Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 5 (2023)

Automatic Temperature Control System for A 4-Stroke Air-Cooled Motorcycle Engine for Optimum Fuel Consumption

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Abstract

One of the primary vital systems for automobiles that manage engine temperature is the cooling system. The efficiency of internal combustion (IC) engines must be improved right now due to a number of variables, including fuel efficiency, the fuel crisis, and eventually higher output. This work suggests an efficient cooling method for an IC engine that is air-cooled. Large amounts of heat are transported to different engine parts during combustion, and if the extra heat is not removed and these elements are not sufficiently cooled, the engine could be damaged. So, one of the main issues with internal combustion engines is adequate cooling. The goal of the current experiment was to demonstrate the idea of intelligent cooling. The intelligent cooling concept is put forth to address the issues that come up when using traditional cooling techniques. When an engine starts in a chilly environment, heat is lost even before the engine reaches the ideal temperature. Lower thermal efficiency and increased fuel consumption are the results of this delay. In this study, an effort was made to evaluate the impact of using a controlled cooling approach for air-cooled engines that maintains an engine's ideal temperature all the time with the option of cooling it only when the engine overheats past the ideal temperature limit.

I. INTRODUCTION

The majority of basic air-cooled motorcycle engines available in the Indian vehicle market typically fall within the 220cc range in terms of capacity. These engines primarily depend on the motorcycle's motion to facilitate heat dissipation and cooling. The regulation of heat is managed through fins located on both the engine block and the cylinder head. Nearly all engines adhere to a standard design for their fin arrangement, size, spacing, material, and distribution, tailored to their specific cooling requirements.

The engine cylinders exhibit various arrangements, including horizontal, vertical, and set at an angle (either leaning towards the motorcycle's front or rear), which are determined by factors like packaging requirements and aesthetic considerations. Motorcycle engines are engineered for efficient cooling across a spectrum of motorcycle velocities and engine speeds. As the motorcycle gains speed, the engine's revolutions per minute (rpm) typically increase, leading to elevated heat production. However, the airflow volume over the fins also escalates, and therefore, a delicate equilibrium is maintained to sustain the engine's optimal operating temperature.

Fans can play a pivotal role in cooling air-cooled motorcycle engines by actively enhancing the circulation of air. Positioned strategically, these fans can draw external air over the engine's finned surfaces, where heat accumulates during operation. By expediting this airflow, fans can potentially accelerate heat dissipation, ensuring that the engine remains within its optimal temperature range. This becomes particularly vital during stationary moments or low-speed riding when natural wind flow might be insufficient. By preventing overheating, fans can contribute to maintaining engine performance, longevity, and overall reliability, resulting in a smoother and safer riding experience.

II. LITERATURE REVIEW

Nalin Kumar Sharma, B K Roy and Santhosh K V [1] employed fuzzy logic algorithm to evaluate the system's performance, revealing the successful integration of the proposed cooling method with the optimization of power utilization and reduction of cooling system waste in the engine. An innovative approach combines air-cooling and coolant-cooling systems to enhance overall engine cooling, with dynamic control over both methods. The variables of thermo fan speed and coolant flow can be adjusted in response to the engine's heat generation. This self-regulating fuzzy logic system ensures efficient optimization and effective control, contributing to enhanced engine cooling.

Kumar Yogesh Doddaiah [5] discovered that implementing an air flow control panel at the front of the engine proved to be a successful method for managing the air cooling system of a motorcycle. This innovation led to an improved mileage for the motorcycle, showcasing the conversion of a portion of lost heat during the cooling process into valuable work. Importantly, the incorporation of the control panel did not have any adverse impact on the engine's operation.

Tomokazu Kobayashi, Kazuyuki Kosei, Sadaaki Ito, and Satoshi Iijima [4] made a significant discovery regarding scooters featuring an air-cooled, four-stroke, single-cylinder petrol engine. They developed a dynamic cooling system for these scooters, achieved by controlling louvers situated at the temperature reduction air inlet through an oil-temperature sensitive actuation unit. This innovative system adjusts the louver's position based on the engine's temperature and load. During cold starts or when the engine burden is small, the louver remains closed, promoting rapid warm-up and maintaining elevated engine oil temperatures to reduce friction losses associated with cooler oil. This approach also eliminates the power consumption of the cooling fan. The rapid warm-up additionally reduces the need for extra fuel injections during cold engine operation. The outcome of this advancement was a notable 3.3% enhancement in fuel efficiency, particularly evident in the Urban Driving Cycle scenarios.

