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Ecofriendly Design and Development of Bladeless Air Conditioning Fan

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Abstract

A bladeless air conditioning fan is designed and developed with the aim of providing cool air to mitigate the heat during the summer without showing any visible blades or making any noise while it circulates air. The goal was to create a small attractive and portable bladeless fan which also included a useful air conditioner. To produce a cooling effect using a bladeless mechanism, a miniature Peltier-based system is used. Also, a blower mechanism is used to suck in air from bottom and blow out cool air through the top. A noise cancellation module is built into the product to reduce noise. This cooling-focused model was used to develop this bladeless air conditioner fan. In terms of cost, style, size, and shape, the bladeless air conditioner is superior to the typical cooler.

Keywords
Bladeless Fan, Air conditioning fan, Portable, Peltier Module and Noise Cancellation Module.

1. Introduction
Traditional fans' revolving blades make them potentially hazardous, loud, dusty, and immobile. A table fan is nevertheless portable. However, because to its large design and casing, the blades are more prone to mishaps. Existing bladeless fans create noise and don't provide any air-cooling features. Moreover, the air coolers available in the market do not deliver effective performance and yet are too costly for middle-class people. With this objective in mind, a bladeless air conditioning fan is developed that eliminates these problems in an affordable way. Safety has been taken as a major concern by dismantling the blades, making it one of the safest cooling products available. The newest type of fan, Bladeless Air Conditioning fans doesn't have any visible blades and doesn't make any noise while they circulate air. An air conditioning fan without external blades that blows air from a tube is known as a bladeless air conditioning fan. Its hidden fan blades direct the gathered airflow through a duct that is being designed and blow a thin, smooth airflow moving at a high speed from the tube or a continuous slot across the duct's surface**.** A Peltier module with integrated heat sink and air-cooling fan used into the base frame to create the cooling effect. Then this cooling air is out from the blowing ring to the user which will provide a satisfactory feeling to hotness. A transformer is used to provide ac power source. The way things stand right now, coolers are essential to our daily lives. It is the most crucial component for stress relief in the summer. Because of this bladeless air conditioning fan, people can work continuously for a longer period of time without becoming frustrated. Existing fans create noise and doesn't provide any air-cooling feature. Moreover, the air coolers available in the market do not deliver effective performance and yet are too much costly for middle class people.

1.1 Objectives
Developing a bladeless air conditioning fan that will eliminate the problems described above in an affordable way. We have also taken safety as a major concern by dismantling the blades making it one of the safest cooling products available. Also, the design of the fan is developed to eliminate noise to make more user friendly. In terms of cleaning, the need has been taken to near to zero. Lastly not the least, our lean engineering approach will make it one the cheapest yet most effective product in the competitive marketplace.

2. Literature Review
Meston (1906) took a United States Patent on a ceiling fan, which claimed a ceiling fan's components include a rotor, wings, a stator, a fixed shaft that is clamped to the stator, a shield to protect the fan, and/or an electric portion that is attached to the fixed shaft. Gageet al. (1928) registered a United States Patent on an electric motor-driven desk fan, which described a table fan with a tubular base containing an enclosed motor and blades. De-Zheng(2013) enrolled a United States Patent on bladeless air fan suggested the design featuring a bladeless

