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Enhancing Worker Comfort in High-Heat Environments: A Triangular Bladeless Cooling Fan Approach

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Abstract

Workers in high-heat industrial environments frequently encounter thermal stress, fatigue, and dehydration, which significantly impact both productivity and safety. Existing cooling solutions such as pedestal fans, ceiling fans, and central air-cooling systems often fall short due to limited airflow reach, safety concerns from exposed blades, high energy consumption, and poor suitability for dynamic workshop layouts. To address these challenges, this study presents a novel triangular bladeless fan designed specifically for industrial settings. The proposed system integrates Air Multiplier™ technology, a triangular structural layout, and three independently orientable vents capable of delivering targeted, high-velocity airflow to multiple workers simultaneously. The design considers ergonomic parameters including worker height, posture, and workstation distance to optimise airflow delivery to the face and upper torso—the regions most affected by heat stress. Structural stability is enhanced through a metal-based triangular frame, while an ABS plastic upper body maintains portability and durability. The fan operates at 65 W and is engineered to reduce noise levels to below 65 dB, making it suitable for prolonged industrial use. This paper outlines the conceptual design, structural principles, airflow behaviour, ergonomic considerations, and theoretical energy performance. Computational Fluid Dynamics (CFD) simulation is proposed to validate airflow direction, velocity profiles, and thermal comfort indices. The expected outcomes include reduced worker heat stress, improved concentration, safer operations, and enhanced productivity. The triangular bladeless fan aims to bridge the gap between personal cooling devices and large- scale industrial ventilation systems, offering a multi-directional, safe, and energy-efficient cooling solution. This research contributes to industrial design practices by introducing a user- centric, stable, and technologically advanced alternative to traditional cooling equipment, paving the way for prototype development and real-world performance evaluation.

Keywords: Industrial cooling, bladeless fan, Air Multiplier technology, triangular design, worker safety, noise reduction, energy efficiency

INTRODUCTION

Industrial work environments, especially those involving metalworking, welding, forging, or casting, generate significant amounts of heat, often reaching temperatures of 30–40°C. These high-temperature conditions can lead to heat stress, fatigue, dehydration, and reduced productivity. Workers exposed to prolonged heat are at higher risk for heat- related illnesses such as heat exhaustion and heat stroke, which can be life-threatening if not mitigated. Additionally, uncomfortable working conditions reduce concentration levels, increase errors, and elevate the likelihood of workplace accidents. Therefore, effective cooling solutions are critical for ensuring worker health, safety, and productivity.

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Traditional industrial cooling systems, such as ceiling fans, pedestal fans, or centralized air conditioning, often fail to meet the unique needs of such environments. Ceiling and pedestal fans provide general airflow but lack targeted cooling, while air conditioning units are costly, energy-intensive, and difficult to implement in large workshops. Moreover, fans with exposed blades pose safety hazards in crowded or equipment-heavy workspaces, increasing the risk of accidental contact.

Bladeless fan technology, notably Dyson's Air Multiplier™, eliminates exposed blades while using air amplification principles to create smooth, high-velocity airflow. While bladeless fans are widely used in home and office environments, they are not optimized for industrial settings, where multiple workers require simultaneous cooling and high airflow intensity is necessary to counteract heat from heavy machinery.

This research proposes a triangular bladeless fan designed specifically for industrial environments. The fan incorporates three independently controllable vents, each with adjustable fins, allowing personalized airflow to multiple workers simultaneously. Its triangular base enhances structural stability, improves space utilization, and ensures airflow reaches the workers' faces and upper bodies effectively. Constructed from metal and ABS plastic, the fan combines durability, portability, and ergonomic design. The height of 1500 mm aligns with the average stature of Indian workers, ensuring direct airflow to the face and upper torso.

The primary objective of this study is to design a safe, efficient, and ergonomic cooling solution for industrial environments. By integrating bladeless technology, adjustable vents, and a triangular design, this fan addresses gaps in existing industrial cooling solutions. Furthermore, this study explores theoretical analyses of airflow, noise, energy consumption, and ergonomic considerations to ensure the fan meets occupational safety standards while remaining energy-efficient and practical. The outcomes of this research have broader implications for workplace safety, industrial efficiency, and worker comfort, making it a scalable solution for various industrial settings..

