Learning about fluid dynamics with the jet-flow facility

1 Objective of the experiment

The objective of this experiment is to investigate and visualize the behavior of airflow generated by a jet-flow facility at different speeds, and to study how this airflow can be influenced and controlled by using acoustic waves produced by a speaker.
This jet-flow facility aims to provide students in the field of fluid dynamics with a practical and easily accessible learning opportunity.

2 Theoretical fundamentals

2.1 Fluid dynamics

Fluid dynamics studies the movement of liquids and gases and plays a crucial role in industries such as automotive, aerospace, and maritime.

2.2 Jet-flow facility

A jet-flow facility produces a focused air jet using fans, compressors, or heated air. This experiment uses a single-jet facility (as seen in Figure 1), the simplest and most efficient jet-flow type, to generate steady airflow. Using a fan, it sucks air in and pushes it out through a nozzle. The diffuser and the honeycomb ensure a laminar flow, which is a smooth and orderly flow pattern.

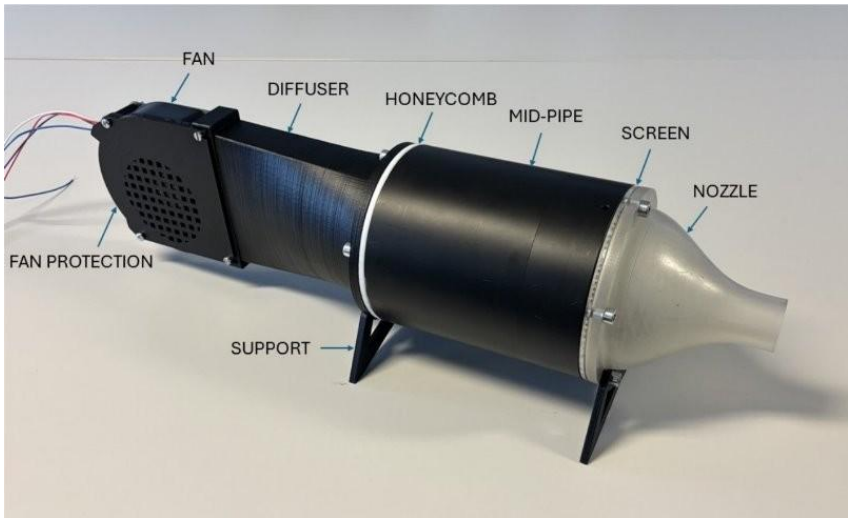

Figure 1 Jet-flow facility
(Dyngeland, Ewers, Hansen, & Mindrebøe, Design and Construction of a Jet Flow Facility, 2024)

2.3 Smoke visualization

Smoke visualization is a common technique to make airflow patterns visible. By injecting smoke into the airflow, it becomes possible to observe the air flow directly with the naked eye. In this case smoke can be introduced with adapters either directly into the fan or around the nozzle to minimize disturbances and clearly visualize the airflow. The smoke machine is a small vaporizer that works by heating a liquid until it turns into vapor.

2.4 Acoustics and airflow control

Acoustics refers to pressure fluctuations (sound waves) spreading through air, causing molecules to vibrate and transfer energy. In this experiment, the focus is on external acoustic forcing. A speaker will be used to actively influence the jet stream, allowing the study of how sound waves affect airflow behavior.

3 Work instructions

3.1 Setting up the facility

See chapter 4 for references and chapter 5 for a picture of the setup.
Make sure the speed control (-SGA1) and the volume level (-SGA2) are set to 0%. Connect the power supply (-TBA1) to an outlet and the control panel socket (-XDB1). Then connect the cold device plug (-XDB2) to an outlet and the amplifier (-TFA1). Switch the power on/off (-SJA1) to turn the facility on. You should now be able to control the speed of the fan with the speed control (-SGA1).

3.2 Smoke modules

Put the smoke machine (-HPB1) in the nozzle adapter (-NAD1) and press the smoke on button (-SJB1) to produce smoke. Do that with different fan speeds by turning the fan speed control (-SGA1) and write down your findings. Repeat that process with the smoke machine (-HPB1) in the fan adapter (-NAD2).

3.3 Acoustic module

For this part of the experiment the fan adapter (-NAD2) should be attached and the nozzle adapter (-NAD1) should not be connected. Mount the acoustics adapter (-XMB1) on to the nozzle. Connect the audio plug (-XDB3) to the amplifier (-TFA1) and to your phone. Switch the speaker on/off (-SJA2) to turn the speaker on. Play different genres and songs from your phone and see how it influences the airflow, by also changing the speaker volume (-SGA2), whilst turning the smoke on (-SJB1). Note your findings.

