DROPLET VELOCITY IN HUMID BUOYANT JET

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TITLE

VITESSE DES GOUTTELETTES DANS UN JET HUMIDE FLOTTANT

RESUME

L'objectif de cet article est d'étudier le comportement de gouttelettes de solution d'eau NaCl de 48 µm dans un jet d'air humide avec une vitesse initiale de 5 m.s^{-1} et une température de 34°C. En utilisant l'anémométrie Doppler laser et l'anémométrie Doppler de phase, nous avons étudié le transport et les gouttelettes dans le jet de gaz en mesurant la décroissance de la vitesse des gouttelettes à différents endroits de la source du jet.

ABSTRACT

The purpose of this paper is to investigate the behavior of 48 µm NaCl-water solution droplets in a humid air jet with an initial velocity of 5 m.s^{-1} and a temperature of 34°C. Using Laser Doppler Anemometry and Phase Doppler Anemometry, we investigated the transport and of droplets within the gas jet by measuring the decay of droplet velocity at different locations from the jet source.

MOTS-CLÉS : gouttelettes respiratoires, anémométrie laser Doppler, vitesse des gouttes / **KEYWORDS:** respiratory droplets, Phase doppler anemomtry, droplet velocity

1. INTRODUTION

Over the last two years, the COVID19 pandemic has resulted in over 235 million infections and 4.8 million deaths. The role of aerosol transmission was questionable when the pandemic began. As a result, public health policies focused on limiting pathogen transport via droplets. However, as infection rates increased, gaps in our understanding of airborne pathogen transmission became apparent. Respiratory diseases spread in two ways: short-range, and long-range. The long-range transmission is linked to the transport of the dry residues of the exhaled droplets by air over long distances (more than 2 meters). While the short-range route involves exposure to a more complex combination of dry residues and droplets going through an evaporation process. Despite the importance of understanding the behavior of the droplet after release, droplet dynamics in a flowfield, such as the one produced by the interaction of human exhalation and the ambient environment, have yet to be thoroughly studied. The goal of this research is to investigate the changes in the velocity of droplets emitted in a human-like exhaled jet. The jet's initial conditions are 34°C, relative humidity of >95%, and a velocity of 5 m.s^{-1}. This jet contains NaCl-water solution droplets with a mode of 48 µm. The following section describes the experimental bench and the procedure that was used.

2. EXPERIMNTAL BENCH

An experimental bench was built in this study to examine the behavior of droplets in a human-like exhaled jet. The experimental setup consists of a generation part and an environmental chamber -with a size of 3.0 m x 2.0 m x 2.7 m- in which measurements were performed. The jet generation section generates a stable humid air jet with a controlled flow rate and temperature. This air jet enters the environmental chamber via a nozzle of 0.01 m diameter which is attached to the chamber wall. The measurements were carried out inside the chamber using a two-velocity component Laser Doppler Anemometry (LDA) / Phase Doppler Anemometry (PDA). The measurement probes are mounted on three-dimensional motorized axes. The droplet generator injects monodispersed aqueous NaCl droplets along the central axis of the nozzle, while the humid jet is introduced by a radial hole in the nozzle body. The air jet and the droplets are then mixed inside the nozzle of 10 cm in length and 10 cm in diameter. The ensemble of this generation system is called the oropharyngeal emission simulator (OES), and its development was part of this research project.

3. RESULTS

We observed an unanticipated production of droplets of less than 10 µm, probably generated during the heating and humidification process of the air. Despite their unexpected generation these droplets allow measuring the velocity of the air, as they are small enough to be considered as a gas tracer. For these droplets and droplets generated by the OES -in the range of 35 µm 70 µ m- we examined how droplet velocity changes with distance from the source nozzle along the horizontal jet axis. In addition to the axial and radial velocity, the LDA/PDA system provides information on the droplet's diameter. The droplet size provided by the PDA system is given in 0.1 µm bins. The analysis of the velocity of the droplets for each droplet size showed that the velocity in a spefic location does not change as a function of the droplet size. The velocity of two size groups of droplets is plotted at different distances from the source in the range of 0.4 m from the exit, as shown in the figure below.

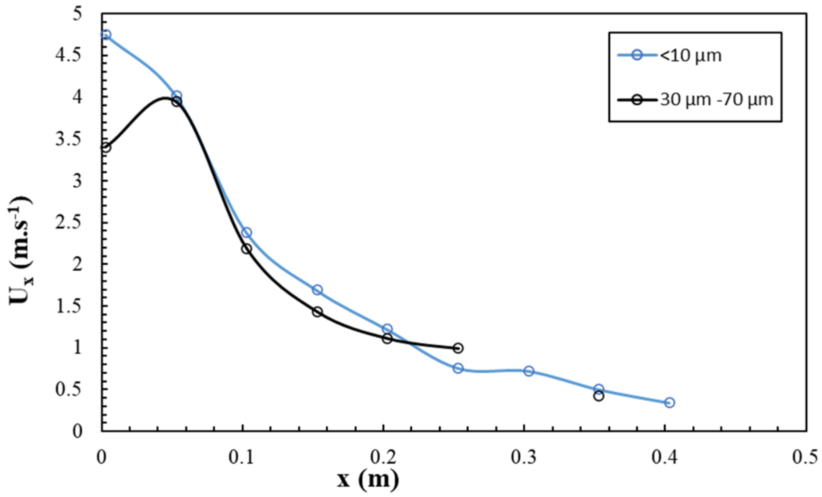

Figure 1. The change of the mean axial velocity of the droplets with distance from the source

The mean velocity of droplets less than 10 µm in size, which are considered tracer particles, decreases from 4.8 m.s^{-1} to 0.34 m.s^{-1} over 0.4 m from the source. The mean initial velocity of the droplets produced by the oropharyngeal emission simulator is less than the velocity of the smaller droplets at nozzle exit. This is due to the fact that the small droplets are entrained by the air in the humid air generator and have air velocity, whereas the OES droplets are injected directly into the nozzle. The nozzle's length was insufficient to achieve equilibrium between the droplets and the air carrying them. In the first 0.05 m from the source, the velocity of the droplets produced by the OES increases until they reach equilibrium with the air jet. After 0.05 m, the velocity of these droplets decreases with distance from the source. It is also worth noting that the droplet count decreased significantly with distance from the source.

4. CONCLUSION

An experimental bench was built in this study to investigate the behavior of NaCl-water solution droplets in a humid buoyant jet. The LDA system is used to measure droplet velocity, while the PDA system is used to measure droplet size. The change in droplet size and velocity with distance is analyzed to determine the evolution of droplet velocity with distance. The droplet velocity decreases with distance from the source to less than 10% over 0.4 m in the jet's horizontal axis.

DOI : 10.25576/ASFERA-CFA2022-28820