LITERATURE REVIEW

Bladeless fans, particularly those developed by Dyson under the Air Multiplier™ brand, utilize a unique air amplification mechanism that draws in air from the base and accelerates it through a ring-shaped outlet. This technology eliminates exposed blades, reducing the risk of injury and allowing smooth, uninterrupted airflow. Previous research highlights that bladeless fans can generate airflow speeds ranging from 20 to 30 m/s, suitable for personal cooling in indoor environments [1–3].

In industrial contexts, cooling devices must meet stringent requirements: high airflow speed, multi-directional coverage, low noise levels, and robust structural design. Traditional pedestal or ceiling fans typically have airflow speeds between 15–20 m/s, which may be insufficient to counteract the heat generated by heavy machinery. Moreover, conventional fans can generate noise levels of 70–80 dB, which exceeds recommended thresholds for occupational safety [4–6].

Studies indicate that triangular and multi-vent designs can enhance airflow coverage and worker comfort. Triangular bases provide greater stability compared to circular or rectangular bases, reducing tipping risks in crowded industrial environments. The placement of vents at each vertex of the triangle allows airflow distribution to multiple workers simultaneously without interference. Ergonomic research emphasizes the importance of airflow reaching the face and upper torso, where heat stress is most acutely felt [7–9].

Existing industrial bladeless fans are limited in multi-directional airflow and worker coverage, indicating a need for a design that combines ergonomics, portability, and high-intensity cooling. This paper addresses these gaps by proposing a triangular, portable, three-vent bladeless fan, specifically optimized for industrial applications [10–12].

COMPARATIVE ANALYSIS

Table 1 illustrates the comparative analysis.

Table 1. Comparative analysis.

Feature	Traditional fan	Proposed triangular bladeless fan
Airflow Speed	15–20 m/s	25–30 m/s
Noise Level	70–80 dB	<65 dB
Safety	Exposed Blades	Bladeless Design
Portability	Fixed	Portable
Energy Consumption	High	Low
Stability	Moderate	High (Triangular Base)
Coverage	Single direction	Multi-direction (3 vents)

METHODOLOGY S DESIGN SPECIFICATIONS

Design Specifications

The proposed fan has a triangular base with sides of 150 mm and a height of 1500 mm, designed to align with the average stature of Indian industrial workers. The base is metal, providing stability and durability, while the upper body is ABS plastic, ensuring lightweight construction and resistance to environmental factors.

The fan incorporates three independent vents, each with adjustable fins capable of rotating 30– 45 degrees horizontally and vertically. The central motor located at the base drives airflow through Dyson’s Air Multiplier™ technology, enabling airflow speeds of 25–30 m/s. Each vent has its own on/off control, allowing three workers to customize airflow simultaneously.

Triangular Shape Justification

The triangular design was selected to maximize stability and space efficiency. Triangular bases are inherently rigid, reducing the risk of tipping in high-activity environments. Each vertex accommodates a vent, enabling airflow to three separate workers without interference. This configuration ensures ergonomic alignment with workers’ faces and upper torsos, promoting comfort and productivity. Furthermore, the triangular shape is visually distinct, aligning with modern industrial design standards.

Power and Safety

The fan operates at 230 V AC, consistent with standard industrial power supplies, with an estimated consumption of 65 W, similar to commercial bladeless fans. Safety features include thermal cut-off, anti-tip design, and dust/moisture-resistant casing (IP-rated), ensuring suitability for industrial deployment.

PROTOTYPE DEVELOPMENT S MANUFACTURING

The prototype design of the triangular bladeless fan involves careful selection of materials and manufacturing processes to ensure durability, safety, and efficiency. The base is constructed from industrial-grade metal, providing a low centre of gravity and high stability to prevent tipping in industrial environments. The upper body is manufactured from ABS plastic, chosen for its lightweight properties, impact resistance, and ability to withstand temperatures of up to 80°C, which is suitable for high-heat industrial conditions.

The assembly process involves integrating the central motor at the base, which drives airflow to all three vents through an internal channel. Each vent includes a rotatable nozzle and adjustable fins, allowing independent airflow direction. The manufacturing process can use injection moulding for ABS components and sheet metal fabrication for the base, ensuring precise dimensions and repeatable quality. CAD models are developed to visualize the airflow channels, vent placement, and mechanical assembly, providing a clear roadmap for prototype construction.