Karthikeyan N, Anish Gokhale, and Ajay Shinde [2] conducted a study focusing on enhancing the cooling efficiency of a two-wheeler scooter's engine through optimal fan performance. Scooters employ centrifugal fans with either regressive or advancing curved blades to facilitate air inflow and outflow. Their research concentrated on comparing and reducing power consumption while enhancing air flow speed across the engine exteriors. A Conjugate Heat Transfer analysis was carried out to evaluate the impact of these fans on flow, power, and engine temperature. A validated numerical approach, utilizing the RANS K-Epsilon turbulence model and the Moving Reference Frame (MRF) model, was employed. Engine cowling geometry modifications were made to prevent recirculation near the fan area and encourage flow extension at the engine head and block. Experimental corroboration was conducted on the modified cowling profile to confirm flow rate, power, and temperature improvements. Remarkably, the optimized fan decreased power consumption by 31.27% (80 Watts at 8000 RPM) under the same operating conditions. This comprehensive methodology offers insights into selecting an efficient cooling fan for engines.

In their study, **K Shahril and colleagues [3]** conducted heat transfer simulations on motorcycle fins using the CFD method. They explored two different engine blocks: Modenas Kriss 110 and Yamaha Lagenda 110z. Their findings highlighted the significant influence of wind velocity on overall heat transfer and the heat transfer coefficient. Additionally, they observed that an inadequate fin design in relation to the requirements could lead to overheating issues.

Mallya Ananth Mohan and Narasimha Krishan Bailkeri [6] aimed at finding out the best working temperature of an air cooled motorcycle engine, where maximum fuel efficiency is obtained under still environments. They concluded that the optimum temperature for the engine lies between 110 – 120ºC near the exhaust port.

III: EXPERIMENTAL SETUP

- The experimental motorcycle chosen for the study is a 2004 model Bajaj Pulsar 150 dts-i, which has been driven approximately 60k km and has experienced typical wear and neglect, as is common for commuter motorcycles. It generates approximately 13 bhp of power at 8500 rpm at the crank.
- A 150 cc motorcycle was opted for in light of speculations regarding a potential ban by the GOI on internal combustion engine motorcycles below the 150 cc category. The Bajaj Pulsar 150 was specifically selected due to its status as the highest-selling motorcycle in its segment.

- Temperature extents at various locations around the fins and in proximity to the exhaust port of the engine were carried out using a non-contact digital infrared thermometer from HTC. This thermometer has a measurement range spanning from -50°C to 550°C and claims an correctness of ±2.0 percent, with a least count of 0.1°C.

To ensure the engine's optimal functioning, the bike received attention from skilled professionals at a bike workshop.
• The professionals conducted an engine oil change.
• New brake fluid and brake shoes were introduced.
• A new battery was put in place.
• Dismantling, servicing, and reassembly of various bike components were performed.
With these thorough preparations, the motorcycle is now fully ready for the experimental phase. After undergoing a comprehensive servicing regimen and being prepared for experimentation, the motorcycle underwent further enhancements by acquiring specific components such as a Mileage Testing bottle, Centrifugal fan, IR Thermometer, Glass tube, and a 12V Battery.

A KTM 390 Duke Radiator Fan was employed to enhance the engine's forced cooling.
The radiator fan has the following specifications, using which the volume flow rate was calculated as follows.

•Diameter of the blade = 22.5cm = 0.225m

•Swept area of the fan = A = $\pi/4*d^2 = \pi/4*0.225^2$

$=0.0397 \text{ m}^2$

•Measured average wind speed at distance 20 cm from fan = V = 3.2 m/s

•Therefore, Volume flow rate = A x V = 0.0397 x 3.2

$= 0.127 \text{ m}^3/\text{s}$

From the provided table, it is evident that Radiator cooling fan is utilized for optimizing engine cooling.

