Design and Fabrication of Mini DC Vacuum Cleaner

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Abstract- Use of Fossil Fuels in Power Generation has its adverse environmental impact. And due to growing population there is a scarcity of Fossil Fuels in today's world. To cope up with this problem this paper suggests the design of D.C operated vacuum cleaner using axial flow fan, which is capable of producing a suction pressure of 0.17- bar. And it is more efficient in cleaning and has less D.C. power consumption. This vacuum cleaner is wireless leading to better approach in cleaning the floor. As this vacuum cleaner is eco-friendly, looking forward to use a cleaner source of energy for the betterment of mankind, planet earth and environment.

Indexed Terms- Flow Velocity; Revolution; Torque; Air Flow Rate; Efficiency.

I. INTRODUCTION

A vacuum cleaner is an electronic device that cleans dust, dirt and garbage from floors, carpets, hardwood floors, hard to reach corners. It is the most easy to use and time saving appliance which is hot favorite in most of the domestic and commercial spaces. It can operate in order to complete the task of cleaning the homes and areas as quickly and efficiently as possible. Especially, without them, it is nearly impossible to carry out the fine cleaning of carpets and huge sofa sets. They add the tag of comfort to the life of a person and make it easy for him to look after his domestic duties with utmost care and effectiveness. The older versions of these machines were quiet heavy and less advanced. But the recent ones are coming in as light weight as possible. They are also equipped with the latest and super smart technologies. The best vacuum cleaner coming these days have the best features like advanced attachments and filters that can absorb the allergens from the air which are settled in the form of dust on the carpets and other such stuff. In this study, the model of mini vacuum cleaner was designed and constructed.

II. MAIN COMPONENTS INCLUSION

a. 12V Battery

Figure 1. The model of 12 V Battery

The device which can use to power the motor is shown in figure 1. The battery used in this project is the main source of power to run the axial flow fan which is responsible for the production of suction pressure.

b. 12 V DC Electric Motor

Figure 2. The model of 12 V DC Electric Motor

An electric motor, essential to the suction of the vacuum is shown in figure 2. It is an electrical machine that converts electrical energy into mechanical energy. Electric motors can be powered by direct current (DC) sources, such as from batteries.

c. Axil Flow Fan Blade

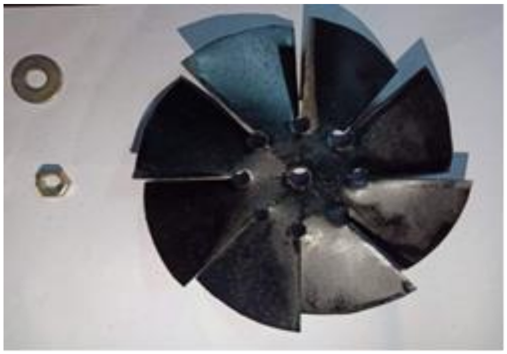

Figure 3. The model of axial fan

An axial fan is used in vacuum to create suction. As seen in Figure 3, an axial fan has precise angles to optimize the amount of air it can displace. The fan has an opening in the center of the blades. This opening is used to be press fitted onto the axial shaft of the motor. The pressed fit creates a strong and tight connection so that the assembly is rigid. It is the main motor which creates the pressure difference inside the cylinder. In Figure 4, the air in front of the fan is at a low pressure and the air behind the fan is at a higher pressure.

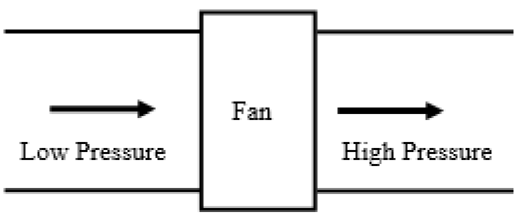

Figure 4. The model of an axial fan

d. Suction Cylinder

(a)

(b)

Figure 5. The model of suction cylinder (a) top view; (b) side view

The suction cylinder, as shown in figure 5, consists of the axial flow fan fitted inside it. Half of the suction cylinder acts as the storage tank. As the suction pressure is produced in the cylinder due to the axial fan rotation, the dirt or garbage is sucked inside the cylinder and gets stored into the cylinder bottom due to self-weight of the garbage. The storage capacity of the storage tank is of liters, which makes it able to store more garbage. And also the number of times of removing dust bag reduces due to more storage capacity.

e. Filter

The filter inside the vacuum housing is where dirt particles and other objects get stored until they are discarded by the user. The filter in figure 6 is important in catching objects before they reach the fan or motor. Dirt and dust can ruin the effectiveness of the vacuum by causing friction in the motor or damaging the fan blades. Also, it is easier for the user to discard the vacuumed objects when they are placed in a single filter.

Figure 6. The model of a filter

f. Dust Collecting Hose

The dust collecting hose is an important part as it is the only medium through which the sucked dirt is sent to the suction cylinder. The dust collecting hose is a flexible part whose length can be adjusted according to the desire. The material used for the hose is PVC as shown in figure 7.

