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Design and Development of a Low Cost Handheld Vacuum Cleaner

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ABSTRACT

A vacuum cleaner, like many other home products, is made to use it easier and more efficient for its customers to complete particular tasks. It must be effective at both collecting up dust particles and eliminating them from the air. This research paper develops a low cost effective vacuum cleaner and its parts. According to the literature review, the vacuum cleaner's performance is mostly influenced by parameters including the impeller's diameter, radius of curvature, strength, and speed. In this study, an unique impeller is designed with Creo, and the flow characteristics of the impeller are examined using CFD. The impeller's thickness, form, and number of blades are all determined using the mechanical design process. In addition, polycarbonate was used as a material for making impeller in 3D printing.

KEYWORDS: *Vacuum cleaner, Impeller, CFD Analysis, 3D Printing*

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1. INTRODUCTION

A vacuum cleaner, like many other home products, is made to use it easier and more efficient for its user to complete particular tasks. A vacuum cleaner collects different types of debris, dust, allergies, etc. by using air flow, which is frequently paired with brushing action. It must be effective at both collecting up these things and eliminating them from the air in order to prevent them from being re-circulated back into the living space. It can be challenging to identify which profile of the impeller of the vacuum cleaner will actually perform the best.

The most crucial component of modern living is time management. In industries and houses, cleaning is one of the most tedious and demanding tasks. An electromechanical tool frequently used to easily clean them is a vacuum cleaner. Cleaning becomes quicker and easier as a result. The vacuum cleaner has an electric motor that rotates the impeller to partially produce a vacuum and suck outside air into the suction chamber. So that the dust and debris close to the vacuum cleaner's nozzle are drawn within the vacuum cleaner. A filter is used to remove dust and grime from the air and they are then kept in storage section.

Methodology for System-Level Analysis of a Fan-Motor Design for a Vacuum Cleaner was summarized by Park et al. 2017. Optimization of the Flow Path Efficiency in a Vacuum Cleaner Fan was given by Son et al. 2018 and they have calculated the fan motor unit for a compact vacuum cleaner and achieved a 30% smaller than a full-size one.

Ashish J. Patel 2015 have investigated Design and Flow through CFD Analysis of Enclosed Impellers and reported the significance of the impeller design. Effect of Blade Number on Characteristics of Centrifugal Pumps was demonstrated by "Effects of blade number on characteristics of centrifugal pumps" 2010. The study examined how a centrifugal pump's performance is impacted by the number of impeller blades. Three distinct impellers with 5, 7, and 9 blades are numerically tested at a rotating speed of 2800 rpm to identify the ideal number of blades.

Gajbhiye, Ahmad, and Tufail 2018 have designed and created applications of a D.C. Vacuum Cleaner Using Axial Flow Fan and the paper served as the inspiration for the design and construction of the vacuum cleaner. Bacharoudis et al. 2008 have done the Parametric study of a Centrifugal Pump Impeller by Varying the Outlet Blade Angle. The simulation of a pump's performance in terms of the impeller outlet diameter, blade angle, and number were dealt in the study. Bhosale and Gore 2017 in their Review article Paper have found Improvement of Impeller Design of a Centrifugal Pump Using FEM and CFD. The paper expressed the centrifugal pump's efficiency and energy which was influenced by a number of factors such as material, blade angle, and blade count. Therefore, it is essential for the growth of the impulse in order to increase the pump's effectiveness.

Khelladi et al. 2005 have reported a new design of the impeller-diffuser interface of a vaned centrifugal fan in this paper, theoretical and experimental work on unsteady three-dimensional (3D) flows has been done in order to better understanding the fluid flow behaviour in vane centrifugal fans.

From the literature survey it is understood that the primary variables affecting the performance of the vacuum cleaner are the impeller's diameter, radius of curvature, strength, and speed. The performance of the vacuum cleaner changes when the impeller size and shape are altered. A new impeller is necessary to enhance the performance of portable light weight vacuum cleaners.

2. PRINCIPLE OF VACUUM CLEANER

- The fundamental working principle of a vacuum cleaner is that materials flow when there is a pressure difference between two points.
- An electric motor rotates the centrifugal impeller. Negative pressure is produced on one side of the impeller as a result of the impeller rotating. So air is drawn into the other side of the vacuum cleaner and forced into it. Any dirt and dust particles present nearby also will be sucked along with the air.
- The vacuum cleaner unit has a function of suction and discharge, and a filter and storage compartment are linked on the suction side. Air is filtered to remove dust and grains, finally the air is sent out to the atmosphere.

3. COMPONENTS DESCRIPTION

The components that are used in the prototype model are as follows, also illustrated in the diagram fig 1.

