

Optimization of Power Consumed by Scooter Engine Cooling Fan

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ABSTRACT

The effective cooling of a two wheeler scooter engine depends on the efficient performance of the cooling fans. In scooters, centrifugal fan with axial air inflow and radial outflow with either backward curved or forward curved blades are used. The air flow enters the unit axially and then spreads out turning to 90 degrees into radially outward direction before meeting the engine. The work aims at the study of performance characteristics of the forward and backward curved fans when put in to engine cowling and to compare the power consumed and flow delivered by the fans. The objective is to compare and reduce the power consumed by the cooling fans and to increase the air flow velocity across the engine surfaces. A Conjugate Heat Transfer analysis has been done to study the effect of forward and backward cooling fans on flow delivered, power consumed and engine surface temperature. RANS K-Epsilon two equation turbulence model was used to solve the 3-D numerical model. Moving Reference Frame (MRF) model was used to simulate the rotary motion of the fan. The engine cowling geometry was modified to avoid recirculation near the fan region and to have flow expansion near the engine head and block. An experimental validation of the fan with the modified cowling profile is done for flow rate, power consumed, temperatures across the fin surfaces. The power consumption was reduced by 31.27% (80 Watts @ 8000 RPM) by the optimized fan for the same operating point. A complete numerical methodology has been developed for the selection of fan for effective engine cooling.

Keywords: Moving Reference Frame(MRF), Forward & Backward curved Fan, CFD, Engine Cowling, Power Consumption

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INTRODUCTION

The scooter engines are not exposed to atmospheric air like motorcycles, hence a forced cooling mechanism has to be employed[1]. In general two wheeler scooter engines are cooled using centrifugal fans. With the need for higher fuel economy scooters, the need to reduce the power consumed by the cooling fan has also increased considerably, as the fan can consume up to 10% of the total brake power of the engine [1]. The use of right engine cooling fan is very important for efficient performance of the engine and optimized engine power consumption of the fans.

The scooter engine cooling mechanism consists of a cowling and a centrifugal fan. The air sucked from the atmosphere is guided in the cowling to the engine surfaces [1]. Centrifugal fan works on a combination of two principles, centrifugal force and deflection of air by the blades. Only the forward curved blades have an effect on flow pattern and performance. The improvement of blades in

centrifugal fans does not have any profound effect as in axial fans, because in centrifugal fans most of the pressure is caused by the centrifugal force [2]. The centrifugal fan has to overcome the flow resistance generated by the engine cowling.

The optimization of the engine cooling fan has the following parameters,

- The fan should remove 1/3rd of the heat generated from the engine surfaces.
- Comparison of forward and backward curved centrifugal fans in the same cowling
- Cowling design modification for lesser flow resistance and increased flow for reduced power consumption.

The flow and heat transfer simulations were carried out using a commercial CFD code SC/Tetra. The work was carried out in six phases. In the first phase, Conjugate Heat Transfer (CHT) analysis is done along with the cowling.

Different mass flow rates of air is forced through the modified engine cowling to check the temperature across the fin surfaces. In the second phase, different mass flow rates of air is forced through the cowling, a system pressure curve is generated for the cowling. The power consumed and flow delivered at the operating point is compared. The fan that delivers the required flow rate at the cowling system pressure is selected. In the fourth phase, both forward and backward curved fans along with the cowling is studied for the flow pattern across and modified in such a way that flow expansion happens only near the engine surface area, recirculation is avoided near the fan region. In the fifth phase, A CHT CFD analysis with MRF model is done for forward and backward curved fans, the temperature at the fin surfaces, power consumed and flow delivered at operating point for cowling is compared with forward and backward curved fans. In the sixth phase, an experimental validation of the selected fan profile with the modified cowling profile is done for flow rate, power consumed, temperatures across the fin surfaces for forward and backward curved fans.

ENGINE SPECIFICATIONS

A single cylinder four-stroke scooter engine was used in this work as already shown in [figure 1](#). Specifications of the engine are given in [table 1](#). A comparative study between backward and forward cooling fans is done in this work.

