t} \right)^{-1,15} \qquad (2)$$

Figure 2 presents a generalized velocity profils in the main zone of the flows under consideration. It may be assumed that the distribution of the measuring points satisfies the following condition:

$$\frac{w}{w_m} = 2,007 \left[\frac{z}{z_{m/2}} \right]^{0,257} \exp \left[-1,406 \frac{z}{z_{m/2}} \right] \qquad (3)$$

This means that the character of a weakly non-isothermal movement of turbulent semi-limited flows is similar in the main zone and does not depend upon the conditions of outflow of the air from the diffusor. Formula (3) has been proposed by the author of the work (1), but its validity has been confirmed only

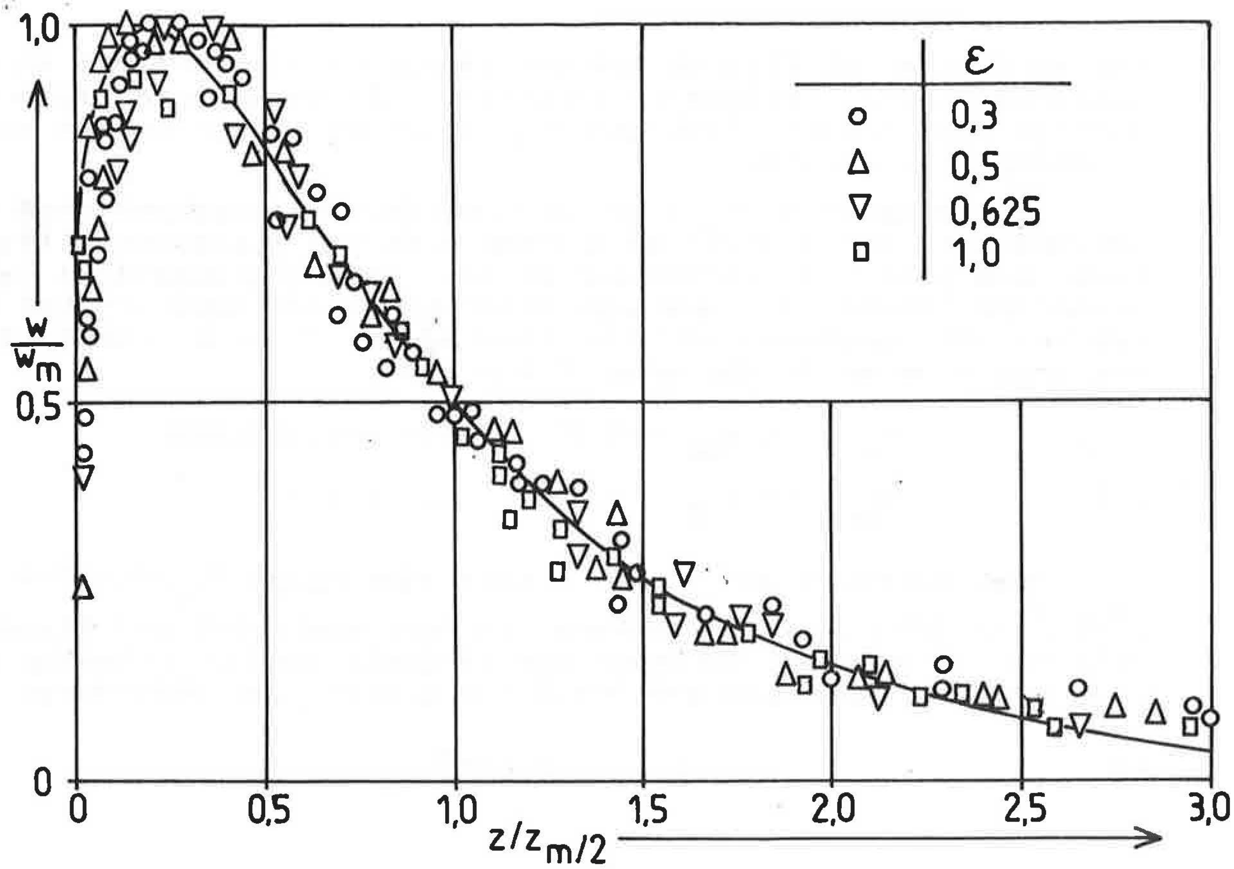

Fig. 2. Velocity profile in the main zone of semi-limited radial flow

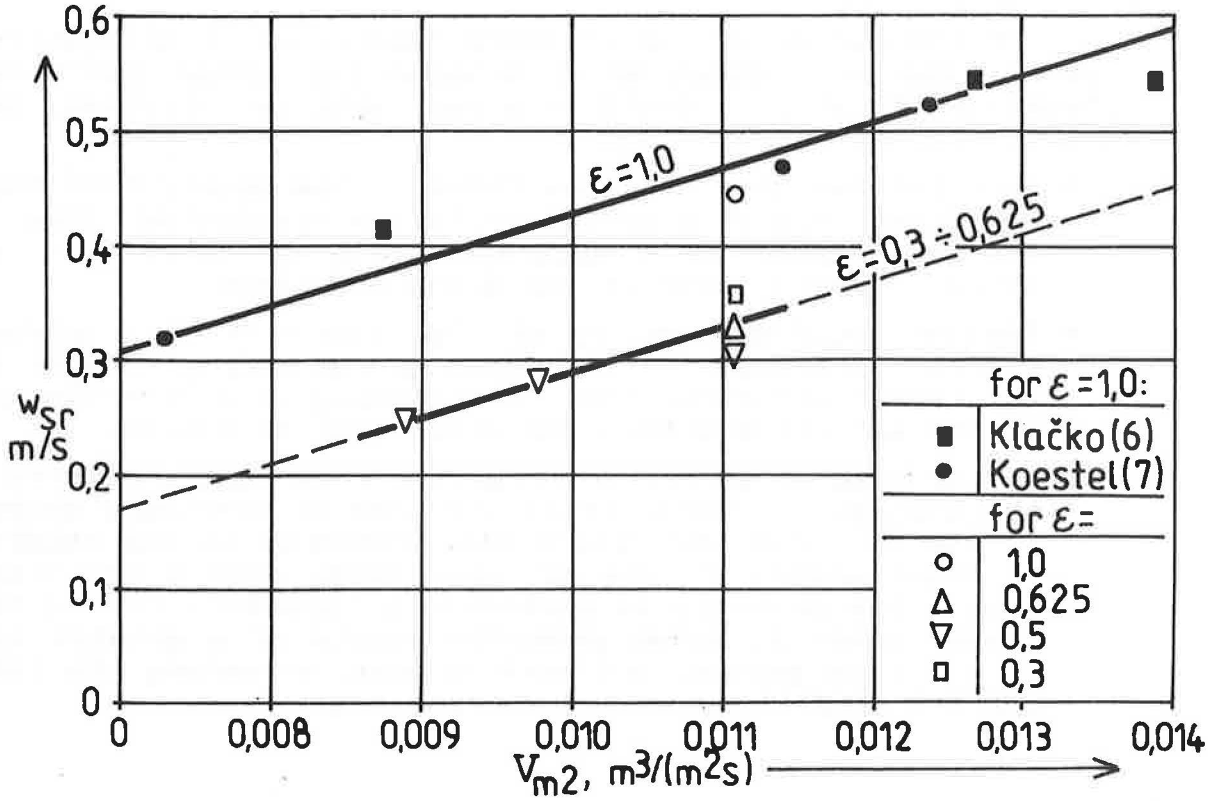

Fig. 3. Mean velocity in the area of secondary motions in the function of an amount of distributed air and a free outlet area ratio from a ring slot of a plate air diffusor

for an isothermal flow of the air leaving a slot without an ad ditional initial turbulence amplifier. The results of these investigations seem to indicate a general character of the relationship given above.