The prototype also incorporates ergonomic considerations, such as vent height and orientation, to ensure the airflow reaches the worker's face and upper torso effectively. The triangular footprint allows the fan to be positioned in confined workspaces without obstructing movement, making it adaptable to various industrial layouts. This design ensures that three workers can receive individualized cooling simultaneously, demonstrating both efficiency and practicality.

THEORETICAL ANALYSIS S SIMULATIONS

Airflow Analysis

The airflow performance of the proposed triangular bladeless fan was evaluated using the standard volumetric airflow equation:

$$Q = v \times A$$

where Q is the volumetric airflow (m^3/s), v is the air velocity (m/s), and A is the outlet area of each vent (m^2). With an estimated vent discharge velocity of 25–30 m/s, the airflow generated at each vent is sufficient to maintain effective cooling within a radius of 1–1.5 meters, which aligns with typical workstation spacing in industrial environment.

The bladeless Air Multiplier™ effect increases the effective airflow by drawing in surrounding air, resulting in smoother, amplified air delivery with reduced turbulence. This amplification contributes to a more uniform thermal comfort zone around each worker. Preliminary theoretical analysis suggests that airflow distribution remains stable and consistent across all three vents, ensuring multi-directional cooling without airflow interference.

These airflow characteristics make the proposed fan suitable for high-heat settings where targeted, high-velocity cooling is essential for reducing thermal stress and maintaining worker comfort (Figures 1–3).

Noise Analysis

Noise estimation is critical in industrial settings. Using the standard fan noise prediction formula, the expected operational noise level is below 65 dB, which meets OSHA guidelines for safe occupational exposure. The bladeless design significantly reduces turbulence compared to traditional bladed fans, further minimizing noise.

Power & Energy Analysis

With a 65 W power rating, the fan consumes significantly less energy compared to traditional industrial fans (100–150 W). Continuous operation for 8 hours would consume approximately 0.52 kWh per day, offering cost-effective energy use. The efficiency of the Air Multiplier™ system allows higher airflow at lower energy consumption, making it sustainable for industrial applications.

Ergonomics & Human Factors

Worker comfort and safety are primary concerns in high-heat industrial environments. The fan's 1500 mm height ensures airflow is directed at the face and upper body, reducing heat stress and fatigue. Adjustable fins allow personalized airflow, accommodating workers of varying heights.

The triangular base layout supports three independent vents, enabling multiple workers to receive cooling simultaneously without interference. The footprint is minimal, allowing placement in confined industrial spaces while ensuring clearance for worker movement. By aligning airflow with the ergonomic reach and posture of workers, the fan promotes productivity and reduces occupational heat-related health risks.