Figure 7. The design of dust collecting hose

g. Voltage Regulator

Figure 7. The model of voltage regulator

A voltage regulator, figure 7, is an electricity regulation device designed to automatically convert voltage into a lower, usually direct current (DC), constant voltage.

III. ESTIMATION EQUATIONS FOR VACUUM CLEANER

a. Estimation of Shaft from The Motor

The torque, $$T = \frac{60P}{2\pi N} \quad (1)$$

Equivalent Twisting Moment;

$$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2} \quad (2)$$

Equivalent Bending Moment;

$$M_e = \frac{1}{2}\left[(K_m \times M) + \sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right] \quad (3)$$

b. Equations For Axial Fan

The flow rate of air across the fan;

$$Q = AV \quad (4)$$

The storage capacity of cylinder collecting the dust;

$$C = \pi R^2 L_2 \quad (5)$$

The area of the axial fan is as follows;

$$A = \frac{\pi D^2}{4} \quad (6)$$

The mass flow rate across the fan is;

$$\dot{m} = \rho AC \quad (7)$$

Bernoulli' Principles for upstream and downstream are as follows;

$$p_a + \frac{1}{2}\rho C_u^2 = p_1 + \frac{1}{2}\rho C^2 \quad (8)$$

$$p_a + \frac{1}{2}\rho C_s^2 = p_2 + \frac{1}{2}\rho C^2 \quad (9)$$

Input power of the fan;

$$P_i = VI \quad (10)$$

Output power of the fan;

$$P_o = Q(p_2 - p_1) \quad (11)$$

The efficiency of the fan;

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} \quad (12)$$

c. Numerical Analysis

In order to get the better design in CFD, following procedure Figure 8 is applied so that fluid flow can easily be modeled.

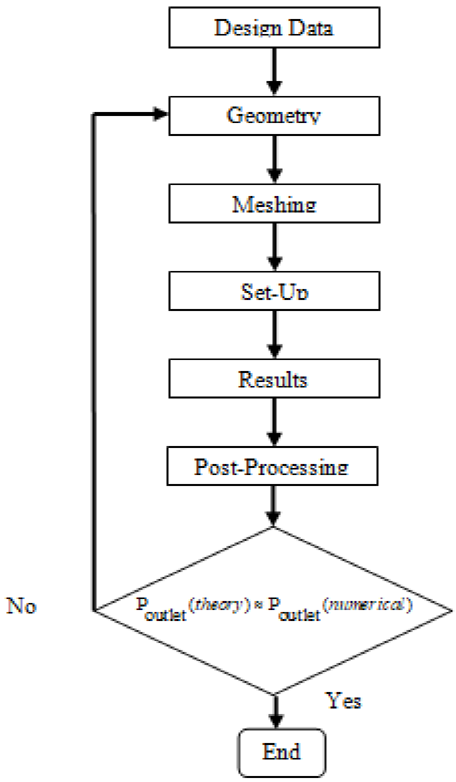

Figure 8. Algorithm for numerical simulation

d. Specification Data

Table 1. Required data for design of vacuum cleaner

Voltage of motor	12 V
Current	0.3 A
Total weight	133 g
Length of shaft extending from motor	1.5 cm
Diameter of blade	15 cm
Radius of cylinder	8.5 cm
Storage length	4.5 cm
K_m	1.5
K_t	1
Density of air	1.22 kg/m3
Acceleration due to Gravity	9.81 m/s^2

IV. PERFORMANCE TEST AND RESULTS

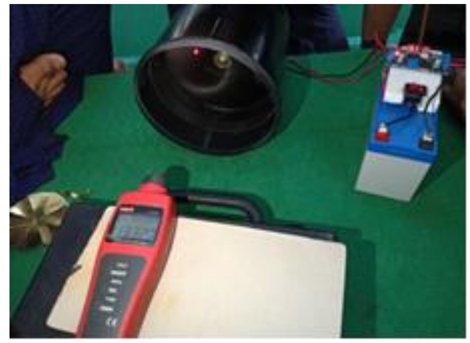

Figure 9. Measuring the motor speed with Tachometer

Table 2. Test data results of motor speed

Voltage (V)	Revolution (RPM)
1.5	1330
2	1740
2.5	2130
3	2530

Figure 10. Measuring the velocity of air with anemometer

Table 3. Test data results of air flow velocity

Voltage (V)	Flow Velocity (m/s)
1.5	1.72
2	2.13
2.5	2.72
3	3.28

The performance tests are done by measuring the motor speed with tachometer as shown in figure 9 and results are shown in table 2. Figure 10 is measured the velocity of air with anemometer and results are included in table 3.

