Flapper Nozzle System

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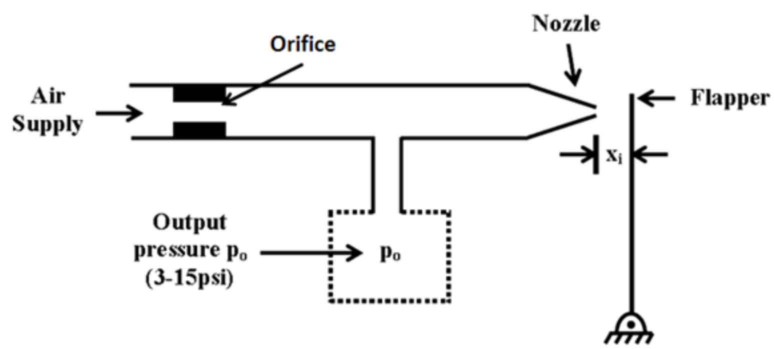
Objective

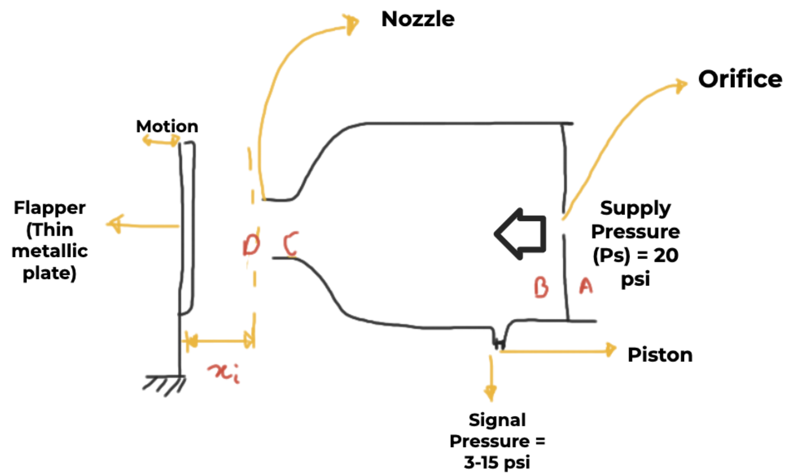
- To study the characteristics of a flapper nozzle system

