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Analysis and Validation of Blade with Skewed Angle for Axial Fan

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Abstract: **The main aim of this research is to investigate the impact with a point of skew on the blade of the axial fan by calculating mass flow, rotor velocity, and pressure acting on the fluid by the fan's blade to obtain optimal efficiency. It has been observed that fluctuations in mass flow due to higher rotational speed (rpm) lead to an uneven distribution of the outlet speed of the flow line located in the ventilation hole of the stator, leading to a lower noise level. The mass flow rate is directly proportional to the performance, and pressure drop of the axial fan. The present work is carried out by considering a range of angles of (0º to 6º) for its rotor blade using trial and error in the CFD technique, we observe the axial fan handles the good volume of air at relatively low pressure and delivers good efficiency in the output airflow. Consequently, the axial fan is designed to operate on high static pressure. This manuscript consists of the computation of the aerodynamic performances of symmetrical blade profiles of a fully axial fan by Computational Fluid Dynamics (CFD) methods, developing a methodology for the design of axial fans, and analysis of the designed fan with CFD methods.**

Keywords: **Axial fan, Pressure gain, Velocity streamline, Computational Fluid Dynamics (CFD), Mass flow rate.**

I. INTRODUCTION

Axial fan has blades that move air parallel to the shaft where blades rotate. In an axial fan with a gate and cylindrical housing, air passes through the gate without changing the distance from the axis of rotation [1]. In general, the axial fan is characterized by a high air flow rate and a relatively small pressure increase in the centrifugal fan, which provides a low flow rate and pressure increases. [2], [3].

The pressure that the fan developed while operating is poor in comparison with the stress developed in a compressor. The airflow through the fan aircraft is not uniform, from favorable at the tip to poor in the structure is influenced by the twisting of the airfoil along the blade [4], [5].

Three elements at any point or radius are characteristic of work done by a fan blade: chord width, airfoil twist, and tangential velocity squared [6], [7].

Therefore, the shape of the blades varies from fan efficiency to overall performance in axial flow fans; the flow of fluid is parallel to the fan axis. The shape of fan blades has also optimized the use of the software [8], [9]. The rapid advancement in computer hardware and software has led to major advances in Finite Element Analysis software (FEA) [10].

II. MATERIALS AND METHODS

A. Analysis of Flow in Rotor and Stator

- Analysis of mass flow by considering various velocities.
- Analysis of stator pressure via various velocities.
- Analysis of mid surface velocity via various velocities.

In axial fans, the flow rate is parallel to the axis of the fan, so friction, velocity, and fluid flow must be steady and the blades must velocity is changed to 1000 rpm, 1800 rpm, and 2500 rpm in this case. Therefore, changes related to the blade section are as the pressure and speed are measured using ansys.

The initial research provides insight into the CFD simulation of an airflow delivery radiator axial fan. In several engineering programs, the axial flow fan is used greatly. Its adaptability has resulted in large-scale systems being introduced, from industrial dryers and air-con equipment to cooling for car engines and in-cabin air recirculation structures.

The direction of the blade also plays a critical role in the air movement in the radiator and fan performance. For a right-oriented blade, the direction of fan rotation is clockwise; for a left-oriented blade, the path of fan rotation is counter clockwise.

The mass flow is directly proportional to its axial fan efficiency, and pressure drop. This work is applied by considering (0° to 6°) for CFD technique's airfoil victimization trial and error, we tend to observe that the axial fan manages the smart air volume at comparatively mass flow, and provides a smart economical flow within the output.

Wherever mass flow, rotor velocity, and rotor pressure have been correctly analysed and validated, the research is carried out by victimization process fluid dynamics simulation.

A fan model is used; Computer Fluid Dynamics Post up is used to measure the rotor-stator velocity and pressure at 1000 rpm, 1800 rpm, and 2500 rpm.

The simulation via a multistage axial fan using a plane model demonstrates the initial boundary conditions are as follows: a 9 blades fan, which rotates at 1800 rpm, creates a flow. In the second step, the flux is "rectified" using a 9 blades fan section located just downstream of the rotor section. The blade is divided into smaller volumes for use in digital resolution methods.

