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RESEARCH ARTICLE

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FABRICATION OF A LOW COST, MODULAR TEST RIG TO DETERMINE FAN CHARACTERISTIC CURVES

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ABSTRACT

Fan curves are very important in selecting the fan for a specific application. The fan curves are also used as input for various simulation purposes. Various test rigs exist for extracting fan curves. But the equipment involved is quite costly and is not so modular. Thus it is decided to fabricate a low cost, modular test rig which can accommodate different fans. The test rig for this purpose is designed using Creo. All the related calculations are performed using MathCAD. The designed test rig is fabricated using Sheet metal. Air velocity while testing is measured using Anemometer and pressure measurement is done using BPM085 pressure sensor.

Keywords— Fan Curve, Orifice, Anemometer, BMP085 pressure sensor

1. INTRODUCTION

Fan curve is a plot of fan discharge vs static pressure. Many methods exist in determining the fan curve numerically as well as experimentally. Experimental investigations into the effect of speed, concentration and size of slurry on the performance of a centrifugal pump are presented in [1]. Numerical model to predict the installation efficiency of jet fans that are installed in tunnels based on experimental results using full scale fans was developed by [2]. Numerical model showed that the air velocity in the tunnel is the major effecting factor on the performance of the fans installed. Design and fabrication of low cost open-loop wind tunnel for investigating the factors effecting the launch of small model airplanes is discussed in [3]. Mathematical model for establishing centrifugal fan performance curve, based on geometry, speed, fluid properties, operating conditions by using thermodynamic principles to relate losses to operating conditions, is given in [4]. Analytical procedure to predict head-capacity characteristic of a centrifugal slurry pump when its working fluid is clear liquid is proposed in [5]. Greenheck [6] discussed in detail, the method of using fan curves to select a fan as per requirements. The causes for discrimination in flow in fan-discharge ducts are detailed in [7]. According to the results of the experimentation done, the reasons are Air pulsations, incorrect location and any possible errors in pitot tubes. Velocity head term is redefined during this process. Sarraf [8] determined fan curves with two different types of blades and used them to compare their performance. The two blades varied in their thicknesses.

Development and testing of a characteristic curve fan model - gray-box model, which expresses fan efficiency as a function of air flow and static pressure is discussed in [9]. Methods of determining, understanding and using fan curves are explained in [10]. The applications of fan curves are also mentioned. Recommendations for fan selection, installation locations for HVAC applications are given [11]. Fan curve importance during this process has been explained. The use of pump curves for proper selection of pump for a given application explained in detail in [12]. Various terminology involved during this process are also explained in that article. The procedures for field testing of fans whenever required are detailed in [13].The testing involves measurement of air volume, fan static pressure and fan brake horse power. Use of fan curves for designing thermal solutions in the field of electronics cooling discussed in [14]. AMCA standard test set-up for testing 18” 6000 RPM Low Noise Fan is described in [15]. A detailed description of the quantities to be measured during testing of a fan, quantities to be computed, equations involved and the methodologies to be followed during testing are described in [16]. Ebmpapst [17] described how fan curve be used to determine the duty point. Also the instrumentation required for measuring the fan discharge and the method of extracting the fan characteristic curves experimentally is described. The schematic of a laboratory scale test rig is given in [18] & [19].

2. Problem Definition

Most of the test rigs involve complex instrumentation and various stages as described in [16]. This is quite demonstrated in many commercially available ones like those in [18] & [19] making the construction a costly affair. Also the described test rigs are not modular i.e. they are not suitable for testing fans of various sizes. Thus it is aimed to design and construct a low cost modular test rig which can accommodate fans of any sizes.

3. Design And Fabrication Of Test Rig

CAD model of the test rig to be fabricated is developed using Creo. Figure 1 presents the CAD model of the test rig. Exploded view is given in figure 2. The test rig is fabricated manually using 0.8mm thick Sheet Metal and Wood. The sheets are joined to one another using M5 screws. At each joining place, foam tape (Figure 3) is used in between the two sheets and the joints are further insulated using Aluminium Tape (Figure 4) to prevent any air leakage during testing. Figure 5 gives the different views of the fabricated test rig. Pressure sensing us done using BMP085 pressure sensor. Arduino Uno board is used for interfacing the sensor. 1602 LCD display is used for outputting the readings (Figure 6).

The test rig is of size 0.5m X 0.5m X 1m. On one side of the test rig, the fan whose characteristic curve to be extracted is placed. The other side, the output flow is regulated using different orifices (Figure 6) which are 3D Printed. Four different orifices are 3D printed using PLA. They are φ100mm, φ80mm, φ60mm, φ40mm. The mounting of pressure sensor is shown in figure 7. The sensor is placed inside a rectangular tube which is mounted just next to orifice exit.