Theory

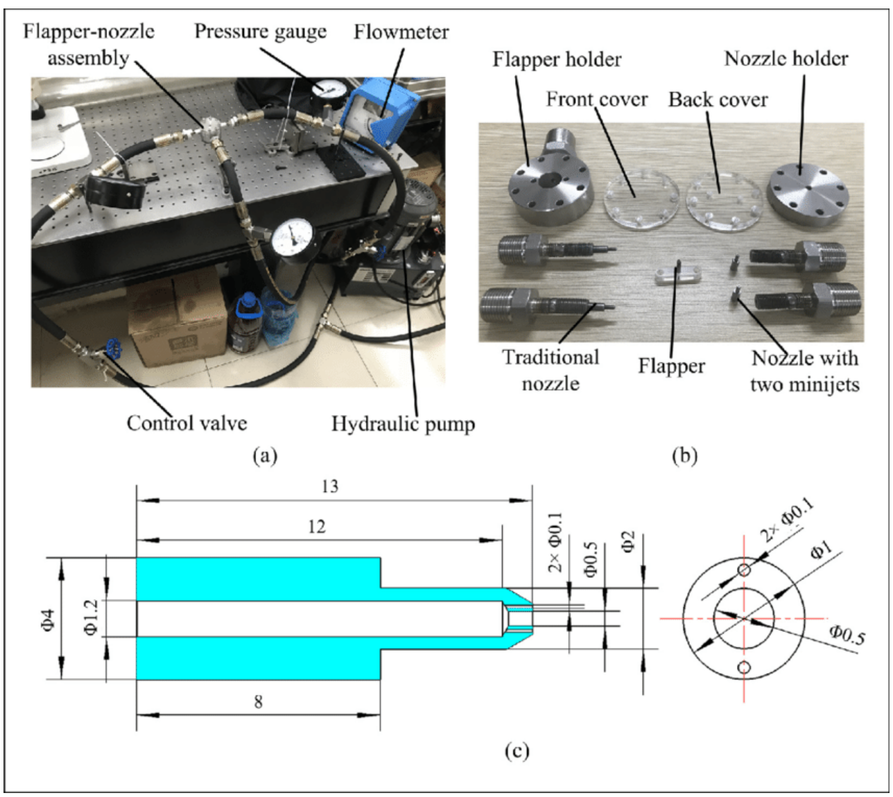
In pneumatic types of devices, the displacement signal is converted to pressure signal.
The device shown below is pneumatic displacement gauge and this is also known as flapper nozzle device Pneumatic systems are still used in process control industries even after the entry and domination of electrical signals, electronic and digital systems. The flapper-nozzle is a basic component of pneumatic measurement, control, and transmission systems.
It functions as a pneumatic secondary transducer, converting tiny displacements into pressure signals. Air is used in a pneumatic displacement gauge system. The control action is initiated by a signal in the form of variable air pressure (often in the range of 3-15 psi, i.e. 0.2 to 1.0 bar).
The flapper nozzle amplifier is one of the most basic components of a pneumatic displacement gauge system. It translates very small displacement signals (on the order of microns) into air pressure variations. The fundamental design of a flapper nozzle amplifier is depicted in the diagram above. One end of the pipeline is supplied with constant air pressure (20 psi). A nozzle and a flapper are located at the other end of the pipe. The input signal determines the distance between the nozzle and the flapper. As the flapper approaches the nozzle, the airflow through the nozzle decreases and the air pressure inside the pipe rises. When the flapper is moved further away from the nozzle, however, the air pressure drops. The output pressure will be equivalent to the ambient pressure if the nozzle is open (flapper is far away). The output pressure will be equal to the supply pressure if the nozzle is blocked. The pressure variation can be efficiently displayed using pressure measurement equipment in the pipeline. The properties are inverse, and as distance increases, the pressure drops. The properties of a flapper nozzle amplifier are depicted in the diagram below. The nozzle and orifice are both extremely tiny. The orifice diameter is typically 0.01 inch (0.25 mm), while the nozzle diameter is typically 0.025 inches (0.6 mm). For a change in displacement of 0.0001 inches, a typical change in pressure is 1.0 psi (66 bar) (2.5 microns). The properties of the amplifier have an approximate linear range of 3- 15 psi, which is the standard operating range.



Schematic of Flapper Nozzle system with all the major components

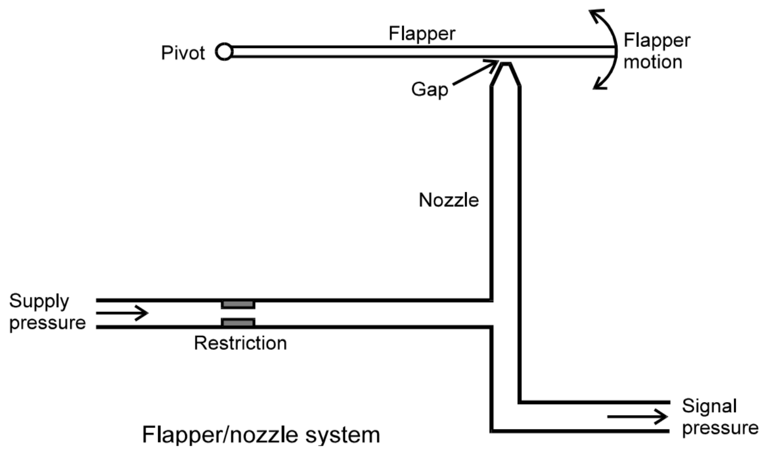


Laboratory arrangement of Flapper Nozzle system



Construction

The flapper, also known as a baffle, is a moveable flat metal affixed to a part whose displacement is being measured. When the flapper is moved in front of the nozzle, it covers or uncovers the nozzle and changes the space between them.



Flapper/nozzle system

A changeable nozzle restriction is connected to a fixed orifice restriction in the nozzle. Through the orifice restriction, a continual supply of pressured air (typically 20 psi or 1.4 kg/cm2) is provided to the nozzle. Through the gap between the nozzle and the flapper, pressured air exits the nozzle.

