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Reverse Engineering And Prototyping Of Engine Cooling Fan

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Abstract: cool air into the engine compartment and circulate it over the cylinder head. This process helps to prevent the engine from overheating, which could result in significant damage. The cooling efficiency of a scooter's engine is heavily dependent on the performance of these cooling fans. Scooters typically use centrifugal fans that have an axial air intake and radial air outflow and are fitted with either backward-curved or forward-curved blades.

This project focuses on the prototyping of an engine cooling fan using reverse engineering techniques. Reverse engineering is used to dissect an existing cooling fan, making it crucial to comprehend its design and functionality. This approach allows for a deeper understanding of the fan's construction and operation.

Key Words: Reverse Engineering, Two-wheeler, Engine cooling fan, 3D model, Scanning.

1. Introduction:

The performance of scooters and motorbikes hinges significantly on the effectiveness of engine heat management. For scooters, maintaining optimal engine temperature relies predominantly on air cooling, while high-performance bikes often opt for liquid cooling systems. Air-cooled engines operate naturally, leveraging ambient air to dissipate heat as the vehicle moves. However, some scooter and bike designs enclose the engine within the vehicle body, limiting natural airflow. To counteract this, a fan powered by the engine facilitates forced air cooling, drawing air through the engine body and fins. This forced air cooling mechanism ensures consistent cooling even in enclosed environments, optimizing engine performance.

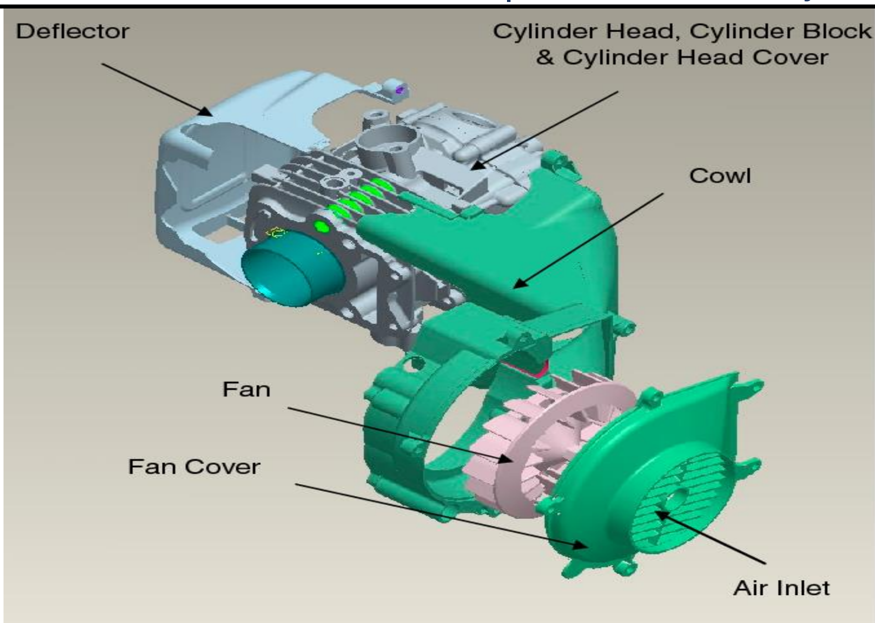
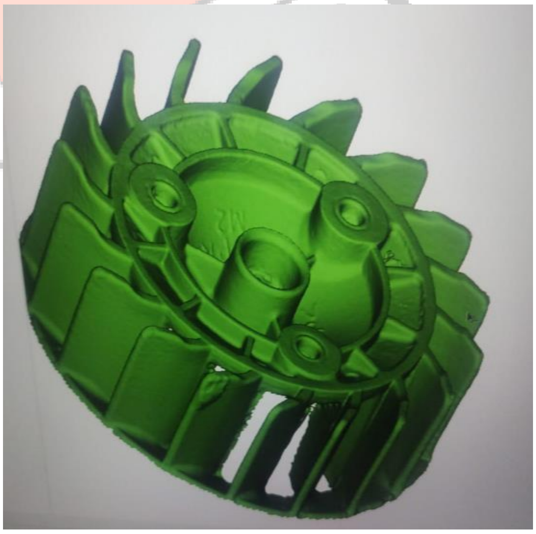


Figure 1: Arrangement of engine cooling fan.