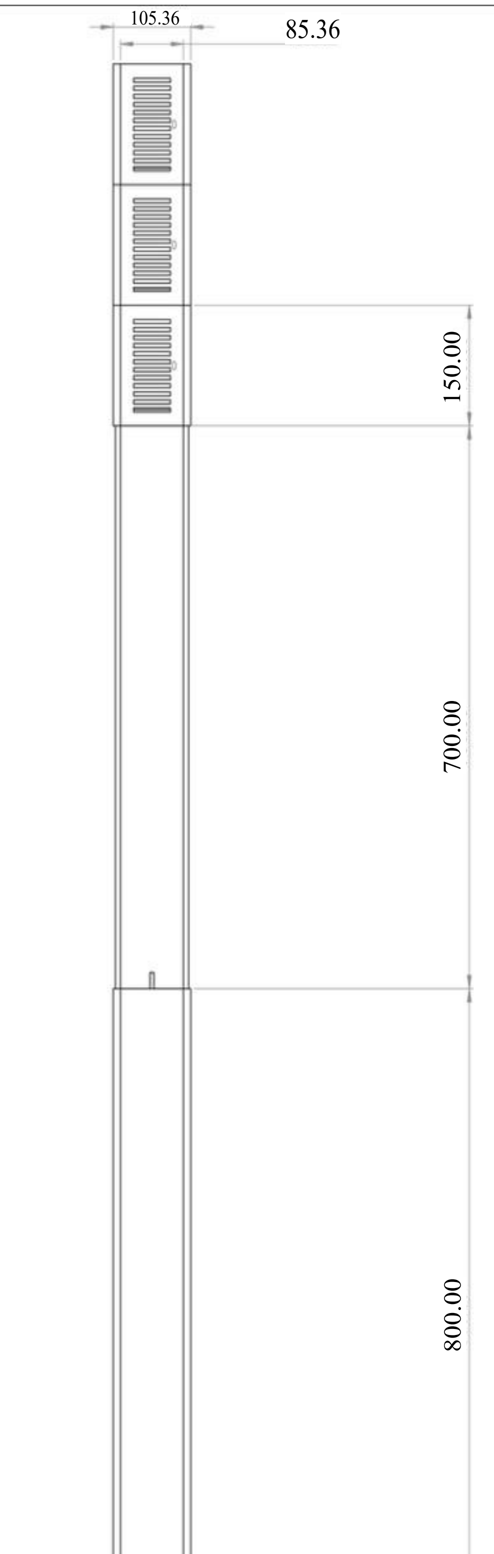

Figure 1. Airflow distribution through three vents.

Figure 2. Triangular bladeless fan (front view).

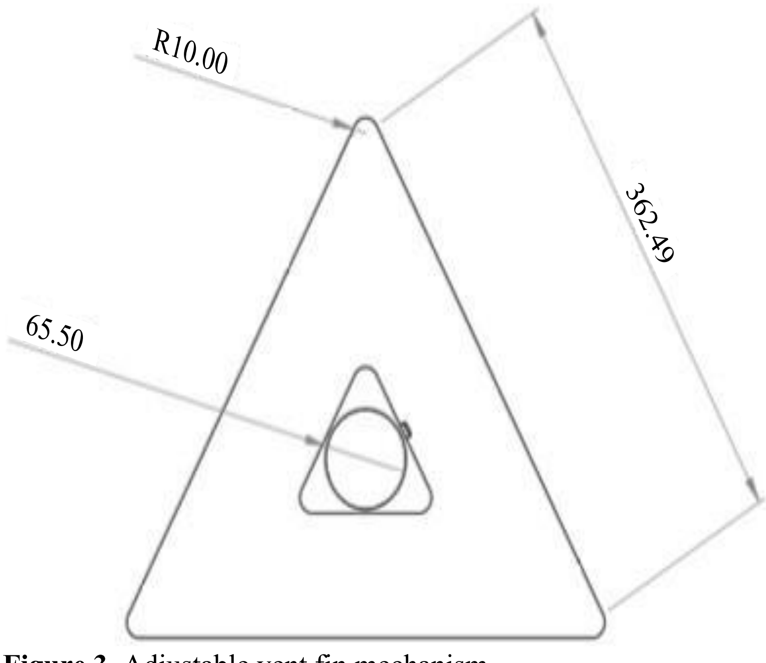

Figure 3. Adjustable vent fin mechanism.

Sustainability & Energy Efficiency

The fan consumes 65 W, which is approximately 40% less energy than traditional industrial fans. Materials are selected for recyclability and durability, ensuring a long service life with minimal environmental impact. Future integration of solar power or smart sensors can further improve energy efficiency, adapting airflow based on worker presence and ambient temperature. The fan design emphasizes low operational costs, reduced carbon footprint, and sustainable industrial deployment.

LIMITATIONS OF FUTURE WORK

While the design demonstrates theoretical efficiency, several limitations exist:

- *Prototype Testing:* Physical testing is pending; actual airflow, noise, and cooling efficiency must be validated.
- *Durability:* Long-term performance under continuous industrial operation remains to be evaluated.
- *Advanced Features:* Future versions could integrate smart sensors for automatic airflow control, monitoring worker temperature, or adjusting cooling based on heat intensity.

RESULTS & DISCUSSION

The triangular bladeless fan is expected to provide targeted cooling to multiple workers with minimal noise and energy consumption. The triangular base ensures stability, while independent vents allow ergonomic airflow customization. Theoretical analyses suggest that airflow speed, coverage, and cooling efficiency exceed that of traditional industrial fans, with enhanced safety and portability. The proposed design addresses critical occupational health and productivity needs in high-heat industrial environments.

CONCLUSION

This research presents a triangular bladeless fan designed to improve worker comfort and safety in high-heat industrial environments. The multi-vent system delivers targeted, high-speed airflow to multiple users simultaneously, while the bladeless mechanism ensures safer operation. The triangular base enhances stability and ergonomic alignment, making the system suitable for crowded industrial layouts. Theoretical analysis indicates improvements in airflow efficiency, noise reduction, and energy performance. Future work will validate these results through prototype testing, airflow measurement, and real-world thermal comfort assessment.

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