The diameter of the nozzle must be 1.5 to 2.5 times bigger than the diameter of the orifice in order to generate sufficient back pressure and ensure appropriate system operation. In typically, the orifice diameter is on the order of 0.25 mm, whereas the nozzle diameter is on the order of 0.625 mm.

Working Principle

The distance between the nozzle and the flapper narrows when the flapper is brought closer to the nozzle. This reduces the amount of air that can flow out of the nozzle and raises the nozzle back pressure. There is no air outflow via the nozzle once the flapper has completely covered it. The maximum nozzle back pressure is equal to the supply air pressure.

The space between the nozzle and the flapper widens when the flapper has pulled away from the nozzle. The nozzle back pressure is lowered as well as the limitation to air outflow via the nozzle. The minimum value of nozzle back pressure is 2-3 psi.

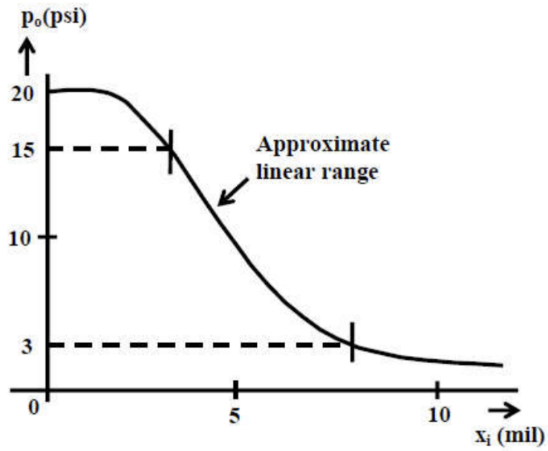


Fig. Characteristics of a flapper nozzle amplifier

The flapper nozzle system can generate output pressures of 3-15 psi (0.2 – 1.0 kg/cm2) from a 20 psi (1.4 kg/cm2) input supply. The flapper nozzle system's output pressure is proportional to the input displacement and can be used to control an indicating instrument or any other system.

Observation

Gap(mm)	Signal Pressure(Psi)
0.05	16.7
0.15	16.5
0.25	16.3
0.35	11.5
0.45	8.6
0.55	5.3
0.65	3.1
0.75	1.8
0.85	1.6
0.95	1.5

Procedure

- The compressor valve is opened and the air is passed through a filter to the system whose supply pressure we maintain at 20psi.
- The distance between flapper and nozzle is increased through a screw and the reading is noted from the displacement gauge.
- The pressure reading from the pressure gauge is also noted.
- The readings are noted for multiple values of displacement and the results are noted in a table.

Calculations and Graphs

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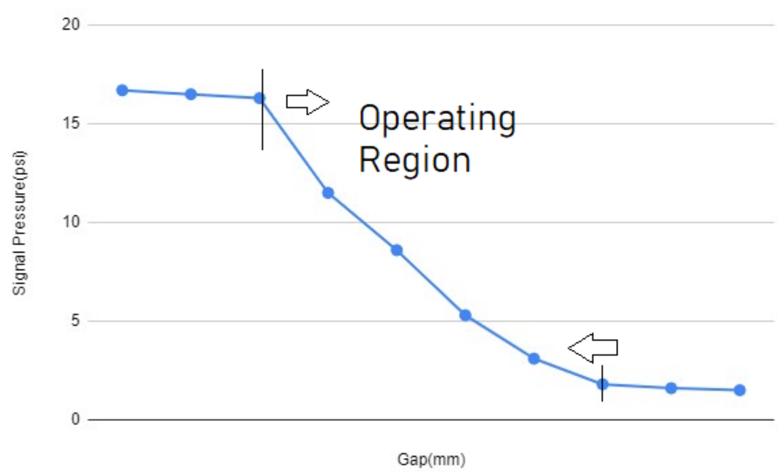