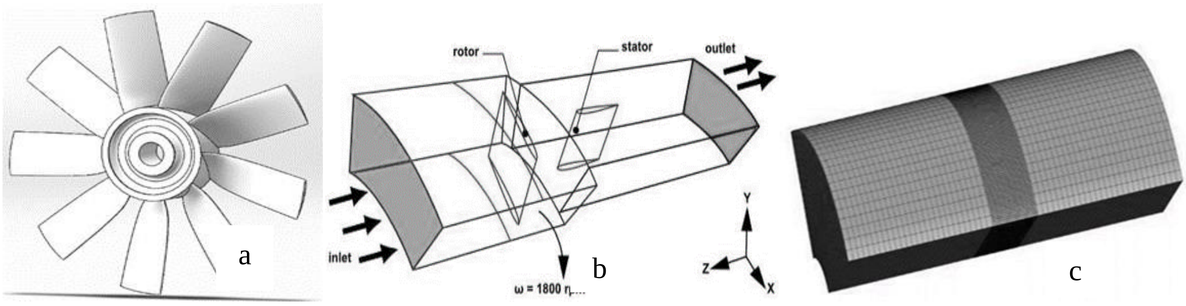

Fig. 1. Axial fan (a) boundary condition (b) complete mesh (c)

B. Initial Design

Through this graph, we see that the mass flow rate of fluid is related to the pressure drop between the fluid particles, and secondly, when the mass flow rate increases, the pressure drop increases.

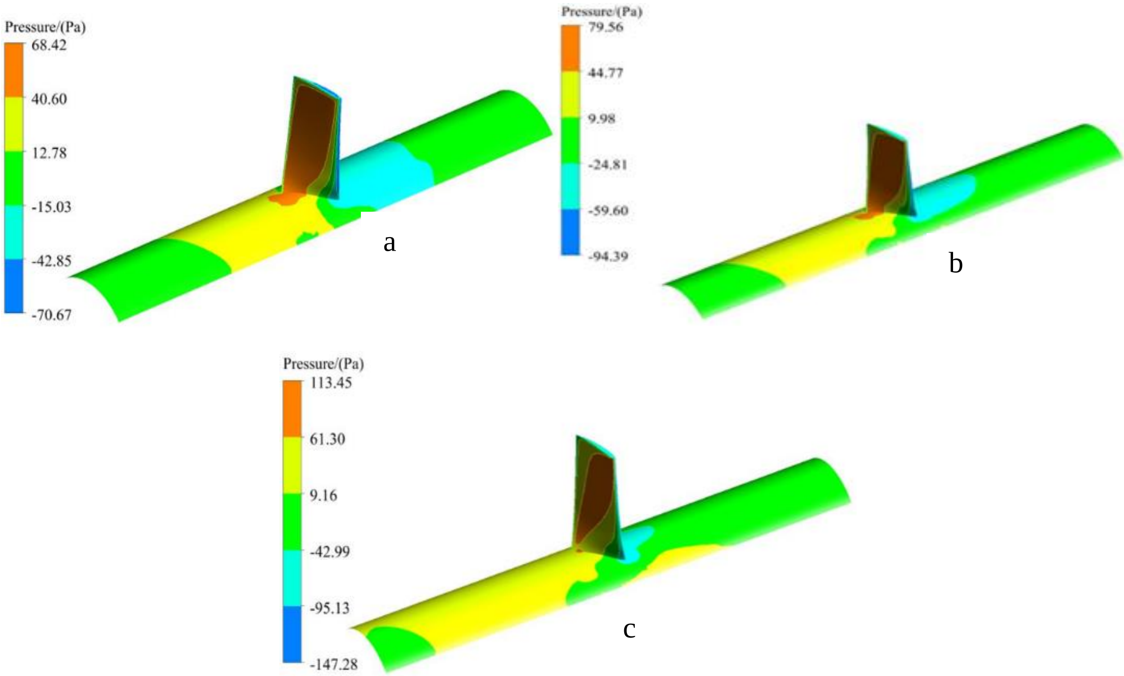

Fig. 2. Original blade pressure 1000 rpm (a) 1800 rpm (b) 2500 rpm (c)

