Experimental investigation of the velocity field of the HBVICU system

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Experimental investigation of the velocity field of the HBIVCU system: *The paper presents experimental results about the mean velocity field generated by the HBIVCU system. The HBIVCU (Hospital Bed with Integrated Ventilation and Cleaning Unit) is a hospital bed equipped with an advanced air distribution system and air cleaning unit that protects both the person lying in the bed and the visitors in the room from cross-infections. Velocity measurements were performed with four HT 428 low velocity omnidirectional probes connected to a HT400 constant temperature thermoanemometers. The results might be used for both evaluation of draught risk and validation of CFD based procedures for numerical investigation of the flow field generated by the HBIVCU system.*

Key words*: velocity field, air jets, thermoanemometer, HBIVCU system*

INTRODUCTION

A novel method for advanced hospital ventilation, called HBIVCU, based on both pollution source control and airflow control was developed by Melikov and Bolashikov, [4, 5]. The HBIVCU system is a subject of patent rights in Europe (EP 09165736.1) and USA (US 61/226,542). The working principle of the HBIVCU system was presented in details in earlier publications [2].

The velocity field of the HBIVCU system is result of a complex interaction between three types of air jets – one horizontal and two vertical (one in upward inclined direction and one in downward direction). The horizontal air jet supplies clean air close to the head of the patient lying in the bed. The supplied air mixed with the exhaled air from the patient is then exhausted from an air terminal device (ATD) located on the other side of the bed. The horizontal air jet generated by the HBIVCU system is rectangular turbulent air jet that develops close to the bed matrass. It is a complex flow that depends on many parameters, [3, 6]. In the case of the HBIVCU system the complexity of the flow increases due to the fact that the air jet interacts with the body of the patient lying in the bed. The occupant affects the flow of the HBIVCU system in three ways – first, its body is an obstacle to the flow, second its body generates an upward convective flow which interacts with the horizontal jet and third during the exhalation through the nose/mouth an air jet is generated which interacts with the horizontal jet.

The velocity field generated by the HBIVCU system horizontal air jet in a case of no presence of a patient was measured with four low velocity thermoanemometers. The purpose of the performed measurements was to determine whether the velocity field of the horizontal air jet creates risk of draught discomfort for the patients lying in the bed. The results from the experiment might be used for validation of CFD based procedures for numerical investigation of the velocity field of the HBIVCU system.

METHODS

Velocity measurements of the HBIVCU system horizontal air jet were performed using four HT 428 low velocity omnidirectional thermoanemometer probes. The velocity sensor was with a diameter of 2 mm which resulted in a short response time. The range of the velocity measured by the instrument was from 0.05 m/s up to 5 m/s. The accuracy of the velocity measurement was 0.02 m/s ±1% of the reading in the range between 0.05 and 1 m/s. All probes were calibrated prior to the velocity measurements into a Wind Tunnel for Calibration of Low Velocity Anemometer Probes, manufactured by Sensor Electronic Poland.

The thermoanemometers were attached to a stand which can move in both direction along the three axes of a Cartesian coordinate system. On Fig.1 is presented the set - up for the velocity measurements. The distance between any two HT 428 probes was set to

0.02 m. The probes were positioned parallel to the jet openings. The velocities at distances X=0.02 m, X=0.20 m, X=0.40 m, X=0.60 m and X=0.63m (0.02 m from the exhaust) were measured.

Figure .1 Velocity profile measurements set- up

The velocity measurements were performed for the following case:

Supply Opening: Cross section: 5 cm x 35 cm, Flow rate – 3 L/s

Exhaust Opening: Cross section: 23 cm x 40 cm, Flow rate – 27 L/s

The velocities corresponding to the tested air flow rates were calculated based on the area of the two openings. The average velocitiy at the outlet cross-section of the supply opening was 0.17 m/s for flow rate of 3 L/s. The average velocity at the inlet cross-section of the exhaust opening was calculated to be 0.29 m/s for flow rate of 27 L/s.

The velocities at distance X=0.02m (Fig 3) from the outlet cross-section of the horizontal jet of the S-ATD were measured along the Z axis at Y = 1.5 cm Y = 2.5 cm and Y = 3.5 cm (Figure 2). First, the four probes were set to position 0-1, which had a length of 0.08 m. The four probes were then moved together horizontally (from left to right) by another 0.08 m from position 0-1 to the new position 1-2, then 2-3, followed by 3-4, and so on (Fig. 2). For each movement of the four probes, the first probe overlapped the position of the fourth probe from the previous measurement. The velocities at distance 0.02 m from the exhaust opening were measured using the same procedure.

