Testing of an axial-flow fan

Experiment Findings · June 2021

DOI: 10.13140/RG.2.2.12332.80007

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BRUFACE

MECAH402
Turbomachinery

Lab 2: Testing of an axial-flow fan

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June 6, 2021

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1 Introduction

In this lab was tested an axial fan, with the objective of experiencing the stall effect that occurs when the pressure demanded is higher than the pressure we can supply. Is was attempted to establish the dependency of :

- The transferred useful specific energy e
- The effective power Pe
- The efficiency

All above mentioned will be derived as a function of volumetric flow "qv" at constant rotational speed "N". Following this, the calculations of main parameters and rotating stall will be analysed and discussed throughtout.

1.1 Description of the set-up

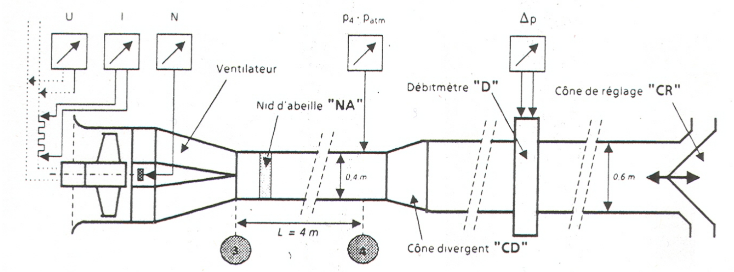

Figure 1: Description of set-up

The axial-flow fan used in this experiment is of the pressure type and it consists of the following elements :

- An inlet intake
- a rotor with 14 blades
- a stator with 17 vanes
- an outlet diffuser

2 Measuring devices

1. INPUTS
    - Rotational speed N (rpm)
    - Voltage on the motor U (Volts)

- Rotor current in the motor I (A)
- Density of the ambient air P_{atm} (kg/m3)
- Pressure difference on the flowmeter ΔP (mbar)
- Outlet pressure P_4 - P_{atm} (mbar)

2. OUTPUTS
   - Efficiency η
   - Effective power P_e (kW)
   - Useful specific energy e (J/kg)
   - Volumetric flow rate q_v (m3/s)

3 Equations and Formulations

3.1 Flow rate

To determine the mass flow rate, we use a flow meter with a nozzle, and we get an equation:

$$Q_m = \epsilon\alpha\sqrt{2.\Delta_{p.p}}$$

where,

- ϵ= 1 (Assumption)
- α= flow co-efficient.

3.2 Useful Specific Energy

Assuming in-compressible flow hence constant density the pressure at room temperature is given by :

$$\rho_{atm} = \frac{p_{atm}}{r.T_{atm}}$$

where,

- p_{atm}= atmospheric pressure
- T_{atm}= atmospheric temperature
- R= Gas constant.

From above mentioned the transferred useful energy is given by:

$$e = \frac{p_4 - p_{atm}}{r.T_{atm}} + \frac{c_4^2}{2} + (e_f)_{3-4}$$

Considering the honeycomb grid at inlet piping and ignoring the Reynold number we can write that:

$$(e_f)_{3-4} = 0.04.\frac{c_4^2}{2}$$

The values of p_4 - p_{atm} are measured using a manometer

3.3 Effective Power of the Fan

The difference between the electrical power supplied to the motor and the sum of all losses experienced by the motor is the effective power. There are three categories of losses: losses caused by energy dissipation, losses caused by brushes, and mechanical and magnetic losses.

$$P_e = P_{ele} - p_{losses} = P_{ele} - P_j - P_b - P_{m+m}$$

where,

- P_{ele}= RI^2 Joule dissipation with R the resistance of the rotor and I the current
- P_b= v_bI brush losses with v_b the brushes voltage.
- P_{m+m}= $2.85 \cdot 10^{-3} \cdot V^2$-$5 \cdot 10^{-7}N\cdot V^2$+$(2.3/10^{-5}) \cdot N^2$+15 with N being the rotor rotation speed.