The parameters of velocity distribution obtained from the measurements for a model of a room with one plate air diffusor have made possible formulation of the following empirical ralationships between the average velocity in the zone of the secondary air movements and the leaving air flow as referred to one square meter of the area of the room:

(4a) $$w_{sr} = 34.V_{m2} - 0,07 \quad \text{for } \varepsilon=0,3-0,625$$

(4b) $$w_{sr} = 34.V_{m2} - 0,07 \quad \text{for } \varepsilon=1,0$$

Both formulae are valid within the range V_{m2}=0,007-0,014 $m^3/(m^2.s)$ (fig.3). Also determined was empirical relationship between the average variance coefficient, outlet velocity and free outlet area ratio ε=0,3-1,0 for a plate air difussors:

(5) $$k_w = 0,06.\varepsilon^{0,5}.w_n$$

Conclusions

On the basiss of the obtained results of investigations we come to the conclusions which broaden the actual knowledge of formation of velocity field in a room with semi-limited, weakly non-isothermal radial flows:

* Specific features of those flows follow mainly from the way and directions of propagation in the ventilated rooms. They can be treated as a separate group of outlet air flows being a special case of the dispersed flows.
* Partial regular covering of the ring slot of a plate air diffusor improves the induction properties of a semi-limited radial air flow, thus contributing to a vigorous mixing of the air flows within the whole zone of action.
* In the case of an air distribution from partly covered slot the average air velocity in the zone of secondary movements is smaller than the values corresponding to the conditions of distribution of the air outflowing from a non-armoured slot. This property is particulary important in low height rooms, since it makes possible supply of a greater amount of air from another diffusor without worsening the thermal comfort conditions in the working zone.

List of Symbols

- H – room height, m
- k_w – average velocity variance coefficient, m/s
- R – distance from the axis of symmetry of plate air diffusor to the side wall of the room, m
- r, z – horizontal and vertical distances in the assumed system of coordinates, m
- r_t – radius of diffusor plate, m
- s – vector of position of the point in the velocity field, m
- V_{m2} – outlet air flow as reffered to the room area, $m^3/(m^2.s)$
- w – local velocity in the main zone of the air flow, m/s
- w_m – maximum velocity in a cross section of the main-zone of the air flow, m/s
- w_n – average velocity of the air outflowing from a ring slot, m/s
- w_o – average velocity at the diffusor inlet, m/s
- w_{sr} – average velocity in the zone of secondary movements, m/s
- $z_{m/2}$ – vertical coordinate of the position of the point where $w=0,5.w_m$, m
- ε – free outlet area ratio of the air outflowing from a ring slot of a plate air diffusor
- ν_ε – kinematic coefficient of an apparent air viscosity for a turbulent motion, m^2/s

References

(1) Waschke G.: Über die Lüftung mittels isothermer turbulenter radialer Deckenstrahlen. Klima-Kälte-Ing., 1976, 4,1

(2) Laskowski L.: Semi-limited Radial Flows in Application for Ventilation of Rooms. Dissertation. Warsaw Technical University, Institute of Heating and Ventilation, Warsaw 1981 (in Polish)

(3) Laskowski L.: Plate Air Diffusors with a Regular Covered Ring Slot. COW, 1983, 15,7-8 (in Polish)

(4) Mierzwiński S.: Industrial Ventilation - Part I. Silesian Technical University, Gliwice 1979 (in Polish)

(5) Nouri Z.: Anwendungen statistischer Verfahren bei experimentellen Untersuchungen von Raumluftstrommungen. HLH, 1978 29,4,5,6

(6) Klačko L.S., Ganes I.L.: The Dimmensioning of Ceiling Air Outlets in Air Conditioning Systems. Vodosn. i San. Tekhn., 1962, 2 (in Russian)

(7) Koestel A.: Jet Velocities from Radial Flow Outlets. ASHRAE Trans., 1957, 63,1618