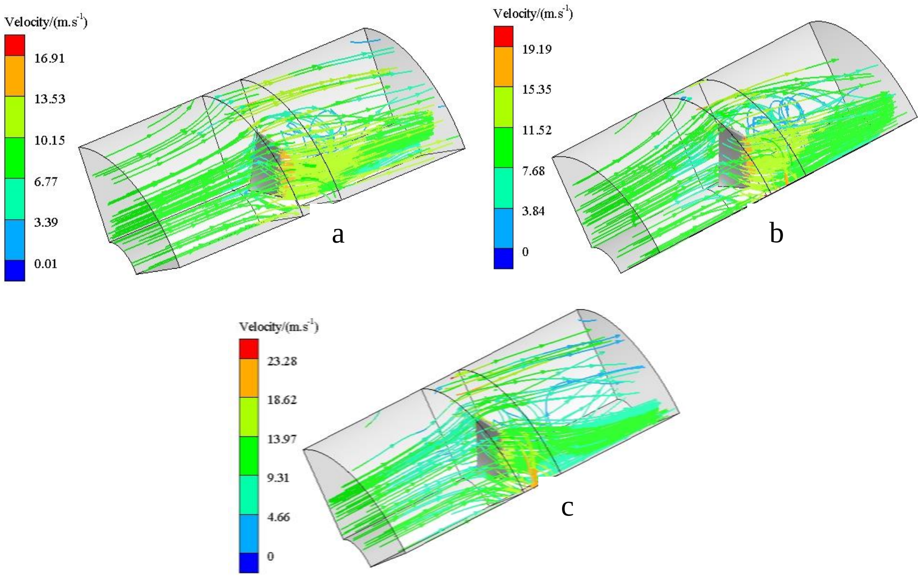

Fig. 3. Original blade velocity 1000 rpm (a) 1800 rpm (b) 2500 rpm (c)

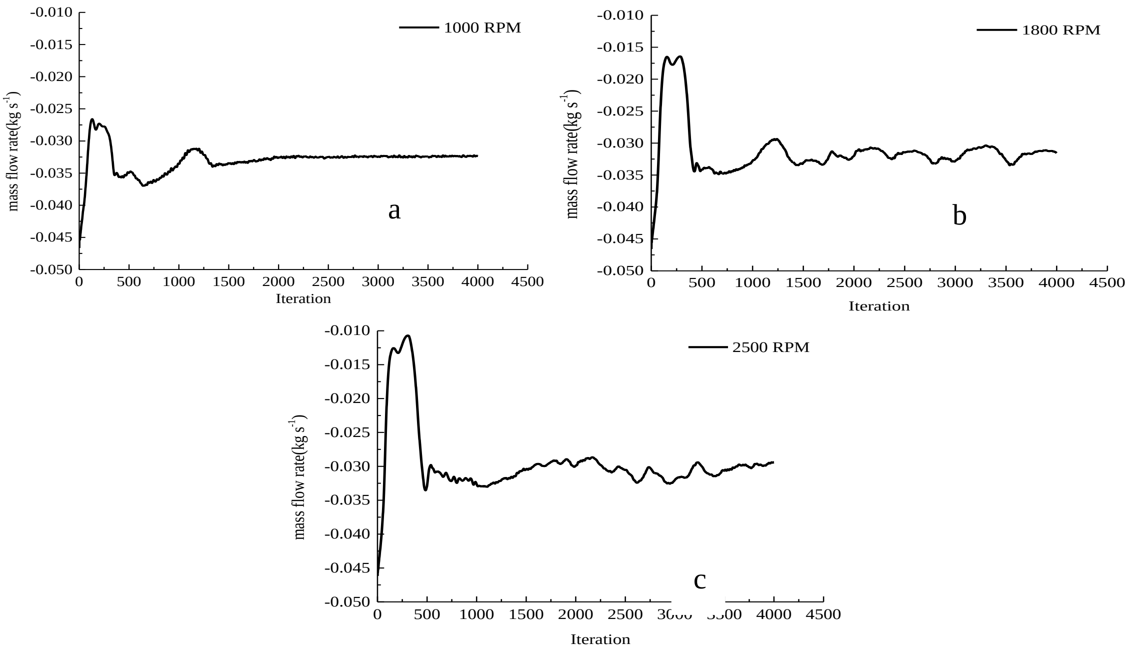

Fig. 4. Original mass flow rate 1000 rpm (a) 1800 rpm (b) 2500 rpm (c)

