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EFFECT OF DIFFERENT GEOMETRIC PARAMETERS OF BLADELESS FAN ON ITS PERFORMANCE

W. P. Teh[1], M. H. Basha*[1], M. F. Hamid[2] and M. Tasyrif[1]

[1] Faculty of Mechanical Engineering & Technology, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis, Malaysia.

[2] School of Innovation, Science and Technology, TAJ International College, 30100 Ipoh, Perak, Malaysia.

*corresponding_hafifbasha@unimap.edu.my

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Abstract— Bladeless fans can generate smooth and steady wind compared to conventional fans, but the effect of different geometric parameters on their performance is not well understood. The lack of understanding creates a challenge in designing and optimizing bladeless fans for maximum performance. In this work, the effect of different geometric parameters of a bladeless fan on its performance is analysed using simulation software. The geometric parameters tested are the blade length, blade angle and outlet slit thickness. A The boundary condition in simulation includes the velocity inlet, pressure outlet and wall.

Two inlet velocity are set, which is 2 m/s and 60 m/s. The result obtained is expressed in the air flow multiplier factor. From the result obtained, the parameters which has most effect on the outlet airflow are the outlet thickness, followed by blade length and blade angle.

I. Introduction

A fan is a device used to create flow within a fluid such as air to give a cooling effect. The commercial fan consists of a rotating arrangement of blades and a hub, known as an impeller, the impeller will rotate about an axis by driving the motor to generate airflow. The movement and circulation of the airflow create wind or breeze. The airflow produced will cause a cooling effect by dissipating heat away through convection and evaporation. There are several types of fans nowadays, which are the centrifugal fan, axial flow fan, mixed flow fan and bladeless fan. The application of fans can be applied everywhere including climate control and personal thermal comfort, machinery cooling system, vacuum cleaner, and dryer with heat combinations.

Dyson, which is a consumer electronics company that is known for its vacuum cleaner introduced a new device to the market called Dyson Air Multiplier/bladeless fan in October 2009. The new design of fan that known as air multiplier or bladeless fan was invented by Peter David Gammack, James Dyson, Arran George Smith and et al. [1]. When the device came to market, it creates an impact on consumers because the air multiplier is a fan with special characteristics, in which it doesn’t have any visible blade. From the appearance, it appears to be a large ring mounted on top of a pedestal. The bladeless fan can create airflow that is 15 times more than the air creates by a motor [2]. The blades in this fan are hidden inside a pedestal, connected with an electric motor that rotates nine asymmetrically aligned blades. The motor that rotates nine asymmetrically aligned blades able to suck 5.28 gallons (about 20 litres) of air per second into the device. The air multiplier uses friction in the air to multiply the amount of air coming. The air generates from the blade collides with air particles inside the ring and shoots out from the slit around the ring to create an airflow through the tube of the ring. This process is called inducement. As the air blows out of the slit, there will a void in the centre of the fan which can be known as the low-pressure zone. The air behind the fan will flow into the void hence it gains momentum towards the front of the fan. At this stage, the air surrounding the edge of the fan will follow the direction of the airflow [3]. This process is called entrainment, which amplifies the air flow [4].

By comparing a conventional commercial fan and a bladeless fan, a bladeless fan has much more advantage indeed. The energy cost of a bladeless fan is only a one third of a traditional conventional fan [5]. Without the external bladed fan assembly, a bladeless fan that lacks the visible moving part is safe to use around young children. Besides, a bladeless fan can create relatively uniform and steady airflow without the choppiness of the conventional fan [6]. By creating a steady airflow, the bladeless fan produces less turbulence than the standard fan and its claims to be quiet too [7].

Although bladeless fan/air multiplier has been introduced to the market for about 10 years, research about it is scarce. Chunxi et al. [8] did an experimental study on the effect of larger blade size on centrifugal fan performance. Other than that, research on the bladeless fan on its feasibility to be designed into large dimension had performed by M. Jafari et al [9]. From their research by numerical and experimental methods, bladeless fans can be designed in large dimensions. Hence, bladeless fans potentially can be utilized in various industries by eliminating the standard bladed fan. However, the effect of various geometric parameters of a bladeless fan on its performance is not well understood. This lack of understanding creates a challenge in designing and optimizing bladeless fans for maximum performance. Hence, the objective of this study is to investigate the effect of different geometric parameter on the performance of bladeless fan. To evaluate its performance, the flow field inside the bladeless fan is analyzed.

