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EXPERIMENTAL INVESTIGATION IN DETERMINING OPTIMUM WORKING TEMPERATURE FOR A 4-STROKE AIR-COOLED MOTORCYCLE ENGINE

Mallya Ananth Mohan[1], Narasimha Krishna Bailkeri[2]

1 Shri Madhwa Vadiraja Institute Of Technology And Management, Bantakal, Udupi, India. Email: ammallya.mech@sode-edu.in, Phone: +91 820 2589182, +91 820 2589183

2 Nitte Mahalinga Adyanthaya Memorial Institute Of Technology, Nitte, Karkala, India

Abstract— Almost every motorcycles on Indian roads is of the commuter variant and typically use air cooled single cylinder four strokes. Depending on the type of usage, these engines are optimized for fuel efficiency, rather than for outright power. Yet, the Indian obsession with fuel efficiency makes the riders run the engines very lean with the sole purpose of extracting the maximum possible mileage. Without sufficient airflow over the fins, these engines characteristically overheat in traffic conditions, affecting fuel efficiency drastically. This work aims at determining the optimum working temperature of an air cooled engine, where maximum fuel efficiency is obtained under static conditions.

Index Terms—engine, temperature, optimum working temperature

I. INTRODUCTION

Most entry level air-cooled motorcycle engines in the Indian market are within the 180cc capacity. These engines rely purely on the movement of the motorcycle for heat dissipation and cooling. The heat reduction is taken care of by fins on the engine block as well as on the engine head. Almost all engines have a standard fin geometry, size, pitch, material and distribution depending on their cooling needs.

The engine cylinders themselves have different configurations such as horizontal, vertical and inclined from vertical (either towards the front or towards the rear of the motorcycle) depending on packaging needs and aesthetics among other factors. Motorcycles engines are designed for cooling based on a range of motorcycle and engine speeds. As the motorcycle moves faster, the engine also usually spins at a higher rpm, generating more heat. But the volume of air flow over the fins also increases, and thus a fine balance maintains the optimum working temperature of the engine.

Most air-cooled engines have their cylinders oriented towards the wind stream and follow tried and tested methods of fin arrangement, number, pitch, material etc. Optimum cooling usually happens when the motorcycle is moving forward with some appreciable velocity. But in static conditions such as in heavy traffic, insufficient air flow over the engine cylinder results in localized hot spots on the cylinder surface, which can result in surface warping, followed by a considerable drop in performance due to overheating. Further overheating can lead to irreversible engine seizure, which can result in catastrophic mishaps.

Some commuters even have the unnecessary habit of keeping their idling speeds extremely low, again in the interests of fuel efficiency. Then to prevent their motorcycles from stalling in traffic, there is another bad habit of twisting the throttle on an idling engine.

All these practices put undue thermal loads on the engine, which can result in the following effects [1]:

- Engine valves warp (twist) due to overheating
- Damage to the materials of cylinder body and piston
- Lubricating oil decomposes to form gummy residue and carbon particles

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- Thermal stresses are set up in the engine parts and causes distortion (twist or change shape) and cracking of components
- Pre-ignition occurs, i.e. ignition occurs before it is required due to the overheating of spark plug
- Reduces the strength of the materials used for piston and piston rings
- Overheating also reduces the efficiency of the engine

II. LITERATURE REVIEW

Kumar Yogeesh Doddaiah [2] used a controlled cooling method by controlling the circulation of coolant (air) around the cylinder. During cold condition when the engine starts it loses heat even when before it reached the optimal temperature. This delay results in higher fuel consumption and lower thermal efficiency. He made an attempt at adopting a controlled cooling method for air-cooled engines by maintaining optimal temperature of the engine always with an option to cool it only when the engine overheats beyond the optimal temperature limit. He concluded that the air cooling system in motor-bike can be effectively controlled by application of air flow controlling panel in front of engine. The mileage of the motor bike increased with flow controlling panel system. It shows that some amount of heat lost in cooling is converted into useful work. The panel does not affect the engine operation.

Duraisivam Saminatharaja [3] used air channels to analyze effective cooling of spark ignition engine with the help of CFD. He tried to provide a better path for air flow, overcoming the restriction of the front wheel, suspension and steering components. He opined that by providing air channel the maximum amount of heat is transferred to air from engine, so that the engine is free from unwanted thermal load due to long traveling and its life would be increased.

K Shahril et al [4] undertook heat transfer simulation of motorcycle fins under varying velocity using CFD method on two type of engine block, viz Modenas Kriss 110 and Yamaha Lagenda 110z, and concluded that wind velocity is one important part that can affected the total of heat transfer and the value of heat transfer coefficient. Besides, they also understood that if the fins design is not too appropriate with the requirement, it can cause overheating.

Dr I Satyanarayana and Pranav G [5] used Solid Works to improve heat transfer, by changing cylinder block fin geometry, thickness, wind velocity and material on models of rectangular, triangular shaped fins in addition to reducing the thickness of the fins from 3mm to 2.5mm. They carried out transient thermal analysis by considering the temperature of cylinder head 220ºC and CFD analysis were carried out, in which working fluid was air at a velocity of 40kmph. They came to the conclusion that triangular fins can be used to reduce the weight of the engine block, but the heat transfer efficiency will be low compared to rectangular fins. Also, Aluminum alloy 6061 is better, reducing thickness to 2.5mm is better and using fin shape as rectangular.

III. EQUIPMENT USED FOR THE EXPERIMENT

The motorcycle procured for experimental work is a 2004 model Bajaj Pulsar 150 dts-i that has run nearly 60,000 km, used and fairly abused and neglected, as a typical commuter motorcycle usually is. Power produced at the crank is approximately 13 bhp @ 8500 rpm.

