Ultrasonic Humidifier

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MCEN 5151: Flow Visualization – Team Third

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Figure 1: Still frame of slow-motion ultrasonic humidifier

Introduction

Figure 1 shows a still frame of a slow-motion video of an ultrasonic humidifier. And ultrasonic humidifier uses a fast-vibrating diaphragm to push water droplets into the air, creating a fog of water vapor. The diaphragm also pushed a column of water into the air. This video captures the movement of that column as well as the fog created.

Ultrasonic humidifiers were invented in the mid-1980s as a quieter, smaller alternative to evaporative ones. The technology for ultrasonic nebulization had previously been used in medical applications for creating aerosols (Highsmith, Rodes, & Hardy, 1988). Nebulizers are the oldest form of aerosol generation. Ultrasonic nebulizers (including humidifiers) use a piezoelectric transducer to generate ultrasonic waves that pass through a fluid and aerosolize it at its surface (Hess, 2000).

Experiment Overview

This video focuses on the surface of the water where that aerosol appears. An ultrasonic humidifier was placed in front of a black sheet of fabric. Based on the movements of the fog, the ambient air in the room is estimated to be moving at approximately $1\ \frac{\text{cm}}{\text{s}}$. The length of the humidifier tank is $20\ \text{cm}$. Based on this length, the Reynolds number is:

$$\text{Re}_\text{L} = \frac{\rho V D}{\mu}$$

$$\text{Re}_\text{L} = \frac{\left(1.01 \frac{\text{kg}}{\text{m}^3}\right)\left(0.01\ \frac{\text{m}}{\text{s}}\right)(0.2\ \text{m})}{1.81 \times 10^{-5}\ \frac{\text{N}\cdot\text{s}}{\text{m}^2}}$$

$$\text{Re}_\text{L} \approx 112$$

Visualization Technique

The experiment was conducted in a semi-darkened room. The ultrasonic humidifier was placed directly in front of a black sheet of fabric. A 60W lightbulb was placed approximately 3' away from the humidifier, 30° behind and to the left of it, and approximately 10" above it. This was intended to video the fog 120° from the light source to maximize scattering and fog visibility.

Photographic Technique

Table 1 lists the camera information and the size of the image.

Table 1: Camera information/settings

Camera model	Google Pixel 6
Image size	1920 x 1080

Field of view	20 cm x 11.25 cm
Frame rate	30 fps

The video was shot at 30 frames per second. A sample frame from the original video is shown in Figure 2. The image was cropped, and the contrast slightly increased. Additionally, the colors were modified to give the original white a blue-green tint, and to make the originally ununiform black background a consistent, dark black. This has the unwanted side effect of reducing the visibility of the fog, although it is still visible in the final video.

The video was shot in 1/8 slow motion. A side effect of this is that the 60 Hz flickering of the lightbulb is visible in the final video. This was somewhat more unnoticeable in the 1/4 speed video, but the motions of the fog and the droplets could not be seen as clearly in those.

Figure 2: Sample frame from original video

Conclusion/Recommendations

The final video produced shows a close view of what happens inside ultrasonic humidifiers. The ultrasonic vibrations propagate up to the water, causing droplets to separate from the surface. Some of those droplets spray into the air and fall back down, some combine into a fountain of water, and the rest are small enough to be carried in the air as an aerosol.

If this experiment was repeated, a real high-speed camera would produce a smoother video, and a DC-powered light source should be used to remove the flickering effect. Additionally, a darker backdrop would remove the need to artificially darken the video, and would preserve the original higher visibility of the fog.

References

Hess, D. R. (2000). Nebulizers: Principles and Performance. *Respir Care, 45*(6), 609-622.

Highsmith, V. R., Rodes, C. E., & Hardy, R. J. (1988). Indoor particle concentrations associated with use of tap water in portable humidifiers. *Environmental Science & Technology, 22*(9). doi:10.1021/es00174a019