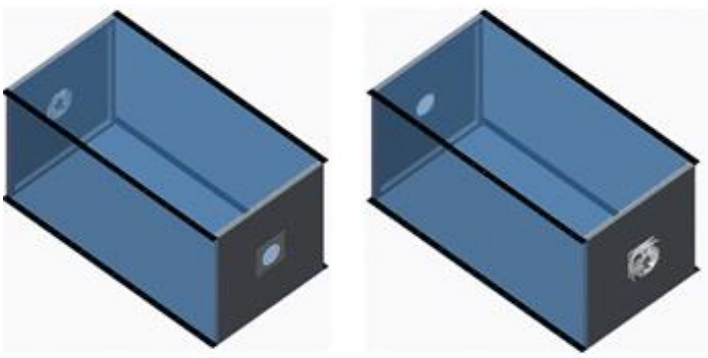

Figure 1: CAD Model of the Test Rig Fabricated

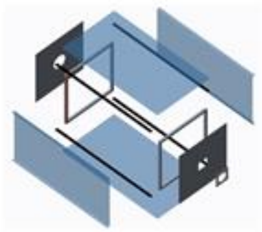

Figure 2: Exploded Model of the Test Rig

Figure 3: Nitrilite Foam Tape

Figure 4: Aluminum Tape

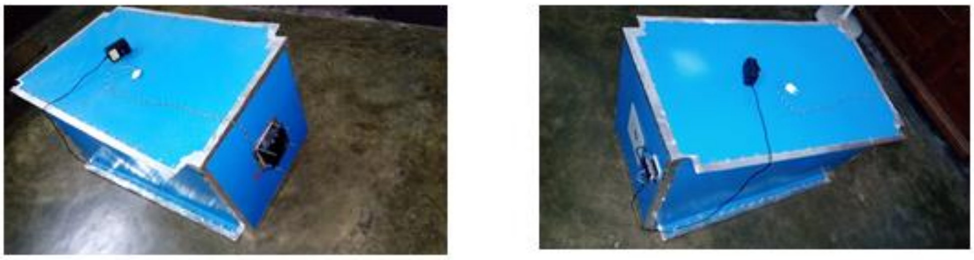

Figure 5: Fabricated Test Rig

Figure 6: Display showing pressure

Figure 7: Display showing the mounting of pressure sensor

Figure 8: Air Velocity measurement

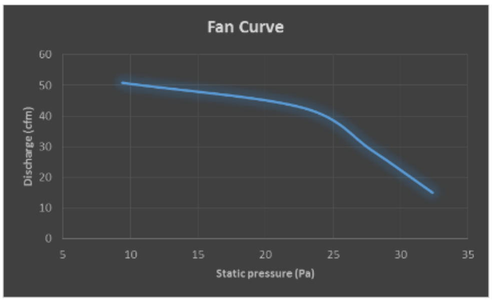

Figure 9: Fan curve generated

$L_s := 18\ in$ $\qquad D_o := 40\ mm$ $\qquad \rho := 1.225\ \frac{kg}{m^3}$

$A_i := L_s^2 = 0.209\ m^2$ $\qquad A_o := \frac{\pi}{4} \cdot D_o^2 = 0.001\ m^2$ $\qquad C_d := 0.77$

$P_o := 100323.02\ Pa$ $\qquad P_i := 100355.4\ Pa$

$\Delta P := P_i - P_o = 32.38\ Pa$

$$Q_{computed} := C_d \cdot \sqrt{\frac{2 \cdot \Delta P}{\rho}} \cdot \frac{A_o}{\sqrt{1 - \left(\frac{A_o}{A_i}\right)^2}} = 0.007035\ \frac{m^3}{s}$$

$vel := 5.6\ \frac{m}{s}$ $\qquad Q_{measured} := A_o \cdot vel = 0.007037\ \frac{m^3}{s}$

Figure 10: Calculations for Computing Air Flow

4. Using Test Rig To Plot Fan Curve

During the testing, fan is initially mounted on one side and sealed completely using Aluminum tape so that there is no leakage from the sides of the fan. On the other side, the opening is controlled by using orifices of various diameter one at a time. For each orifice dia, there is a pressure difference developed between atmosphere and in the box. This difference is the static pressure against which the air is being discharged. The discharge is then calculated using expression (1). MathCAD is used for performing all computations.

$$Q_{computed} := C_d \cdot \sqrt{\frac{2 \cdot \Delta P}{\rho}} \cdot \frac{A_o}{\sqrt{1-\left(\frac{A_o}{A_i}\right)^2}} \qquad (1)$$

Where A_o is orifice area and A_i is Cross-Section area of the test rig. The velocity of air exiting form the orifice is measured using vane anemometer (Figure 8). Model calculations are shown in figure 10. The obtained fan curve is shown in figure 9. It may be noted here that there are no flow straightening devices in this test rig. This is because when using the fans for any applications, the discharge is taken directly. Thus it is necessary to measure the discharge that is coming directly from the fan. Secondly all the panels are joined using nuts and bolts. Thus it is very easy to make changes in the panels that are attached to the rig.

5. CONCLUSION

A Modular Low Cost fan test rig has been fabricated. Using the test rig fan characteristic curve i.e. static pressure vs discharge of the fan are computed. Wane Anemometer is used the measure the air velocity and BMP085 using Arduino controller is used to measure the pressure. For testing the fan at various static pressure, the outlet size is regulated using different orifices.

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