Table 1: Correlating temperature and cooling time with and without radiator fan

Without Radiator Fan		**With Radiator Fan**	
Temp in ºC	Time in sec	Temp in ºC	Time in sec
120.3	0.00	117	0.00
120.7	11.59	115.4	11.54
121.6	24.56	112.8	23.05
121.3	36.50	108.2	34.59
121.6	60.01	105.0	47.65
121.7	74	102.9	60
122.9	88	100.2	73
123.3	101	99.7	83
124.1	114	99.6	97

The engine underwent a 7-minute warming process, with its RPM maintained at around 3500-4000 in all gears. The 5th gear was engaged for the longest duration to mimic real-world conditions of the bike running at 40-50 km/h.

During this period, no additional loads, whether electrical or any other, were exerted on the engine. The outside air temperature stood at 32°C.

The temperature was determined around the exhaust port of the engine, which is the hottest part when the engine is running.

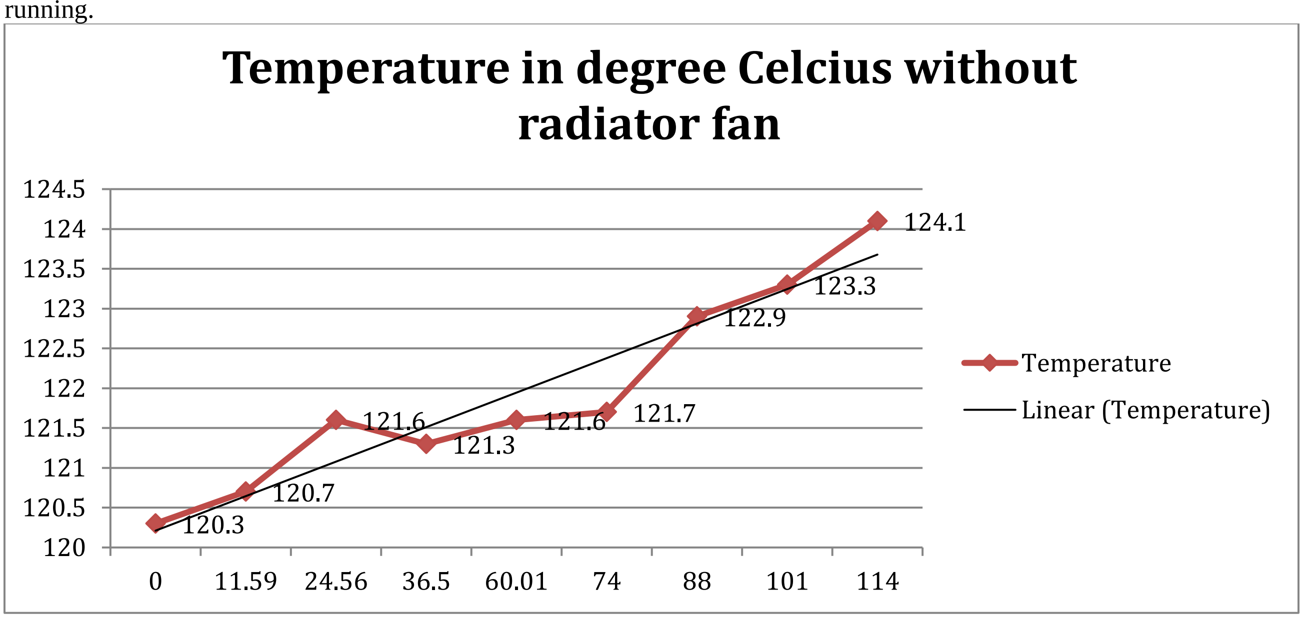

Fig 1: Chart indicating engine temperature rise without radiator fan

The chart indicates a rise in temperature of 3.8 ºC in a time period of 114 seconds (1.9 mins) when the motorcycle engine is run in static conditions with no air flow.