3.4 Analysis

1) How does the behavior of the airflow change at different fan speeds?
2) Describe the transition from laminar to turbulent flow in the jet-flow.
3) Which fluid dynamics principles explain this change?
4) How does the smoke visualization help to make complex flow phenomena visible?
5) What effect do the acoustic waves have on the airflow?
6) Explain through which physical mechanisms sound waves can influence the flow.
7) Discuss how acoustic control can be used as an approach to influence airflows.
8) What practical application could result from this?

4 Material list

The references are based on the IEC 81346-2 standard and are used to uniquely identify components and parts.

Reference	Name	Comment
-CAA1	Capacitor	1nF; 25V
-GQB1	Jet-flow facility	From previous project group
-HPB1	Smoke machine	Small vaporizer
-KEB1	Microcontroller	ESP32
-MAA1	Fan motor	12VDC; 1.3A
-NAD1	Smoke adapter nozzle	3D-printed; two parts
-NAD2	Smoke adapter fan	3D-printed
-PFA1	Power on	3V LED; green
-PHA1	Fan speed	3.3V LCD; black on yellow
-PJA1	Speaker	5” woofer; 4Ω
-RCA1	Limiting Resistor	15Ω; for -PFA1
-SGA1	Fan speed control	10kΩ Potentiometer
-SGA2	Speaker volume level	Turning knob
-SJA1	Power on/off	Momentary toggle switch
-SJA2	Speaker on/off	Toggle switch
-SJB1	Smoke on	Push button; wireless remote
-TAB1	DC-DC-Converter	12VDC to 5VDC
-TBA1	Power supply	12VDC; 3A
-TFA1	Amplifier	50W; 4Ω
-UCA1	Control panel	3D-printed box; laser-cut top
-XDB1	Socket control panel	Barrel socket; 12VDC; 5A
-XDB2	Cold device plug	1.5m power cable; for Amplifier
-XDB3	Audio plug	2.5m audio cable
-XMB1	Acoustic adapter	3D-printed; tubes glued on

5 The experiment’s set-up

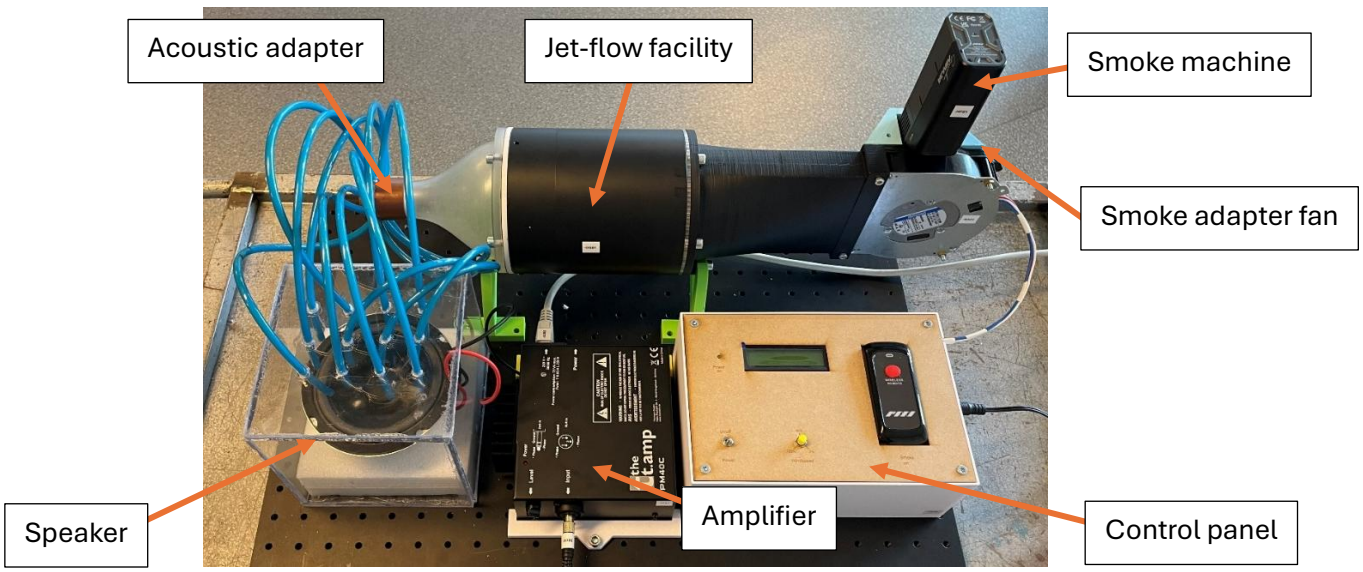

Figure 2 Jet-flow facility with control panel, smoke and acoustic modules