air fan comprising a host and an airflow guiding frame with rotatable sections within each housing section, and a pivoting section. Zou (2013) published another study that suggested a bladeless fan with a base, airflow, and a stationary body positioned under the rotating body. Gammack et al. (2012) suggested a bladeless fan assembly including a nozzle mounted on a base housing a device creating an airflow through the nozzle extending orthogonally about an axis to define an opening through which air from outside the fan assembly is drawn by the air flow emitted from the mouth. Jafari et al. (2016) performed a numerical investigation and figured that the cross-sectional height of the fan, outlet angle of airflow relative to the fan axis, the thickness of the outlet slit, hydraulic diameter, and aspect ratio have a significant effect on the performance of this product. According to Li et al. (2016), an experimental analysis of the annular jet's output flow field measured the output flow field at five Reynolds numbers between 28200 and 40100. It demonstrated that when the Reynolds number rises, the turbulence intensity and time-averaged velocity on the axis all increase as well. Jafari et al. (2017) looked into the impact of geometrical parameters on the aeroacoustics sound performances of bladeless fans using a three-dimensional numerical simulation and suggested that height of fan cross-section, outlet angle of airflow in relation to the fan axis, thickness of outlet slits, hydraulic diameter, and aspect ratio affect how well bladeless fans produce aeroacoustics sound. Patel et al. (2018) in order to solve the problem of getting hot air in the summer, the author proposed a bladeless fan with a cooling effect. It has been done by using a Peltier module to produce cooler air. Chang and Doblack (2018) investigated an integrated heat pump and thermoelectric cooling with a bladeless fan and suggested a cooling system using a Peltier module. Aslam et al. (2021) investigated in this paper the use of a bladeless fan as a conventional circulating fan and suggested an optimum design and parameter values at which a bladeless fan provides maximum outlet volumetric flow. Based on this analysis, they claimed that a bladeless fan was suitable for use as a cooling fan. Ravi and Rajagopal (2022) suggested that the discharge ratio of all the aero foil profiles increases with an increase in slit angle from 20 to 80. From the study, it was observed that the Eppler 473 aerofoil profile with a slit thickness of 1 mm and a slit angle of 80 provided the maximum discharge ratio of 34.17 for an inlet mass flow rate of 80 LPS. Li et al. (2014) Normal surfaces could not produce an effective blowing effect as compared to the Coanda surface. As the authors realized this and analyzed the effect of curvature on a Coanda surface, which was related to the blowing effect of a bladeless fan, Finally, they selected a Coanda surface with optimized curvature, which would improve the blowing effect of the bladeless fan. FAN (2022) research revealed that a bladeless fan that had at least three telescopic brackets and a fan body was provided by the disclosure. The base of the fan was made up of several guide members, each of which was successively arranged into a single telescopic bracket. Tomar et al. (2022)created a product that would give us cool air without using any visible blades. The author also claimed that because they used nichrome wire, it would provide warm air in the winter.They used the evaporative effect to give a sensation of cooling to the user.

According to the aforementioned literature review, traditional fans are stationary, noisy, dirty, and potentially dangerous due to their rotating blades. Even so, a table fan is mobile, it has a bulky shape and a case that make the blades vulnerable to accidents. The design, construction, and various elements were studied and affected the sound and air flow of bladeless fans. The outlet angle of a bladeless fan, as well as the geometric parameters, aerodynamic performance, outlet flow field structure, Reynolds number, and aeroacoustics sound on performance, all have an effect on outflow and performance.The current bladeless fans were observed without any noise cancellation system. Additionally, the current bladeless fan is bulky and has a displeasing design. From the aforementioned literature review, we identified a gap where work can be done on the noise cancellation system, portability, cooling system, and attractiveness.

3. Methods

The following methods were used to design and develop the ecofriendly bladeless air conditioning fan.

3.1 Idea generation:

During the summer, unbearable heat was experienced, prompting consideration of existing cooling devices. Keeping this issue in mind, a survey of 162 respondents was conducted to collect user experience and feedback on the existing cooling device. Perceptual mapping, benchmarking, and reverse engineering techniques were applied to the survey data to generate ideas for new products and find gaps for development.

3.2 Market analysis

To find prices of existing cooling device, major competitor ,users preferences and satisfaction about existing cooling devices a survey was conducted on 204 respondents to find out the basic needs, requirements, satisfaction and preference, market area, potential customer & feedbacks of the consumers on existing cooling product.

3.3 Identifying Customer Requirements

Kano Model Customer Need Assessment frame work was applied on a survey data which was conducted on 32 respondents to know the preference of customers about functions and features. Table 1 shows the findings of Kano Model Customer Need Assessment.

Table1. Outcome of Kano Analysis

No	Features	Status
1	Bladeless	Must Be
2	Air conditioning effect	Must Be
3	Noiseless	Attractive
4	Affordable	Attractive
5	User friendly	Indifferent
6	*Safe & Convenient*	Must Be
7	Portable	Attractive
8	Easy to clean	Indifferent
9	Longevity	Attractive
10	Low energy consumption	One Dimensional

3.4 Objective Tree

Customer requirements found in Kano Model Customer Need Assessment frame work were used to develop an objective tree.The objective tree is a tree shape structure which provides the overall objectives of a product.