3.4 Efficiency

The efficiency (η) is thus calculated as a ratio of product of mass flow rate(q_m) and specific energy consumption(e) divided by the total electric power(P_elec) consumed.

$$\eta = \frac{q_m \cdot e}{P_{elec}} \tag{1}$$

4 Results and Discussions

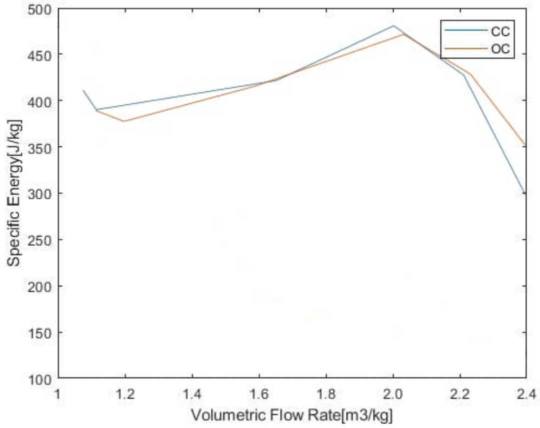

Figure 2: Useful Specific Energy in function of Volumetric Flow Rate

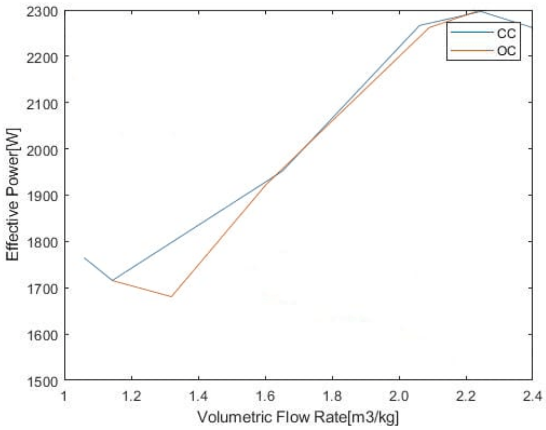

Figure 3: Effective Power in function of Volumetric Flow Rate

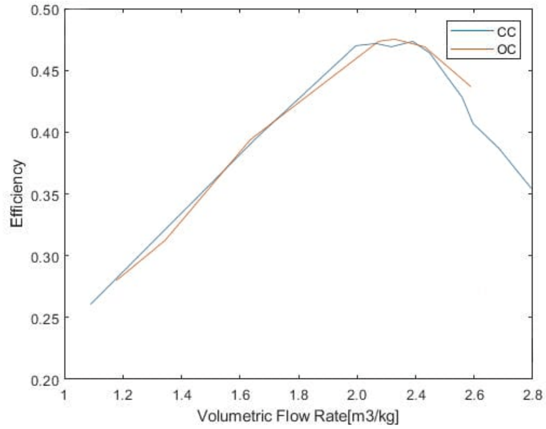

Figure 4: Efficiency in function of Volumetric Flow Rate

These results coincide more or less to the theory. It is expected for the efficiency to increase until the angle of attack of the flow reaches its critical value. Both the efficiency and the useful specific energy start decreasing after the occurrence of the stall.The stall appears for the closing phase at a flow rate which is lower than that for which the stall disappears for the opening phase. The graph plots for both increasing and decreasing flow rate conditions are close by, except for the region of stall.

5 Conclusion

In this laboratory is was explained the operation of an axial compressor, known as axial fan. The objective was to demonstrate how the stall phenomenon appears and its negative consequences. Stall is an undesirable phenomenon in axial turbines like a jet engine. Its impact on the efficiency, power consumption and specific useful energy have been helpful in understanding the requirement for consideration of this phenomenon during deign of axial turbines. It is a phenomenon that does not usually occur because we try to avoid it, but it is very important to study it. Extreme care must be taken when designing and manufacturing an axial compressor to avoid rotating stall.