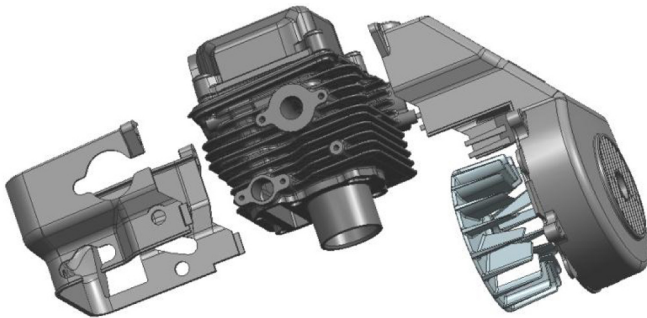


Figure 1. Engine Assembly for Scooter

Table 1. Engine Specifications

DESCRIPTION	SPECIFICATIONS
Engine	4-Stroke, air cooled engine
Displacement	125 cm ³
Peak Power	8bhp@7500RPM
Peak Torque	9N-m@5500RPM

Table 2. Engine Materials

PARTS	MATERIALS
Cylinder Head & Block	Aluminum
Cylinder Liner	Cast Iron
Gasket	Steel Carbonate
Inlet & Exhaust Valves	Steel Carbonate

CONJUGATE HEAT TRANSFER ANALYSIS

Conjugate heat transfer is referred to as coupled solid-fluid temperature calculations. In scooter engines the air is forced on to the engine surfaces through the cooling fan. The engine along with the cowling and fan is taken in a three dimensional space for the analysis. The shape of cylinder head and block makes the analysis more complicated. A CHT analysis is done across the engine assembly. The heat transfer and temperature at the fin surfaces is studied for forward and backward curved fans. The CHT approach provides more detailed information on effect of velocity of air across the fin surfaces and power consumed by different fans for providing the desired cooling. The power consumed by the fans can be improved without affecting the cooling. An improved cooling system can potentially reduce the thermal stress, resulting in a longer engine lifetime [3].

CFD SETUP

The analysis aims at evaluating the temperature distribution within the engine head and block. The computational domain covers full engine, i.e. the aluminum alloy engine head and block, cast iron liner, steel carbonate valve seats and guides and the gasket. The CFD CHT simulation of a whole engine is complex for design and optimization [3]. RANS K-Epsilon two equation turbulence model was used to solve both fluid and the solid domain. MRF model was used to simulate the fan movement in the involute casing and the engine cowling.

Assumptions

- The fan is assumed to rotate at a constant speed.
- Incompressible atmospheric air at 30°C is considered.
- The contact resistance between the fan and mounting is considered negligible.
- The thermal contact resistance between the engine parts was considered negligible.
- An engine cowl with no leakage is considered for the analysis.

BOUNDARY CONDITIONS

The fan sucks the air from the atmosphere, and forces it on the engine surfaces. A total pressure inlet and a Static pressure outlet is given. Heat fluxes are given to combustion chamber, cylinder liner, exhaust port, intake port. The solid regions and other fluid regions excluding inlet and outlet face are given wall condition [4].

Table 3. Boundary Conditions

Region	Type/Value	
Inflow	Total Pressure	0 Pa
Outflow	Static Pressure	0 Pa
Combustion Chamber	Heat Flux	1.35 Mw/m ²
Cylinder Liner	Heat Flux	19000 w/m ²
Intake Port	Temperature	80 °C
Exhaust Port	Heat Flux	4500 w/m ²

HEAT TRANSFER ANALYSIS OF THE BASE MODEL

A conjugate heat transfer analysis is done for base cowling design by forcing different mass flow rates of air. Fan is not simulated in this simulation. Temperature across the fin surfaces with different mass flow rates was analyzed. The velocity distribution pattern across the fin surfaces is only an approximation in this case, it will not give precise results, and we can get rough approximation of what amount of air flow and velocity distribution pattern that is required across the fin surfaces. Figure 2 shows the area averaged temperature distribution across different surfaces. The temperature drop for the flow rates varying from 70CFM to 270CFM is minimal, hence an fan flowing 70 CFM at 5000 RPM is selected.