For smaller engines like those powering scooters, air cooling stands out as the preferred method. Given that scooters typically operate at lower RPMs and generate less heat, air cooling proves both suitable and economical. The engine's temperature regulation heavily relies on the cooling fan, especially in situations like heavy traffic or idling. Through reverse engineering, this project aims to ensure the Activa's engine receives efficient cooling. It focuses on either deconstructing an existing cooling fan or designing a new one based on original specifications. Specifically, a Honda Activa engine cooling fan is chosen for scanning, modeling, and 3D printing. The fan undergoes comprehensive scanning across all axes to ensure precise results. Subsequently, the scanned data is translated into a 3D model using Idea maker software, facilitating the prototype's development.

The angular dimension change from the scanned 3D sample model



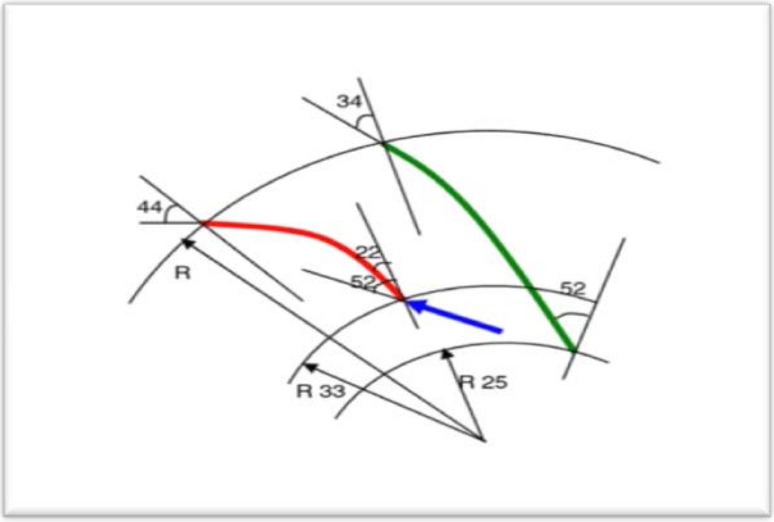


Figure 2: Dimensions of the cooling fan.

2. Methodology:

This involves the steps and procedure involved in this research work. The methodology of how the component is scanned and a 3D model is developed, and prototype is presented below.

1. **Planning:** Identify product or system that needs to reverse engineered and define the objectives and goals of the project.
2. **Information gathering:** Collect as much information as possible about the product or system, such as technical specifications, documentation, schematics, and other related materials.
3. **Disassembly:** Physically disassemble the product or system to gain a better understanding of its internal components, mechanisms, and processes.
4. **Analysis:** Use various techniques such as visual inspection, testing, and measurements to analyze the product or system and determine its functionality, behaviour, and interactions.
5. **Reconstruction:** Use the information obtained from the analysis to create a model or prototype of the product or system, which can be used for further testing and development.
6. **Documentation:** Document the entire process of reverse engineering, including the results, findings, and conclusions.