3.5 Quality Deployment Function(QFD)

Quality Function Deployment (QFD) technique was used to convert customer requirements into technical requirements. The customer requirements found in Kano Model Customer Need Assessment frame work and preferences about various features were used in QFD technique.

3.6 Specification & Design Analysis

A basic design of the proposed bladeless air conditioning fan was developed based on the functions and features found in keno model and QFD. Figure 2 represents the drawing of shape and size of the frame and blowing ring. Figure 3. shows arrangement and drawing of cooling fan heat sink and Peltier module. Figure 1 describes the functional structure of the bladeless air conditioning fan.The design of the fan and Peltier module and the functional structure of the fan are given below. The functional structure represents how the proposed fan converts inputs like air, power into cool air .

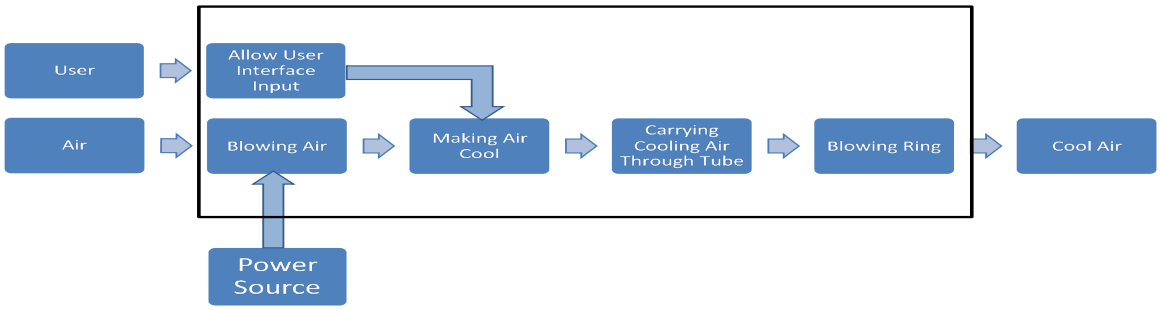

Figure 1. Function structure for Bladeless Air Conditioning Fan

The required components to build the proposed features and functions are divided into electrical and mechanical components. Required electrical components are: blower motor, Peltier module, heatsink, cooling fan, electrical and wiring, switch, transformer, and noise-canceling module. Required mechanical components are:motor

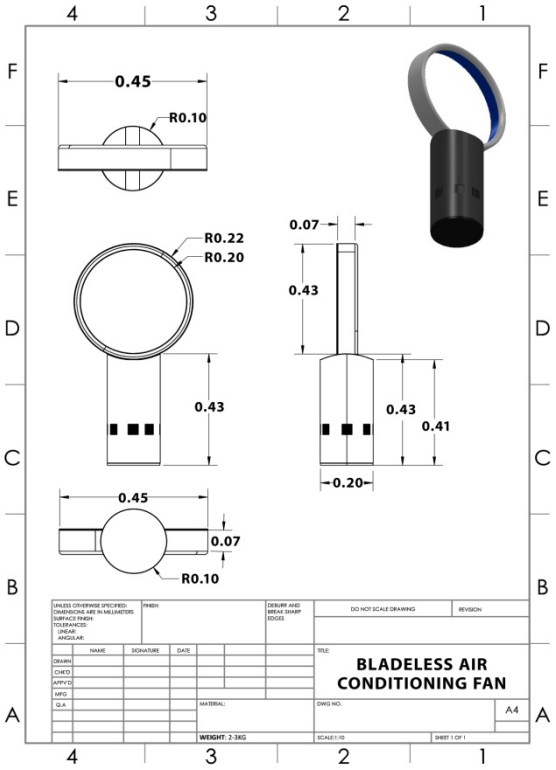

Figure 2. Drawing of Base Frame and Blowing Ring.