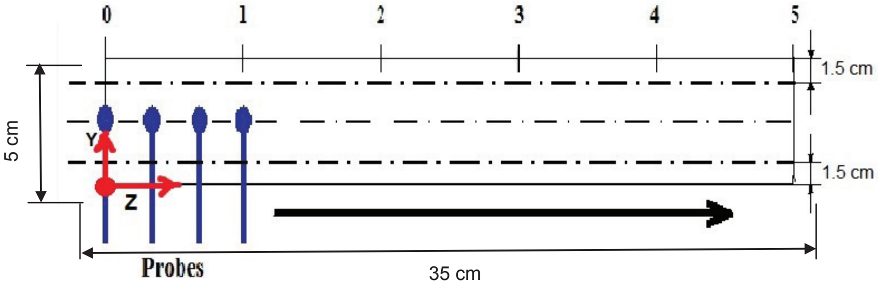

Figure 2. Measurement with the four HT428 probes at the outlet cross-section of the supply opening

For the other three measured distances (X=0.20m, X=0.40m and X=0.60m) the velocities were measured using the approach presented on Fig 2 along the heights, shown on Fig.3. The number of measured heights was increased in X direction due to the fact that when discharged from the supply the jet entrains air from the surroundings and spreads.The velocity at each position was measured for 3 minutes with a sampling rate of 5 Hz and the mean value was recorded automatically.

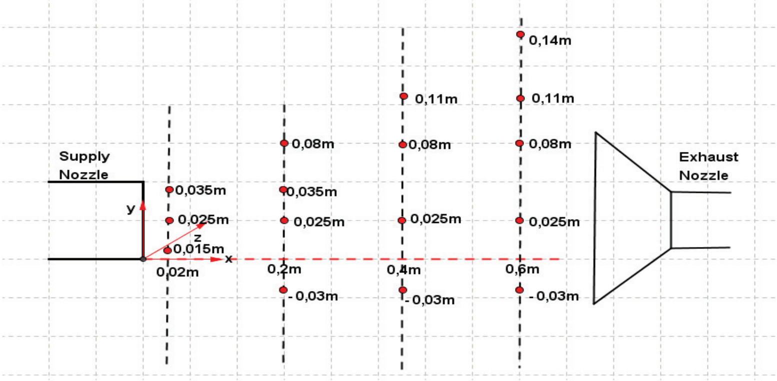

Figure .3 Measurement distances from the supply opening and measurement heights

RESULTS AND DISCUSSION

The acquired data was recorded and analysed using Microsoft Excel. The average for every point was used in order to present the velocity field of HBIVCU system at several XZ planes (Y=constant). Here are presented experimental results for the measured case:

The velocity profiles V (Z) at distance X=0.02m from the supply opening and for Y=0.015 m, Y=0.025m and Y=0.035m at flow rate of 3 L/s are presented on Fig.4

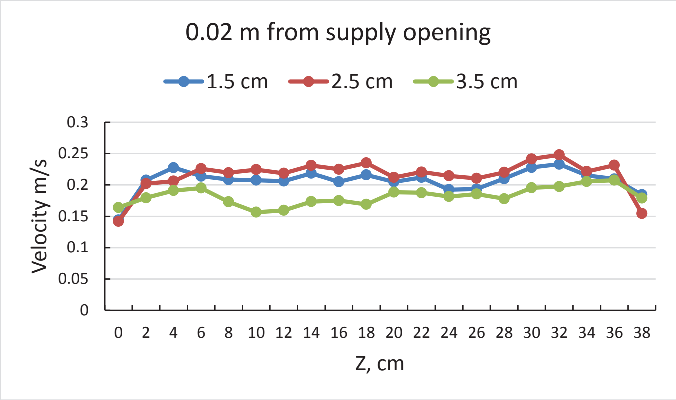

Figure 4 Velocity Profiles at X=0.02 m

The velocities measured along the three heights had similar behavior. The highest values were measured along the symmetry axis of the opening (Y=0.025m). The average velocity from all readings was 0.20 m/s (with standard deviation - 0.025), which is close to the calculated velocity for the tested flow rate (0.17 m/s). The velocity field in the plane close to the supply opening was non-uniform. The level of uniformity can be estimated by comparing the smallest and the largest velocity measured to the average value. The uniformity of the velocity field in the plane was within +15% to -30%.