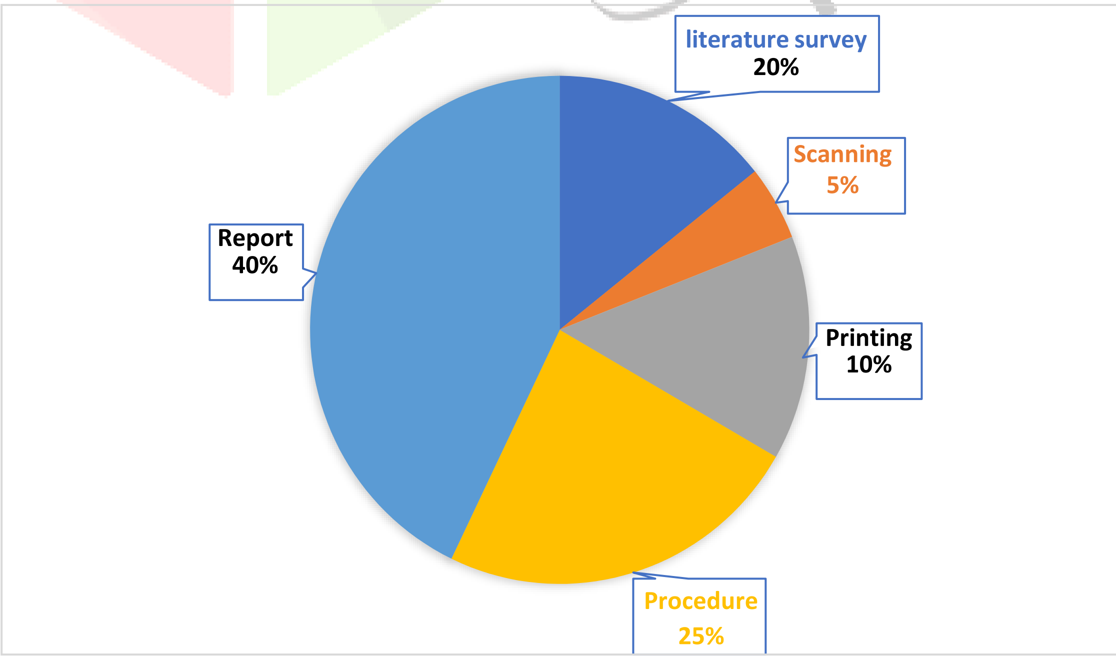


Figure 3: Timeline of project.

2.1 Scanning:

The component underwent scanning utilizing a Calibry 3D scanner, a pivotal step in the project's execution. To facilitate accurate scanning, reference points were established on the component. Initially, scanning occurred solely from one side, after which the reference points were adjusted, enabling scanning of the opposite side in a similar manner. This meticulous approach ensured comprehensive data collection. Subsequently, the gathered data was leveraged to generate a digital 3D model. Such digitized data holds immense utility across diverse applications, underscoring its significance in this project's progression.

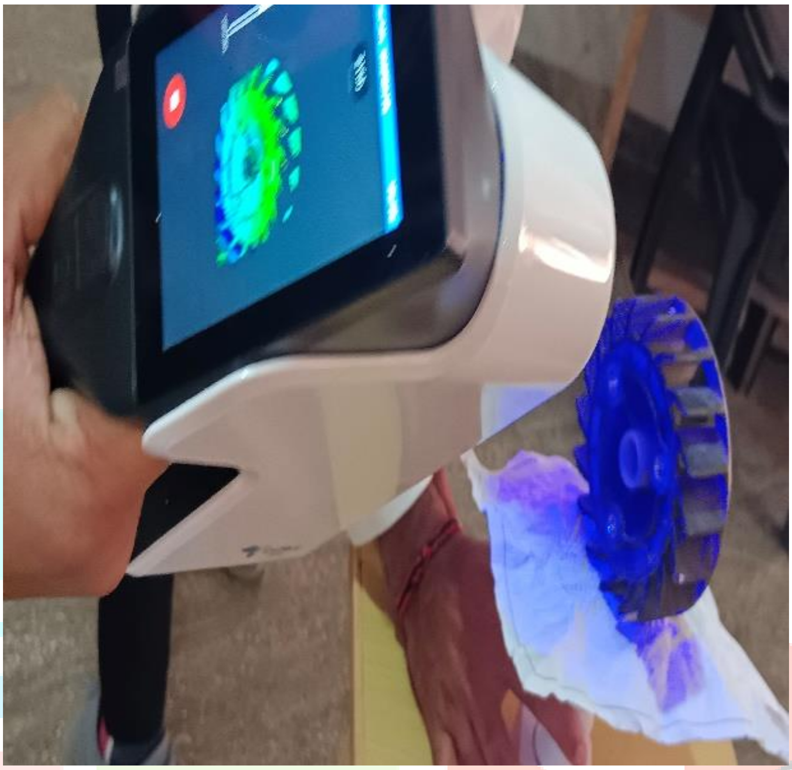


Figure 4: Scanning of the component.

2.2 Design and Analysis:

Upon completion of the scanning process, all captured frames are stored in a file format denoted by ".ascan" extension. These files are stored on the laptop connected to the scanner. Following this, the files can be processed using Calibry Nest. This flexibility allows for seamless data management and analysis, ensuring efficient utilization of the scanned data.