The designed fan has nine blades, the compiled results for such fan look as follows: on Fig. 2 the pressure is at a rate of 68.42 Pa for 1000 rpm, 79.56 Pa for 1800 rpm, and 113.45 Pa for 2500 rpm with the outside pressure. Fig. 3 shows the results were compiled for the velocity rate of 16.91 m/s for 1000 rpm, 19.19 m/s for 1800 rpm, and 23.28 m/s for 2500 rpm who are similar to the original experiment. Fig. 4 shows the mass flow rate output at 1000 rpm, 1800 rpm, and 2500 rpm over up to 4500 iterations.

C. Optimal Design

The following is the experimental research and numeric analysis of the overall efficiency of an axial flow blade. Firstly, according to the research of the axial blade, the overall performance of the inclined blade could result in the following conditions: decrease in pressure by approximately 5%, increase in mass flow rate and decrease in aerodynamic noise from 2 db to 4 db. In addition, the total efficiency increases up to 5%.

Secondly, after the analysis of the flow of the axial blade with 6° skewed blades, the following results have been received: the skewed blade operates more efficiently at low flow rates, with a delayed start. The initial work has shown that the overall loss could have been reduced by changing the blade angle or the blade itself, which would result in higher airflow.

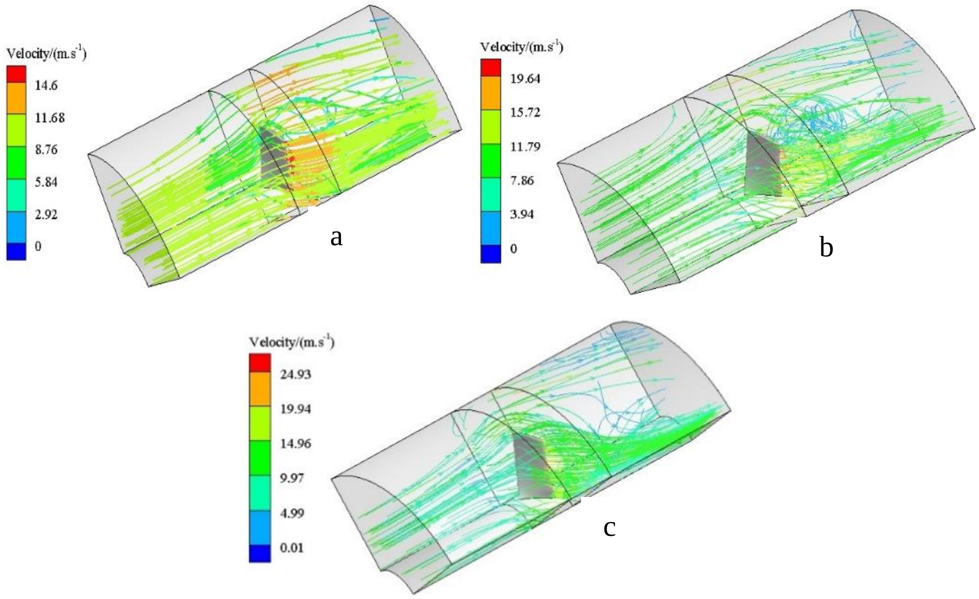

Fig. 5. Optimal blade velocity 1000 rpm (a) 1800 rpm (b) 2500 rpm (c)

Fig. 5 shows the velocity at 1000 rpm, 1800 rpm, and 2500 rpm when the angle is modified at 6°, the velocity streamlines of the optimized designed fan. By looking at the graphic, velocity normalizes, which means flow becomes even and steady (at input and output) so that the output velocity corresponds to the parameters.