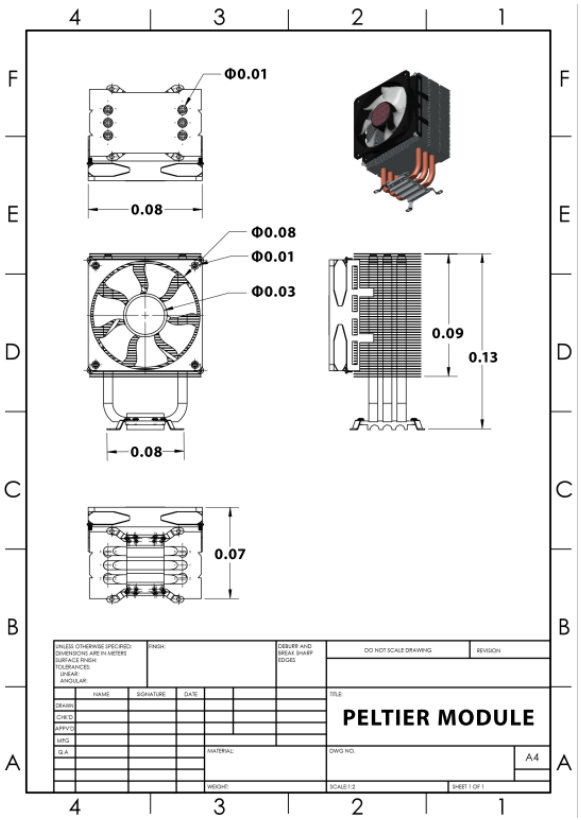

Figure 3. Drawing of Peltier Module

mounts, base frame, supporting frame, screw &fittings, steel mesh, blowing ring. Table 2 and Table 3 Shows the specifications chart of the proposed design.

Table 2. Required electrical components of the fan

Parts Name	**Quantity**
Blower Motor	1
Peltier Module	4
Heatsink	2
Cooling Fan	2
Electrical & wiring	Not fixed
Switch	1
Transformer	1
Noise Cancelling Module	1

Table 3. Requiredmechanical components of the fan

Parts Name	**Quantity**
Steel Mesh	1
Blowing Ring	1
Motor Mounts	4
Base Frame	1
Supporting Frame	1
Screw & Fittings	Not Fixed

4. Data Collection

The entire sets of data were collected via four surveys on 621 participants of Bangladesh, where 162, 204, 32, and 223 respondents participated in the idea generation survey, market analysis survey, Keno model need Assessment survey, and evaluations of the proposed design and development functions survey, respectively. Table 4Represents the number of total participants of different professions. At the time of data collection, bias was restricted ensuring respondents of different places, organizations and institutes. Some contradictory questions were added to the survey to identify false answers. To make the data more diverse, the four surveys were done with different types of professions and different ages of respondents. Students, employees, businessmen, teachers, etc. were the participants in the survey. In the idea generation survey, the goal was to collect people's perceptions, feedback, and experiences to discover the existing products' lackings and scopes of development and create a user-focused product at an affordable cost. The market analysis survey was conducted mainly to find people's needs, requirements, and preferences for cooling devices. Also, to identify people's interest in the proposed fan Keno Model Need Assessment survey was performed to identify users or peoples desires and preferences regarding various functions and features of bladeless fan like Bladeless, Air conditioning effect, Noiseless, Affordable, User friendly, Safe & Convenient, Portable, Easy to clean, Longevity, Low energy consumption. An evaluation of the proposed design and development functions survey was done to take user feedback on the proposed design and development of the bladeless fan. All surveys were conducted offline and online.

Table 4. Profession of participants

Profession	numbers
Students	334
Teachers	86
Employees	73
Businessmen	47
Others	81

5. Result and Discussion

The proposed design of the fan is in the design and development phase. The main study on the development in functions and features of existing bladeless fan. So, the design and features, including an approximated cost, were described and explained to 223 persons. After the explanation and description, feedback and evaluation were taken from the persons. According to the survey results, 67% of the respondents were new to the product and 73% of the respondents were satisfied with the proposed features and functions. Market analysis survey result shows 73% respondents of 204 respondents were highly interested to try out the proposed bladeless fan.