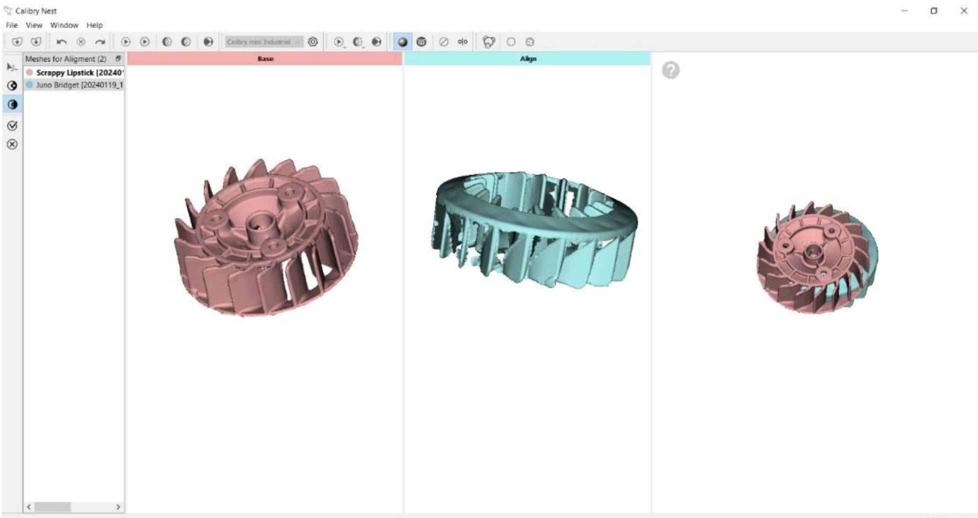


Figure 5: 3D Model developed in the software.

2.2.1. Analysis of the cooling fan:

In the present analysis the 3D model is converted into ".step" from ".stl" format and then imported to Ansys software. The mesh is generated for the 3D model, then the geometry is defined and adjusted accordingly. Now the fluent has to be selected and the fluid flowing through the blades of the fan is choosen as air. Initially as per the vehicle conditions the rpm is assumed as 2000. Heat transfer analysis and combined flow(Conjugate analysis) was conducted with the engine head and block modeled as solid medium and fan cooling system modeled as fluid medium. Cowl geometry was modified for providing better guidance to flow over engine surfaces and to get maximum utilization of cooling capacity of flowing air. Fan size and blade shape were altered to increase the flow rate and reduce fan power consumption. Validation of flow parameters along the cooling path and engine surface temperatures is conducted against experimentally measured values on a test rig. The final design achieves a notable 24°C reduction in oil temperature and a 3.1% decrease in fan power consumption, all while maintaining the same flow rate.

Table 1: Experiment considerations.

Thermal Mass Flowmeter ABB FMT700-P (Sensyflow P)	
Measuring Principle	Hot-film anemometer
Range	10 to 400 kg/h
Measuring error	< ± 1 % of the measured value
Repeatability	< ±0.25% of the measured value
Temperature Effect	< ±0.03 %K of the measured value
Pressure Effect	<± 0.2% /100 kPa of the measured value
Response time	$T_{63} \approx 12$ ms

Table 2: Experimental flow results.

RPM	**Flow rate (kg/h)**	**Static pressure (Pa)**		**% of error**
		Measured	Simulated	
2000	32.5	40	45	11.5
3000	52.3	110	124	6
4000	71.6	205	214	3.5

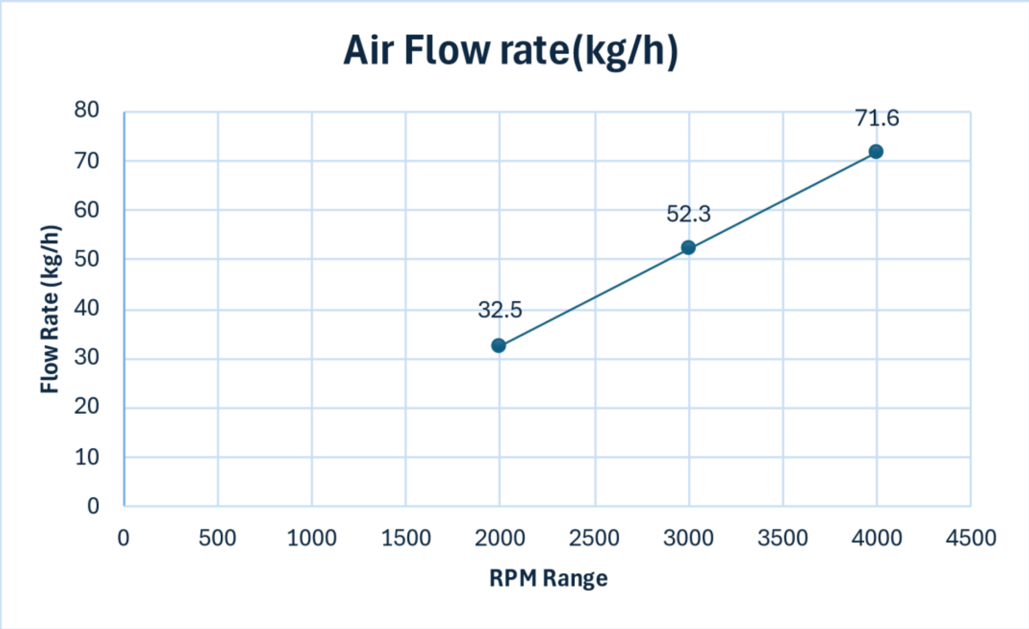


Figure 6: RPM vs Flow Rate graph.