- Impeller
- Motor
- Filter
- Collecting area
- Inlet
- Mini 2 pin SPST switch

3.1. IMPELLER

A vacuum cleaner's impeller generates actual suction. It is a disc-shaped device with blades that are always positioned directly on the suction motor's shaft, causing it to rotate rapidly and is shown in fig 2. Suction is produced by the effects of centrifugal force on the revolving air inside the impeller. A partial vacuum is created as the impeller rotates, which causes the rotating air to move away from the core and allow more air to flow into the vacuum cleaner. The primary variables determining the performance of the vacuum cleaner include the impeller's diameter, radius of curvature, strength, and speed.

3.1.1. IMPELLER DESIGN

Impeller design is done by PTC Creo software.
Specification of the impeller:

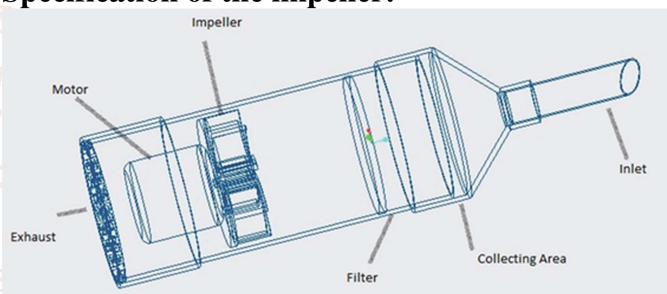

Fig. 1 Components of Vacuum Cleaner

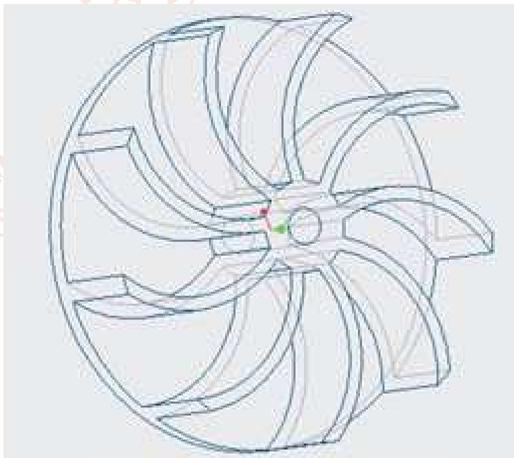

Fig. 2 Impeller

Table 1 Specification of the impeller:

S. No.	Geometry	values
1	Disc diameter = 98mm	98mm
2	Disc thickness = 5 mm	5 mm
3	Blade thickness = 3mm	3mm
4	Shaft hole diameter = 6mm	6mm
5	Radius of curvature = 30 mm	30 mm
6	Number of blades = 9	9

3.1.2. CFD Analysis

Fluid dynamics is a subfield of computational fluid dynamics. CFD analyses and resolves fluid flow problems by using numerical analysis and data structures. The following three stages generally make up a CFD analysis:

3.1.3. Pre-processing:
The problem statement is now transformed into a customised and idealised computer model. The type of flow that will be modelled is assumed to exist. The creation of the mesh and the use of the initial and boundary conditions are included.

Calculations have already been completed at this point. There are numerous solutions, and they all have varying degrees of ability to address particular physical phenomena.

3.1.4. Solving:
At this point, the computations themselves are finished. There are numerous solutions, each with a unique capacity for addressing certain physical phenomena.

3.1.5. Post-processing:
During the post-processing phase, the results are visualised and examined. We can now review the findings and make judgments. Results obtained in a range of formats, including static or dynamic graphs and tables or graphs and the performance is given the graph fig 3.

Input parameters,

The impeller design generates a pressure of 25.17 kpa, according to the CFD analysis. It works well enough to capture dust particles. So 3D printing is used to create this impeller design.

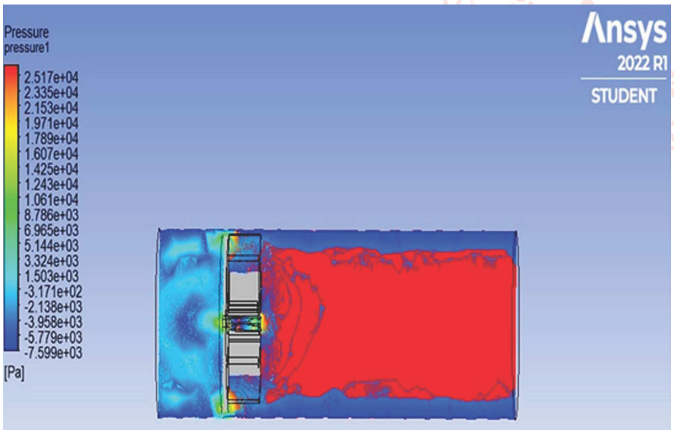

Fig. 3 Post Processing Results

Table 2 Input parameters

S. No.	Input parameters	media or values
1	Fluid	Air
2	Impeller material	Polycarbonate
3	Polycarbonate density	970 kgm^3
4	Rotational speed (N)	6500 rpm
5	Inlet air pressure(Pi)	101325 Pa (absolute)
6	Inlet air temperature(Ti)	30 deg C

3.2. 3D PRINTING
A digital file is used to build three-dimensional solid things using the additive manufacturing process known as 3D printing. A 3D printed object is made by adding layers of material successively until the desired shape is achieved. The product obtained from the Company and is given in fig. 4 to fig. 5.