5.1 Graphical Results

Figure 4 represents objective tree of the bladeless air conditioning fan. All objectives and requirements of the fan identified from the Keno Model Need assessment, and surveys are categorized into three main objectives based on safety issues, economic aspects, and quality aspects to represent the whole objectives of the proposed development affordably. Also, the objective tree caters to the whole functions and features into a plate in an easy representation.

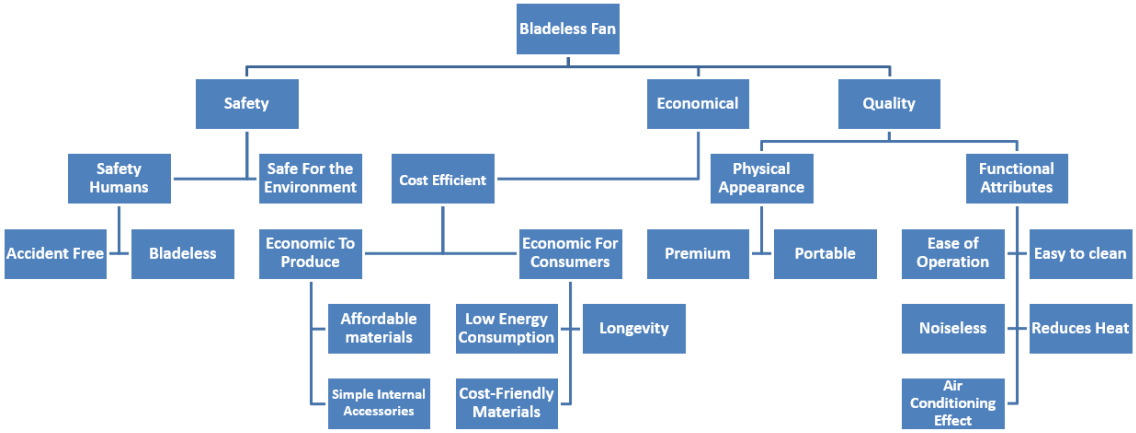

Figure 4. Objective Tree of the Bladeless Air Conditioning Fan

To uphold the relation between the product function and customers, some certain symbols for ease of understanding are used in QFD analysis. Table 5 depicts the direction of improvements of the technical requirements. The symbol means the technical functionality must be increase as much as possible. On the other hand, the symbol means

Table 5. Direction of improvement for technical requirements

Improvement	Direction
Increase	▲
Decrease	▼

Table 6. Number to define relationship between the customers and technical requirements

Types of correlation	**Symbol**
No relation	0
Weak relation	1
Moderate relation	3
Strong relation	9

Table 7. Symbol to illustrate correlations between technical requirements

Types of correlation	**Symbol**
Strongly positive	++
Positive	+
No correlation	Blank
Negative	-
Strongly negative	--

Customer importance rating	Functional Requirements (How's) → / Customer Requirements - (What's) ↓	Bladeless	Power	Peltier effect	Dimenssion	Attrative	Noise Cancelling Module	Weighted Score
	Desired direction of improvement (↑,0,↓)	▲	▼	▲	▼	▲	▲	
10	Air Conditioning Effect	3	9	9	3	0	0	240
10	Safe & Convenient	9	0	0	3	1	3	160
9	Affordable	9	3	9	9	3	0	297
9	Noiseless	9	0	0	0	1	9	171
9	Longevity	1	0	3	0	0	0	36
8	Portable	0	0	0	9	9	0	144
8	Low Power Consumption	1	9	3	0	0	0	104
7	Easy to clean	9	0	0	3	1	0	91
7	User friendly	3	0	0	1	0	0	28
	Technical importance score	383	189	222	241	125	111	1271
	Importance %	30%	15%	17%	19%	10%	9%	100%
	Priorities rank	**1**	**4**	**3**	**2**	**5**	**6**	