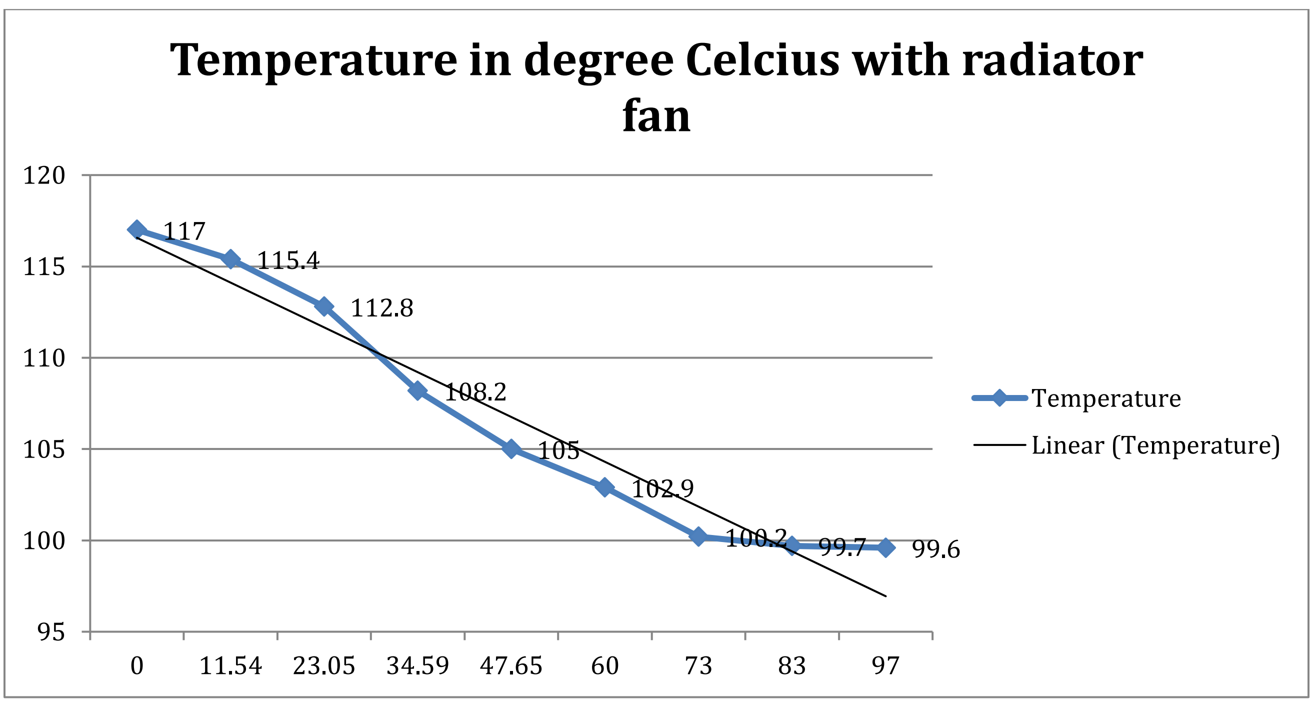

Fig 2: Chart indicating engine temperature fall with radiator fan

The chart indicates a fall in temperature of 17.4 ^{o}C in a time period of 97 seconds (1.6 mins) when the motorcycle engine is run in static conditions with the radiator fan throwing out a volume flow rate of 0.127 m^3/s of ambient air over the engine cylinder fins.

Fig 3: Experimental setup with radiator fan and FE testing equipment in place

Fig 4: Experimental setup with radiator fan angled towards cylinder fins

After successful experimentation, the subsequent task involved the semi-automated control of the fan using Arduino. The components necessary for establishing this semi-automated fan control system included:

- Arduino UNO board
- LCD display
- LM35 Sensor
- 1 kΩ Resistor
- Jumper wires
- 12V Battery

With the Arduino device set up, the radiator fan could be operated automatically. The utilization of the LM35 Sensor facilitated the detection of engine temperature. In instances of elevated engine temperature, the Radiator Cooler system would autonomously identify the high temperature, prompting the Arduino device to activate the radiator fan in order to cool the engine. Once the engine temperature returns to the optimal level, the radiator fan ceases its operation automatically.

The radiator fan was driven by an external 12V sealed lead acid battery for experimentation purposes.

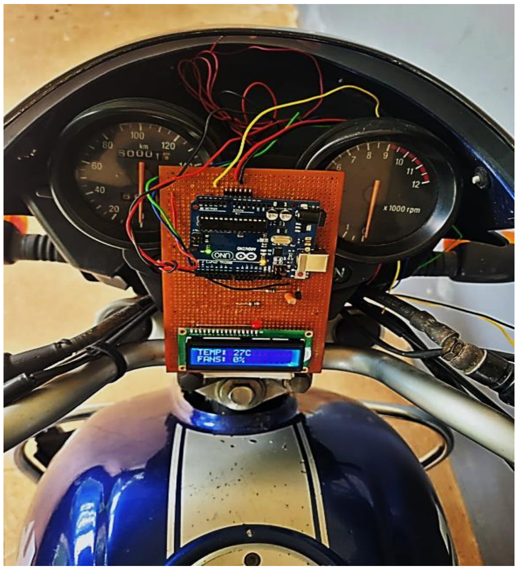

Fig 5 and 6: Motorcycle fitted with Arduino Uno board programmed to automatically turn on and turn off the radiator fan based on set temperatures