The output velocity corresponds to the given parameters due to the even flow. The noise also lessens and all the acoustic problems disappear, thus efficiency increases. The maximum value of velocity acting at the setup is 14.60 m/s for 1000 rpm, 19.64 m/s for 1800 rpm, and 29.93 m/s for 2500 rpm while the minimum value is 0.00e+0 m/s for 1000 rpm, 1800 rpm, and 2500 rpm.

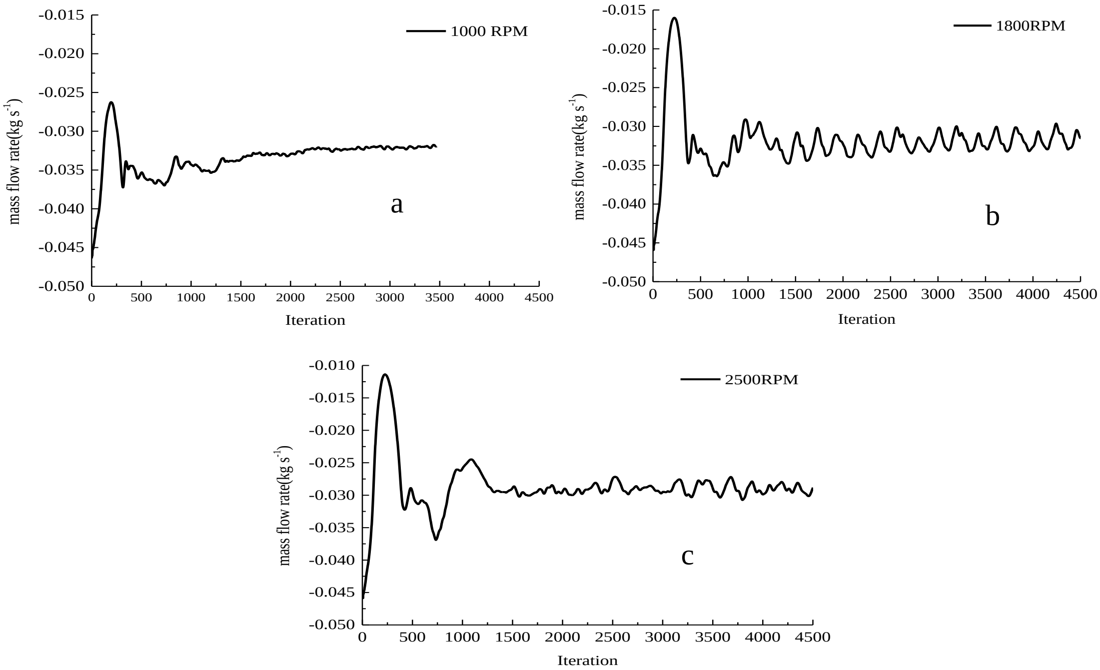

Fig. 6. Optimal mass flow rate 1000 rpm (a) 1800 rpm (b) 2500 rpm (c)

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Fig. 6 demonstrates the assorted velocities in x, y, and z-direction, with continuity (*k*), and epsilon (*ε*) plots against the number of iterations. The number of interactions in figure 8 demonstrates the rate of the mass flow at the output, which equals 1000 rpm, 1800 rpm, and 2500 rpm. Although the result is not displayed, theoretical calculations make it easier to see the variation of import.