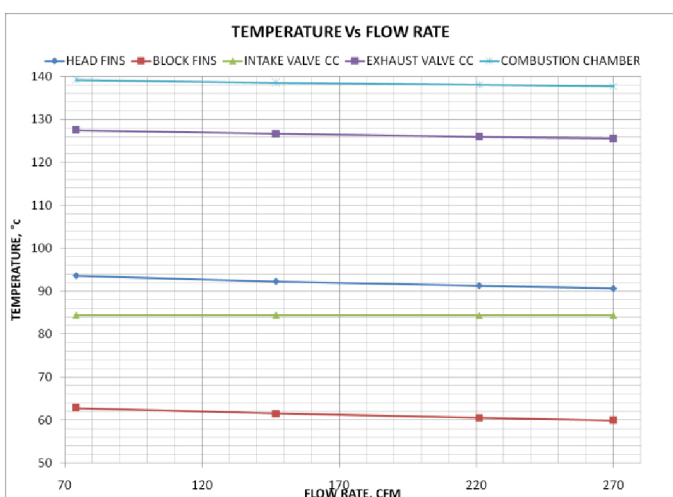


Figure 2. Flow Rate Vs Temperature

SYSTEM RESTRICTION FOR COWLING

The static pressure developed in the system is defined as system restriction. The summation of static pressure loss in a system is the system resistance. The system restriction varies with square of volume flow rate through the system. The system resistance increases with the increase in the air flow [5]. The system pressure developed for various flow rates is generated. The engine cooling fan is selected based on the system restriction curve that was generated. The chosen fan should be able to deliver flow required to cool the engine overcoming the system restriction being generated. Forward curved and backward curved fan delivering around 70CFM is selected. The flow characteristic of forward and backward curved fan is analyzed in the engine cowling for effective cooling and power consumed by the fan. Figure 3 shows the system restriction curve generated from different flow rates.

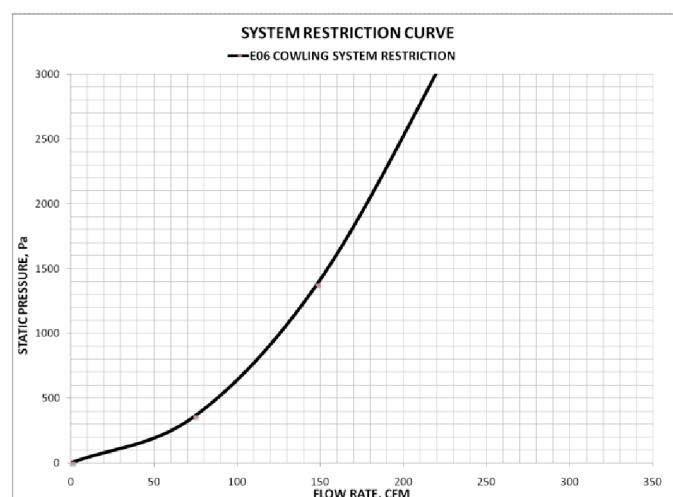


Figure 3. Cowling System Restriction curve

FAN PERFORMANCE CURVES IN INVOLUTE COWLING

Fan curve is the performance characteristic curve for a given condition. The performance of a fan such as power consumed and flow delivered were initially analyzed by using an involute casing. MRF model is used to simulate the rotary motion of the fan. The flow delivered and power consumed by forward and backward curved fans is compared. Forward curved fan flows 39% higher compared to backward curved fan. Forward curved fan consumes 60% higher power compares to the backward curved fan. Figure 4 shows the flow delivered and power consumed by forward and backward curved fans. Figure 5 and 6 shows pressure distribution of forward and backward curved fan in an involute casing.