Velocity profiles of mean velocity along the short axis of the supply opening are presented on Fig.5. At X=0.20 m the average velocity, averaged along the Z axis, decreased to 0.12 m/s compared to the measured values at X=0.02 m. The velocities were still the highest along the symmetry axis of the opening. It was observed that the velocities at heights Y=0.035 m and Y=0.08 m were increasing. This is result from the fact that with increasing the distance from the supply opening the air jet entrains air from the surroundings and spreads. At distance X=0.40 m the tendency for having the highest velocities across the geometric center of the opening was kept. The average velocity for this distance was 0.068 m/s. The velocities measured along the heights Y=0.08 m and Y=0.11 m were higher compared to the velocities measured along the same heights for the previous distance of X=0.20 m. At distance X=0.60 m from the supply opening the average velocity was 0.076 which was higher compared to the measured values at the previous distance (X=0.40 m). This can be explained with the influence of the exhaust which was operating with flow rate of 27 L/s. At distance X=0.60 m it could be observed that the maximum velocities were obtained along the heights of Y=0.08 m and Y=0.11 m. This indicates that the central line of the horizontal air jet moved upwards with increasing of X. The shift of the central line can be explained with the fact that during the measurements the background room temperature was lower (measured on average 21oC) compared to the temperature of the supply air jet, which was kept constant at 23^{o}C.

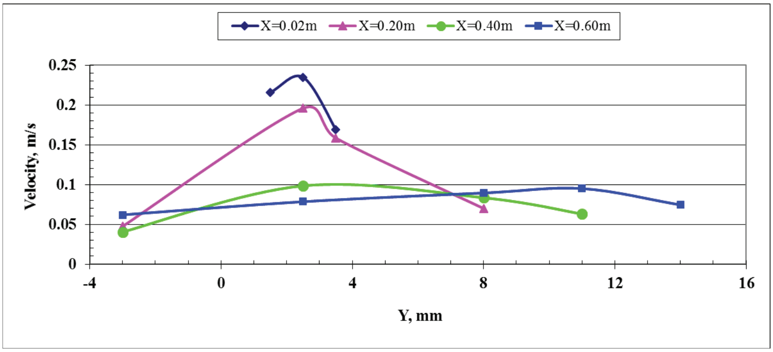

Figure .5 Velocity profiles along the short axis of the supply opening

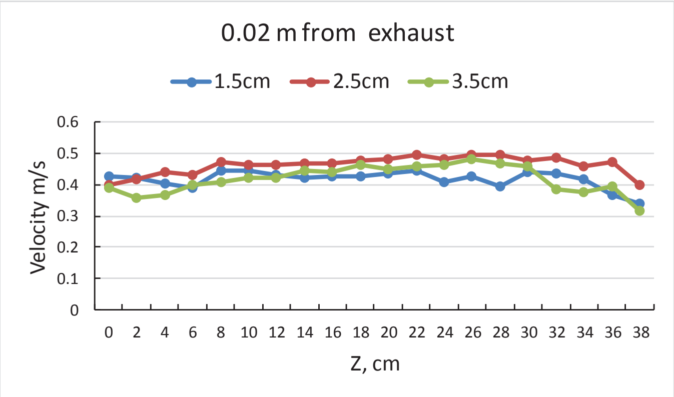

Figure 6 Velocity Profiles at X=0.63 m

Fig. 6 presents the velocity field measured at X=0.63 m (at distance of 0.02 m from the exhaust opening) for three heights - along the symmetry axis passing through the geometric centre of the opening and along the sides of the opening at distance 0.015 m from the lower and the upper edges. The average velocity from all readings was 0.43 m/s which was higher compared to the calculated value of 0.29 m/s. The velocities measured along the three heights had similar behavior. The highest values were measured along the symmetry axis of the opening – 0.46 m/s. The velocity field in the plane close to the exhaust was non-uniform. The minimum value was 0.31 m/s and the maximum 0.49 m/s The uniformity of the field in the measured plane was within the range of +14% to -26%.

CONCLUSIONS

The general conclusions that can be made based on the measured results are:

- The generated velocity field by the horizontal air jet with supply flow rate of 3 L/s and exhaust flow rate of 27L/s was non-uniform.
- The velocities measured close to the exhaust were lower than the rated by the ISO 7730, [1], standard velocity of 0.5 m/s. The profile generated by the HBIVCU system might not cause risk of draught discomfort.

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This paper has been reviewed.