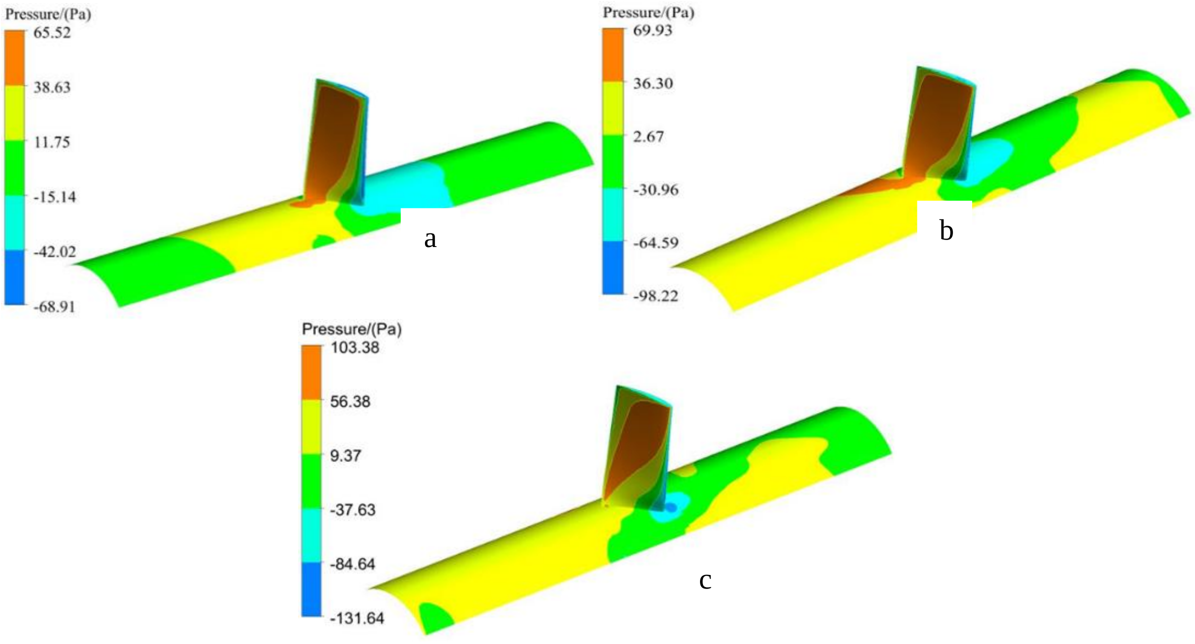

Fig. 7. Optimal blade pressure 1000 rpm (a) 1800 rpm (b) 2500 rpm (c)

Fig. 7 shows the reduction of the pressure at 1000 rpm, 1800 rpm, and 2500 rpm when the angle of the blade is modified at 6° compared to the original blade where the pressure contour is high.

The changes in pressure happen due to using the modified skewed angle, the pressure on the blade is low compared to the blade pressure of the initial fan, which considerably increases the work efficiency of the fan. According to Fig. 7, the blade pressure contour displayed at 6° skewed blade is low. This optimization to 6° blade angle demonstrates the pressure displayed on the fan blades and the hub under the turbulence is lower than the displayed pressure applied to the original blades, which can be determined in any variety of blades.

However, the power of the pressure may be higher because the distance allowed for the passage of air becomes much less important. As can be seen, the most reliable variety of blades can vary from 5 to 12, the higher number of blades obstructs the flow passage. The maximum blade pressure values acting on the blades are 65.52 Pa for 1000 rpm, 69.93 Pa for 1800 rpm, and 103.38 Pa for 2500 rpm while the minimum value is -131.64 Pa for 2500 rpm, -98.22 Pa for 1800 rpm, and -68.91 Pa for 1000 rpm. As can be seen, the minimal pressure directed to the bladed can be lessened.

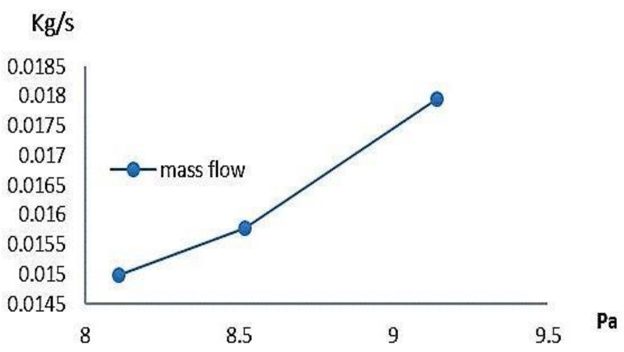

Fig. 8. Graph of pressure and mass flow

From Fig. 8, it can be seen that the mass flow rate is directly proportional to the pressure between the fluid particles. The increase in the mass flow is proportional to the increase in the pressure that applies to the blades.