II. Methodology

A. 2D Modelling using SolidWorks

The two-dimensional (2D) modelling of the bladeless fan was done by using SolidWorks software. There are three different parameters in this research which are the chord/blade length, blade angle and outlet slit thickness. There were some constraints set for each parameter during designing the bladeless fan which was shown in the Table 1.

The isometric, front, section and detail view of the bladeless fan parameter design is shown in Figure 1. The labelling of each geometric parameter is also shown. It consists of several alphabet for labelling, L refer to blade length, H refer to cross section height, OS refer to outlet slit, t1 is the thickness of the annular ring (2mm), Dh refer to hydraulic diameter, D is the outer diameter of the pedestal while t2 refer to the thickness of pedestal (3mm). The outer diameter of pedestal is set as 116mm except for the blade length parameter. The outer diameter cannot set as 116mm because the smallest blade length design is 100mm only, hence 82mm are set as the outer diameter of the pedestal for blade length parameter. Another fixed constraint shown on Figure 1, which is the degree of outlet blade are set as 45° for all parameters.

Table 1: Different parameters of the design

Parameter	Cross section height (H), mm	Blade/Chord length (L), mm	Hydraulic diameter (D_h), mm	Blade Angle, deg	Outlet slit (OS), mm
Blade length (L), mm	30	100, 150, 200	300	11	1.5
Blade Angle (BA), deg	30	150	300	11, 13, 15	1.5
Outlet slit (OS), mm	30	150	300	11	1, 2, 3

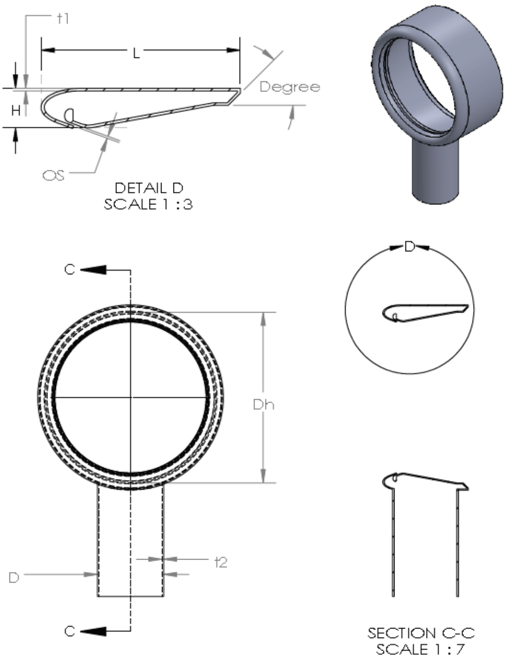

Figure 1: Reference of dimension labelling in Bladeless Fan

B. Simulation via ANSYS

ANSYS FLUENT is used for the simulation process. The simulation predicts the fluid flow changes because of different bladeless fan design. ANSYS FLUENT is a software that contains wide range of physical modelling capability for model fluid flow, heat transfer, static structural, turbomachinery and so on. It provides various type of viscous model such as laminar, inviscid, one equation Spalart- Allmaras, the model going to use in this research two equation k-epsilon models and so on. Other than that, the type of meshing in ANSYS FLUENT includes triangular or quadrilateral cells in 2D, hexahedral, tetrahedral, pyramid and polyhedral in 3D.

The bladeless fan design will be illustrated in a 2m height, 2m width and 4m length enclosed room. The air inlet is placed at the pedestal, which is the bottom parts of the bladeless fan while the air flow will be passing through the air foil shape design and flow out at narrow outlet slit. The inlet velocity that uses in this research will be setting as 2 m/s and 60 m/s in normal direction to the surface pedestal base. The inlet velocity is set as 2m/s and 60m/s are due to the empirical result from literature review. There is three geometric parameter that going to be study in the simulation.

III. Result And Discussion

A. Result of blade/chord length on the inlet and outlet volume flow rate

In this section, the influence of geometric parameter blade/chord length to the bladeless fan volumetric flow rate had been studied. There are three design of blade/chord length had been studied which is 10cm, 15cm and 20cm. The flow increase curve in the Figure 1 are shown the inlet versus outlet volume flow rate for blade/chord length 10cm, 15cm and 20cm.