Figure 5. QFD Analysis of the Bladeless Air Conditioning Fan

the technical function must be decreased as much as possible.Table 6 represents the relationship status scores between customer requirements and technical requirements, where 0,1,3 and 9 mean no relation, weak relation,

moderate relation, and strong relation, respectively. Table 7 provides the meaning of symbols '++', '+', 'Blank', '-', and '- -' used in QFD analysis to show the correlations between technical requirements. Figure 5 shows QFD analysis output and finding of technical requirements, relationships between technical functions and direction of improvements of the technical functions. From the QFD analysis, it can be seen that the main priority of the product is the bladeless effect, which reduces power consumption. Again, the Peltier effect is highly proportional to power consumption, as cooling the environment requires a lot of power. Also, if the size of the blower ring increases, the whole dimensions of the product increase. The Peltier module also takes up space inside the frame, so the more the Peltier module attaches, the larger the frame will be. A noise cancellation module is attached to increase the product's attractiveness. The analysis also shows that the dimension has some effect on the attractiveness of the product. The QFD analysis also shows that the bladeless effect should be increased as much as possible. Power consumption should be reduced as we want to make it energy-saving. Furthermore, the Peltier effect should be stronger so that the environment can be cooled quickly. The size of the product should be minimal so that it can be moved easily from one place to another. Customers will love the attractiveness of the product, so the attractiveness of the product should increase. Finally, the noise cancellation module will reduce noise, which will satisfy the customer, so function should be improved. To fulfill the customer requirements the required main technical components are:base frame, blowing ring, blower Motor, Peltier Module, cooling fan ,noise cancelling module ,transformer.

Table 8. Priority list of the technical requirements of the fan according to QFD analysis

Priority list	Function
1	Bladeless
2	Dimension
3	Peltier effect
4	Power
5	Attractive
6	Noise cancelation module

Table 8. represents the findings of QFD analysis where the technical requirements are arranged by their priority ranking.

6. Proposed Improvements

The study was mainly performed to add some new features and functions and development in some sections of traditional bladeless fan. The study proposes a low-cost attractive portable bladeless fan with air conditioning effect. Also, the proposed fan will not produce any noise. It also offers user-friendly features such as easy cleaning, ease of operation, and no risk of injury. Also, the design will provide an attractive outlook.

7. Discussion

As all data used in the study are collected from surveys. Therefore, the proposed design and development are based on the people's perceptions, desires, and needs. So, the proposed design and development may not fit in some cases because of the different wants, perceptions, and needs of different people in different geographies. Furthermore, the project is still in the design and development stages. So, some proposed features and functions may vary at the time of manufacturing.

8. Conclusion

The bladeless air conditioner fan design is effective in every manner. The proposed design and functionality can satisfy the needs and demands of the users. It is appropriate for use in homes, offices, and other places. It is a reasonably priced air conditioning model. As a result, the middle and lower classes may be able to afford it. The successful implementation of the product will enable a more feasible and cost-effective solution to air cooling than traditional methods for people of all economic backgrounds. The business prospects of the development are also immense. The aim is to make the product renowned in the market, making its use as frequent as regular fans, which are fulfilled by the proposed features and functions. It has the potential to have a dominant position in the competitive market for air cooling. The main contributions of the study develop and design a noiseless, attractive, and portable bladeless air conditioning fan at an affordable price for people of all economic backgrounds.

9. Future Scope

The bladeless air conditioning fan offers the functionality of air cooling. But it is also to be noted that the Peltier module used in the product is also able to increase temperature, being a thermoelectric module. The module enables it to implement as a heater, too. This will further extend the product's capability as a multi-functional device for warming and cooling simultaneously.

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Md. Nehal Hossen is a student of the Department of Industrial and Production Engineering at the Rajshahi University of Engineering and Technology. He is currently studying in 3rd year. Aside from his studies, he is a motion designer and an animator. He is also a 3D modeller and has worked on some 3D projects.

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Nayeem Uddin is an engineering undergrad who attends Rajshahi University of Engineering and Technology (RUET) in Industrial and Production Engineering. He puts a lot of effort and enthusiasm into his work and strives for excellence. These assist him in continuously updating his knowledge and learning new things. He currently works with "Team Crack Platoon" as a business team member. He adores playing football and cricket. In 2015, He received the "President's Scout Award." He possesses various abilities, including leadership and proficiency with Microsoft Word, PowerPoint, and Excel. Also, he wants to be a good person.

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