Fig 7: Final Experimental Setup

Legend:

1. Mileage testing bottle with petrol

2. Running radiator fan fixed to the left side crash guard

3. 12V Lead Acid battery driving the radiator fan

IV: RESULTS, OBSERVATIONS AND CONCLUSION

Table 2: Correlating Fuel consumption per cubic cm of petrol with temperature and time without fan

Temperature ºC	Time (secs)	Time difference (secs)
Trial 1		
114.6	0	
115.5	10.56	10.56
115.6	24.5	13.94
115.9	39.58	15.08
116.6	49.5	9.92
117	62	12.5
117.5	75	13
118.5	86	11
118.9	99	13
Trial 2		
123.2	0	
124.3	12.56	12.56
124.5	24.5	11.94
125	37	12.5
125.5	49.13	12.13
125.7	63	13.87
125.69	74	11
126	86	12
124.6	98	12
Trial 3		
131.3	0	
131.5	12.09	12.09
132.3	22.1	10.01
130.7	41.5	19.4
131.6	55.49	13.99
133.8	72	16.51
134	79	7
134.4	91	12

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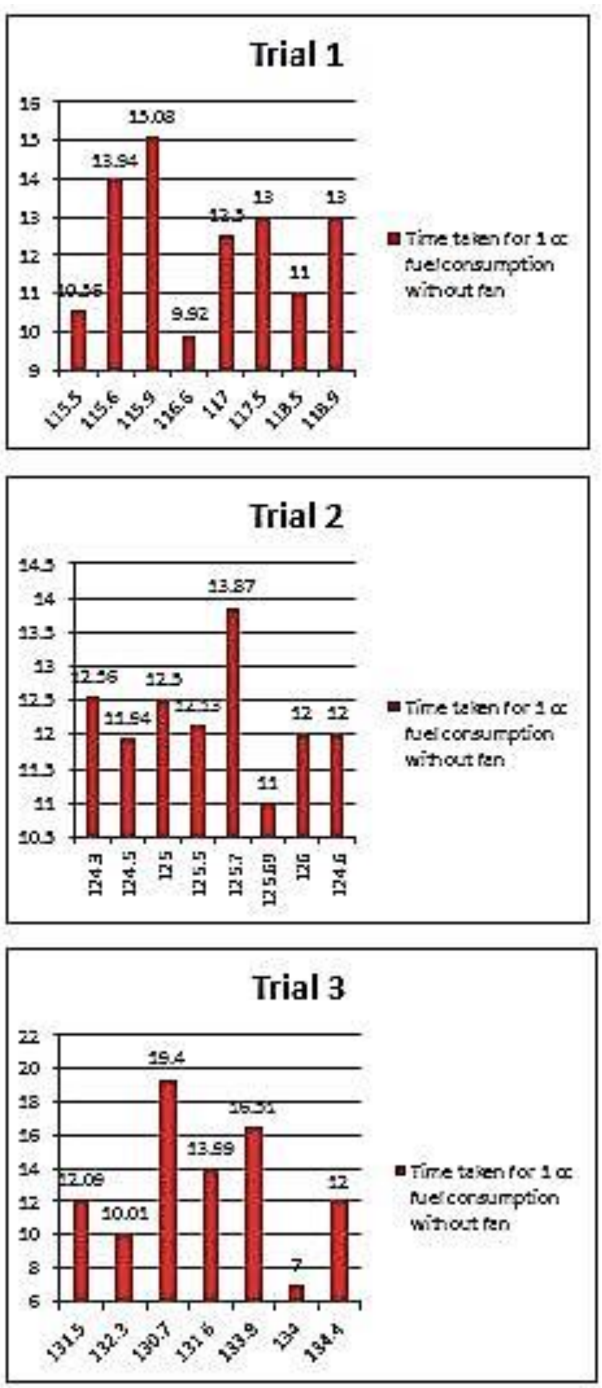

Fig 8: Charts indicating time taken for 1 cc fuel consumption along with corresponding temperature, without radiator fan

Table 3: Correlating Fuel consumption per cubic cm of petrol with temperature and time with radiator fan