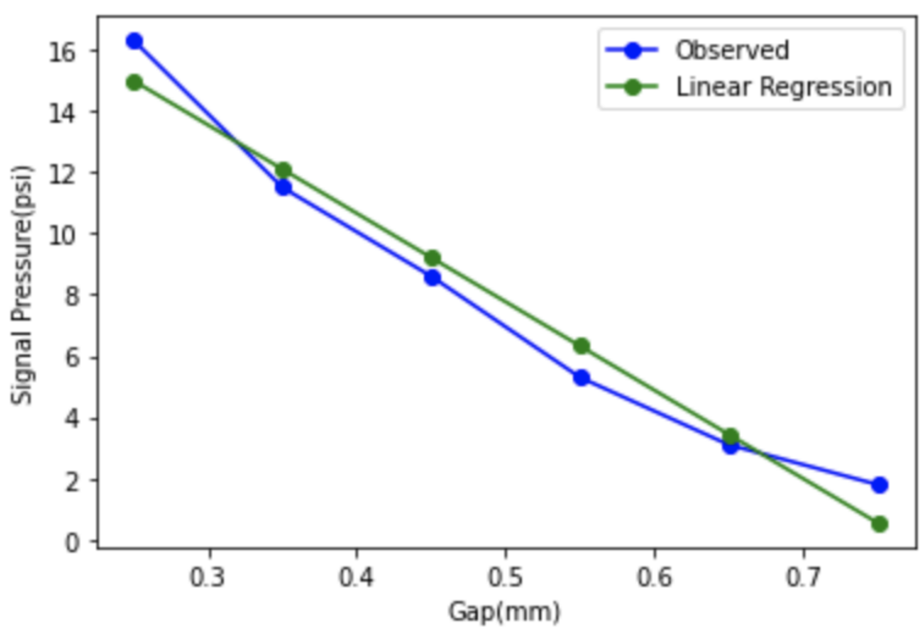

Discussion

- Pneumatic power systems are widely used in various branches of industry. For instance, they have been applied in several systems, such as manufacturing systems for precise positioning and assembly tasks, pneumatic vibration isolation systems, caregiver and medical robots as rehabilitation tools.
- In pneumatic position and force control systems, nozzle-flapper type servo valves are normally used for obtaining quick response and precise control results due to their simple structure, high sensitivity and wide frequency range. The nozzle flapper pressure servo valve is a kind of high-precision hydraulic component that is widely used in the aircraft brake system.
- A comparison of mathematical analysis and data obtained experimentally shows that the latter deviates from the former at lower pressures and the values of displacement are greater than those calculated from the mathematical formula. The reason might be the effects of viscosity and high degree of turbulence.
- Some advantages of pneumatic systems over other systems are:
    - low-cost
    - Simplicity
    - self-cooling properties
    - high-power weight
    - easy maintenance
    - environmental safety

Results

- There is a mean squared error is 0.9295843071647587

Resources

- http://instrumentationinnutshell.blogspot.com/2018/06/flapper-nozzle-system.html
- https://automationforum.co/what-is-a-flapper-nozzle-mechanism-principle-of-operation/
- https://www.brcmcet.edu.in/downloads/files/n5e296e1fcbfa1.pdf
- **Code :** https://colab.research.google.com/drive/1VvO4gddBAuM_DlL20VMPRwMpmq9gkgUy?usp=sharing#scrollTo=CWu6XCgSbUbd

Code

```
import numpy as np
from sklearn.linear_model import LinearRegression
import matplotlib.pyplot as plt
from sklearn.metrics import mean_squared_error

x = np.array([0.25, 0.35, 0.45, 0.55, 0.65, 0.75]).reshape((-1, 1))
y = np.array([16.3, 11.5, 8.6, 5.3, 3.1, 1.8])

model = LinearRegression()
model.fit(x, y)
model = LinearRegression().fit(x, y)

r_sq = model.score(x, y)
print('Coefficient of Determination:', r_sq)

print('Intercept:', model.intercept_)
print('Slope:', model.coef_)

y_pred = model.predict(x)
print("Predicted Y:",y_pred)


plt.plot(x, y, "o-b")
plt.plot(x, y_pred, "o-g")
plt.legend(["Observed","Linear Regression"])
plt.xlabel("Gap(mm)")
plt.ylabel("Signal Pressure(psi)")
plt.show()

rms = mean_squared_error(y, y_pred, squared=False)
print("Mean Squared Error",rms)
```