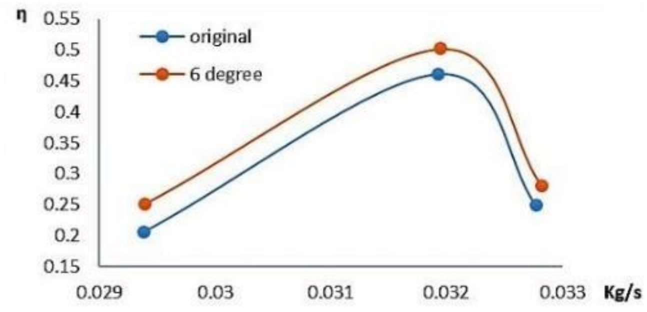

Fig. 9. Graph of efficiency original blade and optimal blade

According to Fig. 9, the mass flow rate is directly proportional to the rotor speed. The higher the rotation speed (output), the higher the mass flow and reciprocally.

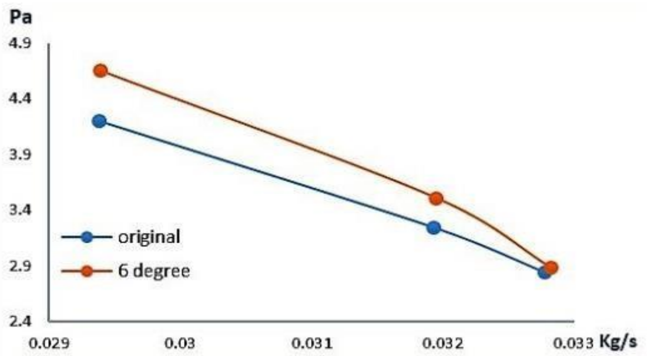

Fig. 10. Validation of pressure and velocity

According to Fig. 10, it can be seen that the mass flow rate is directly proportional to the pressure between the fluid particles. The increase in the mass flow is proportional to the pressure reduction that applies to the blades.

III. RESULTS AND DISCUSSIONS

D. Validation and Convergence Condition

In order to optimize the design of the blades of 9 blade fan, the results were compiled for the same operating conditions as the originally designed fan. The conditions include airflow, velocity, and output pressure.

The study shows an optimization in the velocity of the optimized designed fan. The velocity streamlines of the fan are uniform, which means that airflow is also uniform and requires variation in velocity across the axial blade. The changes in pressure and velocity of the fluid happen because of the modified skewed angle used. The changes in pressure and velocity variation are almost the same at the blade surface. This can also be seen in the color pattern of the temperature contour of the blade.

This design reduces the risks of thermal cracks, the pressure on the blades becomes lower as well and the velocity becomes higher than on the original blade. The modified model of the axial blade will increase the effectiveness of the work of the fan and maximize the durability of the fan. The work efficiency of the fan also increases by lowering the pressure of the blades as well as increasing the velocity.

The color of the streamlines is almost the same across the blade at input and output. We receive the desired velocity output according to the parameters given. Because of even flow, we receive negligible noise, all-acoustic problems are solved and therefore efficiency is increased.

TABLE I. MASS FLOW (Kg/s)

Rotation Speed (rpm)	Mass Flow (Kg/s)
1000	0.0470951
1800	0.0470951
2500	0.0470951

TABLE II. FLOW VELOCITY (m/s)

Rotation Speed (rpm)	Lowest (m/s)	Highest (m/s)
1000	0.237738	32.7
1800	0.203943	36.7
2500	0.238836	40.2

TABLE III. FLOW PRESSURE (Pa)

Rotation Speed (rpm)	Lowest (Pa)	Highest (Pa)
1000	0.114369	225
1800	0.134073	886
2500	0.174787	1750

E. Acknowledgement

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IV. CONCLUSION

The results from the simulations provided insights into the behavior of fluid flow using a modified skewed angle. The numerical Computational Fluid Dynamics analysis was established for both initially designed and optimized axial blades. The numerical CFD results for optimized design were compared with the initial axial blade. The research looks at the fan with an optimum number of blades and compares it to the fan with a fewer number of blades. We have taken 3 completely different iterations at a different rate. These are 1000 rpm, 1800 rpm, and 2500 rpm to get the subsequent result for it. As the rpm of the rotor increases, the mass flow at the outlet increases as well, and the increases in output are no longer linear.

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