Table 2 shows the multiplier factor of the specific parameter for the fan design. The multiplier factor is calculated to show the ratio of outlet to inlet volume flow rate from the fan. Higher multiplier factor shows that more air is moving through the outlet. The multiplier factors of blade length 10cm design are 17.2 which is the highest value compared to 16.3 of blade length 20cm and 13.8 blade length 15cm.

It shows that bladeless fan with 10cm blade length able to produce the higher outlet volume flow rate compared to the other two design, followed by the 20 cm and 15 cm blade length. It can be said that 10 cm blade length is the best parameter.

Table 2: Multiplier factor of different blade length parameter.

Blade length, cm	Multiplier Factor
10	17.2
15	13.8
20	16.3

The graph of inlet velocity versus outlet velocity are show on the Figure 2. From the Figure 2, the outlet velocity is not influenced by the geometric parameter blade length. When the inlet velocity input is set as 2m/s, the outlet velocity for three designs is approximately 12m/s while when the inlet velocity is set as 60m/s, the velocity magnitude are approximately 379m/s. This is because, bladeless fan works on the Coanda effect [10], and the difference in blade length have limited effect on the air velocity. where the stream flows over a curved surface and is deflected in the direction of the surface curvature. Different blade length has minimal effect on the surface curvature, thus have limited effect on the air velocity.

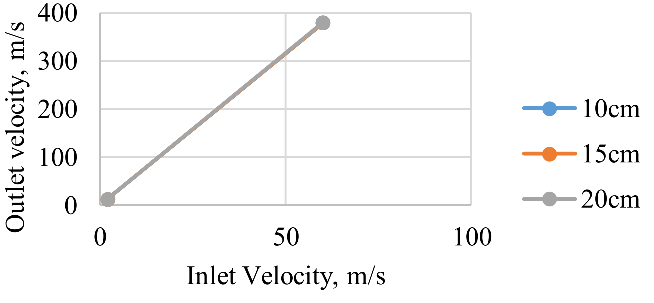

Figure 2: Inlet velocity versus output velocity for different blade length

B. Result of blade angle on the inlet and outlet volume flow rate

The influence of geometric parameter blade angle on the multiplier factor is shown in Table 3. From the result of the simulation, the multiplier factor of 15 degree of blade angle is 14.2 which is the highest among the three designs, thus the best design is the blade angle 15 degree.

The graph of inlet velocity versus velocity magnitude of blade angle are shown on the Figure 3. The design with blade angle of 11 degree have the highest velocity magnitude which is 27m/s when inlet velocity is 2m/s and 813m/s when the inlet velocity is 60m/s. While for the blade angle 13degree, the velocity magnitude is 25m/s at inlet velocity 2m/s and 766m/s at inlet velocity 60m/s. The velocity magnitude for blade angle 15 degree during inlet velocity 2m/s are 24m/s and 720m/s while inlet velocity is 60m/s.

The area of the bladeless fan geometry decreases with the blade angle. Hence the fan with higher degree of blade angle has larger area and results in the higher volume low rate. The volume flow rate is directly proportional to the area and the velocity; hence the velocity of the design increases with the blade angle.

Table 3: Multiplier factor of the different blade angle

Blade angle, deg	Multiplier Factor
11	13.5
13	14.0
15	14.2

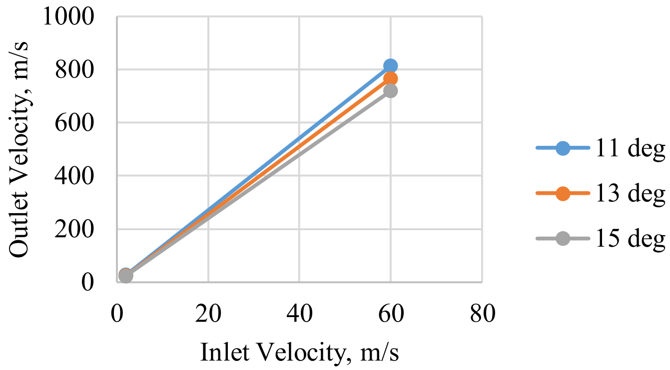

Figure 3: Inlet velocity versus output velocity different blade angle

C. Result of Outlet Thickness/Slit parameter on the inlet and outlet volume flow rate

The effect of outlet thickness 1mm, 2mm and 3mm on the multiplier factor is shown in Table 3.

The multiplier factor is 17.1, 11.9 and 11.1 respectively for outlet thickness 1mm, 2mm and 3mm when the inlet velocity is 60m/s. The multiplier factor decreased with increasing thickness, in which 1 mm thickness provides the highest multiplier factor.