Temperature °C	Time (secs)	Time difference (secs)
Trial 1		
123.9	0	
121.8	8	8
117.8	23	15
117.3	34	11
116.2	46	12
115.1	58	12
113.3	70	12
113.2	82	12
111.7	98	16
Trial 2		
131.2	0	
127.4	14	14
122.6	27	13
119.3	41	14
116.5	55	14
115.1	70	15
112.2	83	13
109.1	98	15
108.5	112	14
Trial 3		
130.3	0	
127.4	12	12
123.5	24	12
121.1	37	13
118.7	49	12
116.3	62	13
114.4	75	13
112.6	89	14
110.4	110	21

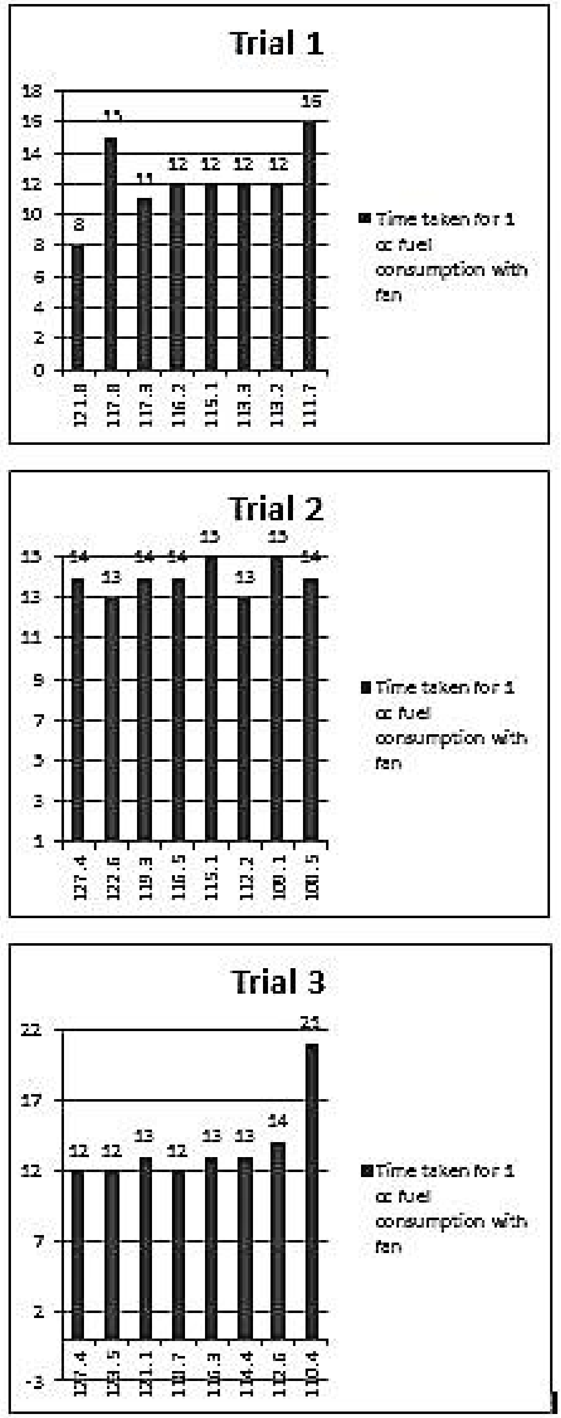

Fig 9: Charts indicating time taken for 1 cc fuel consumption along with corresponding temperature, with radiator fan

Table 2 and the charts in fig 8 indicate a fall in the time taken for 1 cc of petrol consumption by the engine as the temperature rises. The overheat temperature of the engine begins from around 130^oC, after which there is a drastic reduction in the time taken for fuel consumption.

The automatic control of the radiator fan is set before this overheat temperature is reached.

Table 3 and the charts in fig 9 indicate a stability in the time taken for 1 cc of petrol consumption by the engine as the temperature falls. The optimum working temperature of the engine lies between 110 and 120^o C, where there is a large improvement in the time taken for fuel consumption.

The automatic control of the radiator fan is set such that this optimum temperature range is maintained.

The future scope of the work would be to integrate the fan control with the vehicle battery, and to test the NO_x emission reduction due to the reduction in peak cylinder temperature due to forced cooling and temperature maintenance by the fan.

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