Using polycarbonate, the impeller is produced in this way.

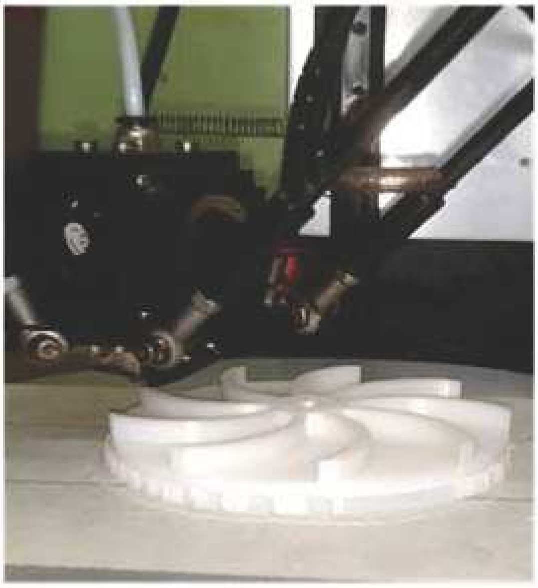
Fig. 4 Casing

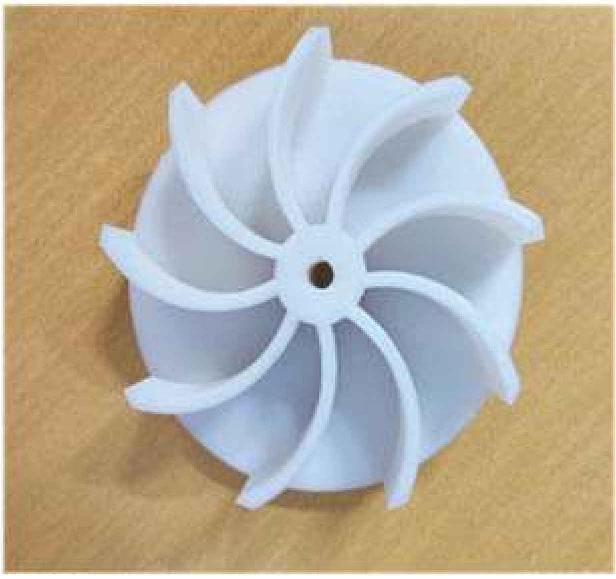
Fig. 5 Inlet Pipe

Table 3 Motor specifications

S. No.	Description	Values
1	Volt	230
2	Watts	60
3	RPM	6500
4	HP	120
5	Brand	Swastik

3.3. Motor
An electric motor is an electrical machine that converts electrical energy into mechanical energy.

Motor is used to rotate the impeller. It is illustrated in fig.

3.4. CASING
Casing is an airtight chamber surrounding the impeller. In this project 4 inch PVC pipe used as casing fig. 6.