The result of inlet velocity versus velocity magnitude are shown on the Figure 4. the line of outlet thickness 1 mm is steeper with outlet velocity of 40.17 m/s and 1207.70 for 2m/s and 60m/s inlet velocity, respectively. This finding is like the findings of Jafari et al. [11].

As the outlet thickness is decreased, it causes the velocity of air to increase, making larger pressure gradient between the front and the back of the fan, thus increasing the air flow rate.

Table 4: Multiplier factor of the different outlet thickness

Outlet Thickness, mm	Multiplier Factor
1	17.1
2	11.9
3	11.1

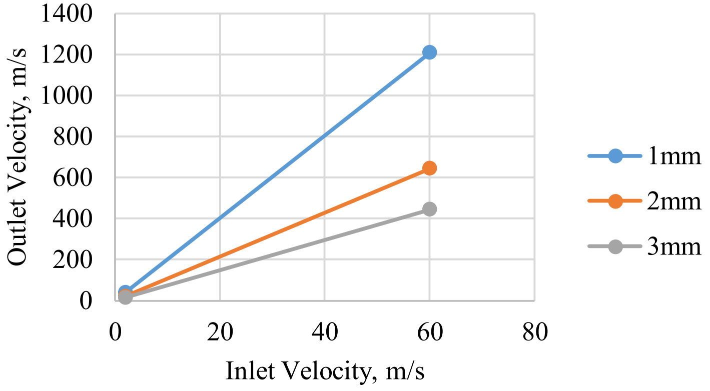

Figure 4: Inlet velocity versus output velocity different outlet thickness

IV. Conclusion

In this research paper, investigation of the effect of geometric parameter of bladeless fan on its performance has been done. The geometric parameter that had been discussed in this research paper are blade length, blade angle and outlet thickness. The results are presented by the multiplier factor, and flow velocity curve are plotted by inlet volume flow rate and outlet volume flow rate.

For the blade length parameter, it is found that shorter blade length produces the higher multiplier factor compared to longer blade length. The output velocity of air is comparable regardless of blade length. For the blade angle parameter, higher angle results in higher multiplier factor. However, for the output velocity, higher blade angle results in lower output air velocity. For the outlet slit/thickness, lower thickness result in higher multiplier factor and higher output air velocity.

V. Acknowledgement

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VI. References

[1] Dyson, James, Peter David Gammack, and Tom Vallance Hamilton Crawford. "Fan." U.S. Patent Application No. 29/331,008.

[2] Durdin J, "Inventing the 21st Century": An Exhibition at the British Library. World Patent Information. 2011; 33(2): 190–191

[3] Strickland J & N Chandler, How The Dyson Bladeless Fan Work, 2009.

[4] Lin, Han-Tang, Yunn-Horng Guu, and Wei-Hsuan Hsu. "Design and Fabrication of a Novel Window-Type Convection Device." Applied Sciences 11.1 (2020): 267.

[5] Fan, Guijie. "A New Appearance Design for Bladeless Fan." Machinery, Materials Science and Energy Engineering (ICMMSEE 2015) Proceedings of the 3rd International Conference. 2015.267.

[6] Li, Ang, et al. "Noise Source Identification and Noise Directivity Analysis of Bladeless Fans by Combined CFD and CAA Method." Fluids Engineering Division Summer Meeting. Vol. 83716. American Society of Mechanical Engineers, 2020.

[7] Mehmood, Kashif, et al. "Numerical analysis of bladeless ceiling fan: An effective alternative to conventional ceiling fan." Journal of Wind Engineering and Industrial Aerodynamics 221 (2022): 104905.

[8] Chunxi L, WS Ling, & J Yakui, The performance of a centrifugal fan with enlarged impeller. Energy Conversion and Management. 2011; 52(8–9): 2902–2910

[9] Jafari, M., et al. "Experimental and numerical investigation of a 60cm diameter bladeless fan." Journal of Applied Fluid Mechanics 9.2 (2016): 935-944.

[10] Li, Guoqi, et al. "Influence of Coanda surface curvature on performance of bladeless fan." Journal of thermal science 23.5 (2014): 422-431.

[11] Jafari, Mohammad, et al. "Numerical investigation of geometric parameter effects on the aerodynamic performance of a Bladeless fan." Alexandria Engineering Journal 55.1 (2016): 223-233.