Figure 11. Testing the vacuum cleaner with the light particles

Table 4. Theoretical results for vacuum cleaner

Power consumption by suction fan	0.9 Watt
Torque acting on the shaft	3.39×10^{-3} N-m
Bending moment of the shaft	0.0196 N-m
Equivalent twisting moment of the shaft	0.0296 N-m
Equivalent bending moment of the shaft	0.0295 N-m
Flow rate of air across the fan	0.058 m^3/s
Storage capacity of cylinder	1.021×10^{-3} m^3
Pressure difference	6.56 N/m^2
Efficiency of the fan	42%

The designed results for shaft, axial flow fan and suction cylinder are shown in table 4.

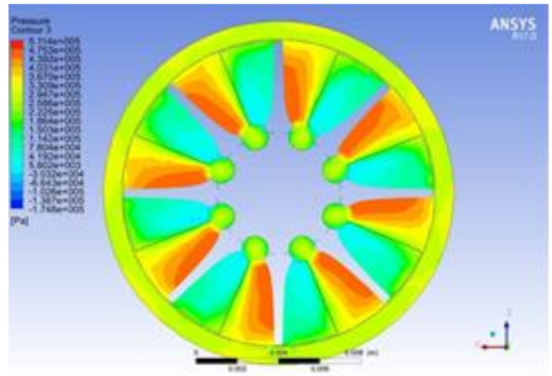

Figure 12. Static pressure distribution of an axial fan

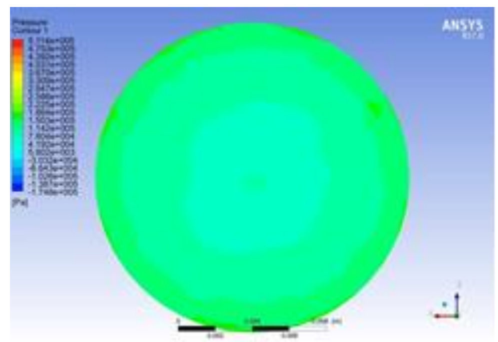

Figure 13. Outlet pressure distribution of a cylinder

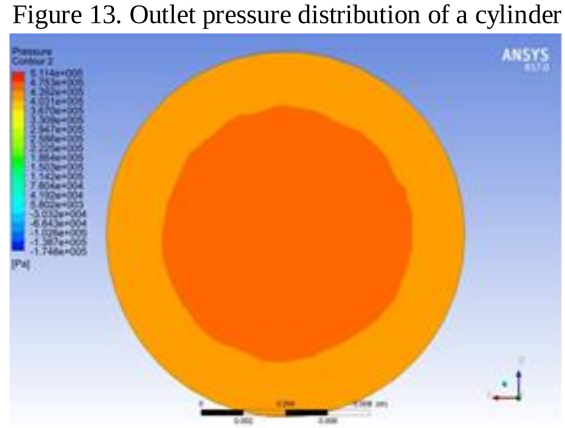

Figure 14. Inlet pressure distribution of a cylinder

In the numerical analysis, the inlet pressure 1atm, the outlet mass flow rate 0.0607 kg/s is set-up. The temperature is assumed at normal room temperature 25°C. According to Figure 14, high pressure region is observed at lower part of the blades and decreased gradually at the higher part.

V. CONCLUSION

This project has been studied the axial fan used in the vacuum cleaner. In this project, axial fan is designed for 0.9 W vacuum cleaners. The pressure difference across the fan is calculated by using slip steam theory. After the calculations, the pressure difference across the fan is 6.56. The efficiency of the machine is 42%.

The biggest challenges of this project were to create vacuum inside the container for suction and the proper designing and choosing the blade material. Creating vacuum was overcome by inserting a V-shaped cone at the suction and making holes at the other end for the air coming from the filter to exit. The spacing between blade and the container had become a major consideration in creating vacuum. For the blade material, mild steel is chosen so that it can withstand the air drag force and shaft centrifugal forces. Designing of the blade is done with Auto Cad software. By carrying out this project, the blade design is the critical factor for the good efficiency of vacuum cleaners was known. The lack of precision in blade design had made the project equipment to have lower efficiency.

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NOMENCLATURE

- T : Torque of shaft (N-m)
- P : Motor power (Watt)
- N : Motor speed (rpm)
- P_1 : Pressure at the Inlet of Fan (N/m^2)
- P_2 : Pressure at the Outlet of Fan (N/m^2)
- P_i : Input Power of Fan (W)
- P_o : Output Power of Fan (W)
- W : Total weight (g)
- M : Bending moment (N-m)
- T_e : Equivalent twisting moment (N-m)
- M_e : Equivalent Bending Moment (N-m)
- Q : Volumetric Flow Rate of Air (m^3/s)
- R : Radius of Cylinder (m)
- A : Area of Blade (m^2)
- K_m : Factor for Bending Moment
- K_t : Factor for Torsional Moment
- V : Velocity of Air (m/s)
- C : Storage Capacity (m^3)
- L_2 : Storage Length (m)
- D : Diameter of the Fan (cm)
- m : Mass Flow Rate (kg/s)
- ρ : Density of Air (kg/m^3)
- η : Efficiency of the Fan (%)

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