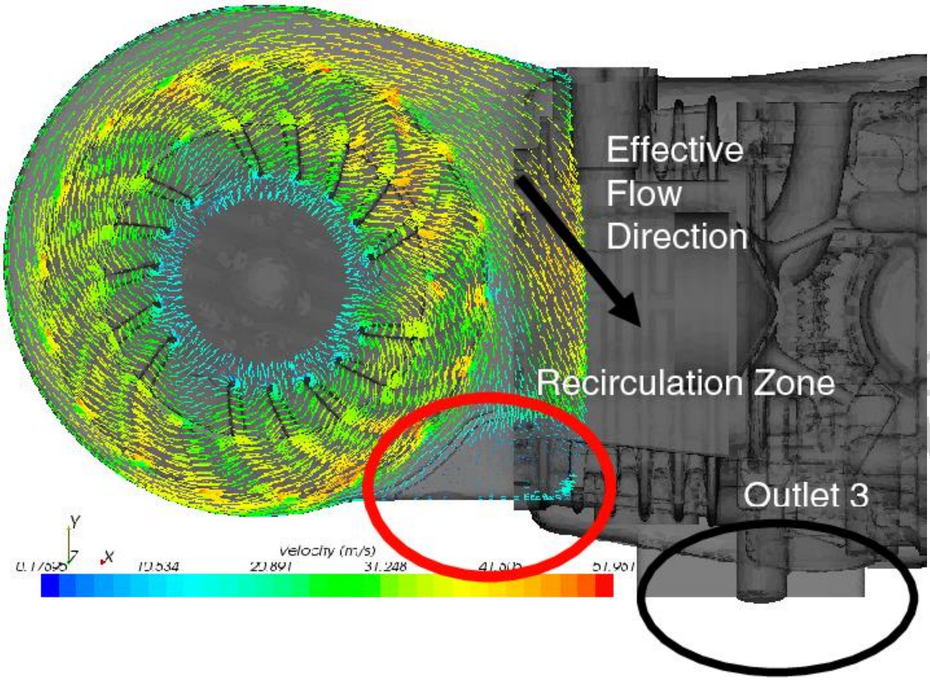


Figure 7: Heat flow from the cooling fan.

2.3 Prototyping:

The selection of 3D printing technology is crucial for fabricating the prototype. In this instance, the design data is converted into STL format for compatibility with the chosen 3D printing method: Fused Deposition Modeling (FDM), a type of rapid prototyping. This process involves layering melted thermoplastic materials to gradually build up the prototype according to the digital design.

This process is simple and includes 3 phases:

1. **Pre-processing:** In this phase we make cad design using cad software such as Autodesk fusion 360. After this, the design model is converted into STL (standard triangle language) format which slices the model geometry and determines the path of layer deposition.
2. **Production:** The 3d printer heats the thermoplastic resin and converts it into a semi liquid form. Then it deposits the resin in an ultra-thin bead to form the model. Where support is needed the 3d printer deposits removable material that acts as scaffolding.

3. **Post processing:** The actual finished model is ready and does not need any further machining. The support material is removed by hands or by dissolving it into a detergent or water.

Figure 8: 3D Printing the cooling fan.

3. Conclusion:

This study presents the outcomes of 3-D numerical simulations aimed at optimizing the cooling system of a fan in a two-wheeler engine. The primary objective was to enhance the flow rate and distribution of airflow over the engine surfaces, ensuring that the maximum temperature of the engine oil and surfaces remains well within the lubrication and material limits, respectively, while minimizing the increase in fan power consumption.

The research focused on reducing the engine oil temperature by 20°C. A combined flow and heat transfer analysis, utilizing Conjugate analysis, was conducted. Here, the engine head and block were modeled as a solid medium, while the fan cooling system was represented as a fluid medium. To account for the fan's rotation, the Moving Reference Frame approach was employed.

Modifications were made to the cowl geometry to optimize the guidance of airflow over the engine surfaces and maximize the cooling capacity of the airflow. Additionally, alterations to the fan size and blade shape were implemented to boost the flow rate and reduce fan power consumption.

The simulation results were validated against experimentally measured values obtained from a test rig, ensuring the accuracy of the model. The final design achieved a remarkable 24°C reduction in oil temperature and a 3.1% decrease in fan power consumption, while maintaining the same flow rate, showcasing the effectiveness of the optimization efforts.

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