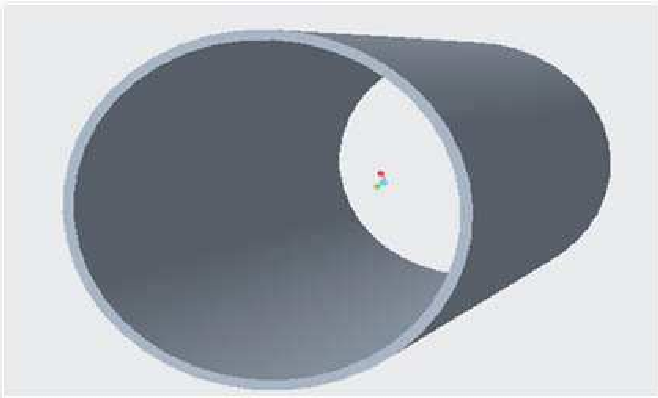

Fig. 6 Casing

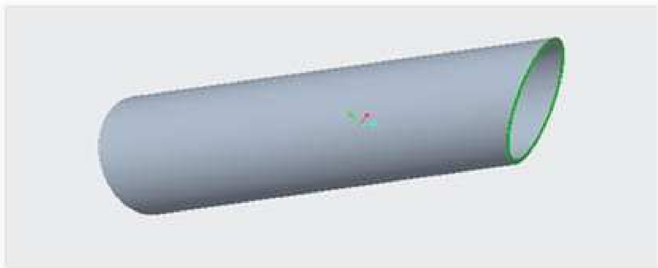

Fig. 7 Inlet Pipe

3.5. FILTER
The purpose of the filter is to separate dust from the air fig. 9.

3.6. INLET
A vacuum cleaner inlet hose is a long cylindrical object which connects to a port on a vacuum. Once attached, the suction is pulled through the hose in order to remove dirt, dust, and debris from areas that may be hard to reach using the main section of the cleaner. In this project 1 inch PVC was used as inlet hose. fig. 7

3.7. COLLECTING AREA
A bagless vacuum cleaner includes a separating unit for storing dust. In this project 4/1.5 reducers were used as a collecting area as well as nozzle. fig. 9

3.8. MINI 2 PIN SPST SWITCH
A Single Pole Single Throw (SPST) switch is a switch that only has a single input and can connect only to one output. A Single Pole Single Throw switch serves in circuits as on-off switches. fig. 11.

Fig. 8 Motor

Fig. 9 Dust Collecting Bag

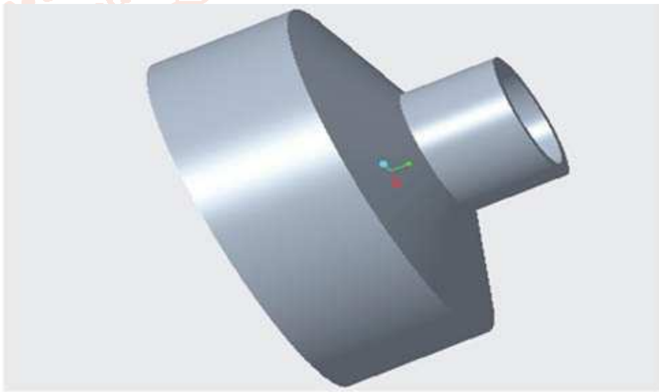

Fig. 10 Dust Collecting Section

Fig. 11 Switch

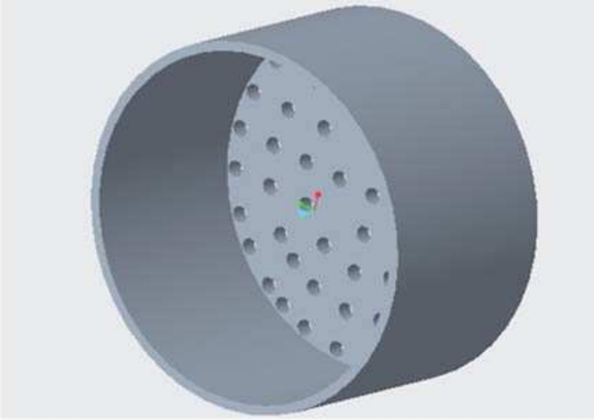

Fig. 12 Exhaust

3.9. EXHAUST
Exhaust is used for releasing the filtered air in to the atmosphere. 4 inch coupling with holes are used as exhaust in this project.te diagram is shown in fig. 12

3.10. FABRICATION
STEP 1: The impeller is fabricated by 3D printing technology.

STEP 2: The fabricated impeller is fixed with the motor.

STEP 3: The 4 inch PVC pipe is cut into required dimensions and 2 holes have been created for clamping the motor.

STEP 4: Motor and impeller assembly fixed inside the casing by clamp.

STEP 5: Holes are drilled on the coupling and the coupling fixed behind casing setup.

STEP 6: Filter is fixed near the impeller.

STEP 7: The 1 inch pipe is fixed into 4/1.5 inch reducer with the help of 1.5/1 inch bush.

STEP 8: The reducer is attached to the casing unit.

STEP 9: Handle setup is fixed on the casing.

STEP 10: The wires are connected to the motor for electrical supply, plug and switch are attached on the wire.

STEP 11: The ON / OFF switch is fixed on the handle.

STEP 12: Check the working of vacuum cleaner.

3.11. Assembled Model
The components are perfectly assembled and its various images are given in figs. 13- 15

Fig. 13 Assembled Model1

Fig. 14 Assembled Model2

Fig. 15 Assembled Model3

4. CONCLUSION
The centrifugal impeller is designed to a portable low cost handheld vacuum cleaner and The designing of components were made in Creo and analysis for the product was done in ANSYS CFD, and impeller was manufactured in the 3D printing machine with polycarbonate material. Also all major parts of the vacuum cleaner are produced from plastics except motor and assembled. The vacuum cleaner works well and performs effectively.

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