A 150 cc motorcycle was selected due to the rumor that the Government of India might ban IC engine motorcycles under the 150 cc category. The Bajaj Pulsar 150 was selected as it is still the highest selling motorcycle in its segment.

A digital infrared non-contact type thermometer from HTC, with a measurement range of -50 – 550 ^{o}C and with a claimed accuracy of ±2.0 percent and resolution of 0.1 ^{o}C was used for the temperature measurements at different points around the fins and near the exhaust port of the engine.

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Fig 1: Bajaj Pulsar 150, 2004 model in stock condition

Fig 2: Close up of the engine

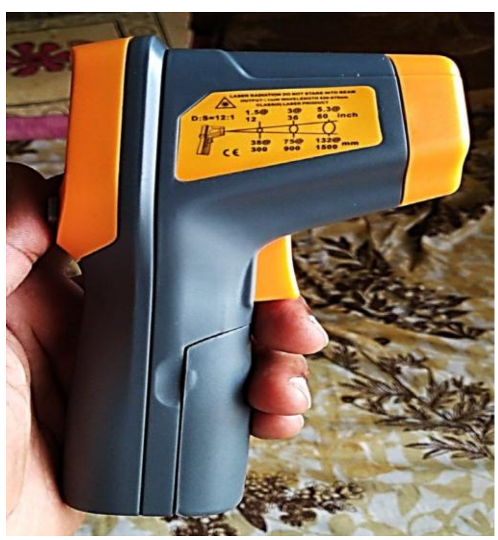

Fig 3: HTC Infrared Thermometer

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IV. EXPERIMENTAL PROCEDURES, RESULTS AND DISCUSSIONS

The user manual of the Bajaj Pulsar 150 specifically asks the user not to idle the engine beyond 3 minutes to avoid overheating. Most users conveniently ignore this warning. Also, it is nearly impossible to follow this rule in real-world conditions, especially when in bumper to bumper traffic.

The initial experiment was carried out to verify this claim of overheating after 3 minutes of idling.

The bike was revved to about 4000 rpm for about 1 minute to allow the engine oil to circulate adequately and then the temperature measurements were taken.

The carburetor fuel screw setting for ideal conditions is 3 - 4.5 turns as per the factory settings for the best compromise between performance and fuel efficiency. The motorcycle had a default setting of 3.75 turns. All tests were carried out at this setting.

The ambient temperature was 25.4 ^{o}C at 17:00 hours when the test was conducted. The motorcycle was run on electric load of a 35 W headlamp, 6 W pilot lamps, 5 W tail lamp and 21 W brake lamp (switch is stuck).

The temperature was measured under the exhaust port, where the fins will typically experience the maximum temperature.

The table below shows the variation of temperature with respect to time around the engine's exhaust port.

Table 1: Variation of temperature with time around the exhaust port of the engine

Sl No	Time (s)	Temp [^{o}C]
1	10	50
2	20	51
3	30	51.4
4	40	51.2
5	50	51.4
6	60	55.7
7	70	57
8	80	58.9
9	90	59.3
10	100	60
11	110	60.8
12	120	61
13	130	62.1
14	140	63.2
15	150	64.5
16	160	64.8
17	170	65
18	180	66.3
19	190	67.5
20	200	69.1

From the initial experimentation without any warmup and simple idling at about 1400 rpm (Table 1), it was indeed found that the engine fin temperature increased suddenly and exponentially after the 180 second mark as was mentioned in the user manual.

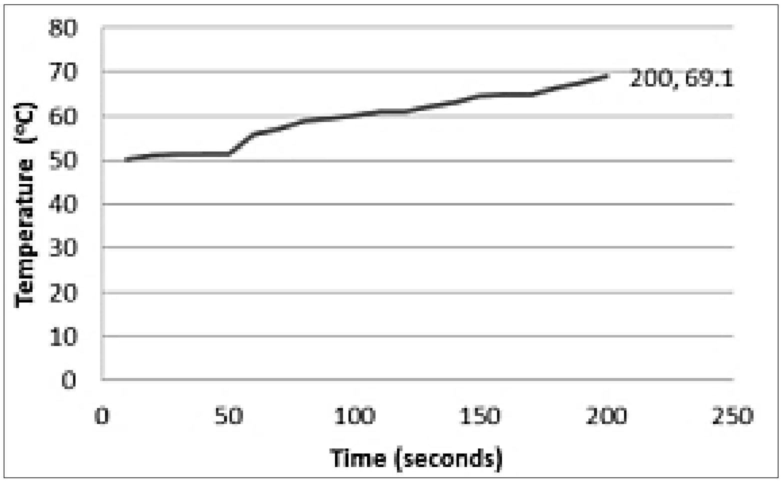

Fig 4: Variation of temperature with time at the exhaust port of the engine

The second experimentation was done to determine the top and bottom fin temperatures at a few selected locations on the engine surface. Left, right and exhaust port sides were selected.

A plot of temperature in degree Celsius vs time in seconds, measured at intervals of 10 seconds was obtained for the engine. The engine was warmed up for a period of 7 minutes with the engine run at approximately 3500-4000rpm in all gears and for the longest time in the 5th gear to simulate the bike running at 40-50kmph in real-world conditions.

No other load (electrical or otherwise) was applied on the engine. The ambient temperature was 27.6^{o}C.

The table below shows the variations of temperature with respect to time at fins on the left, right and exhaust sides of the engine.

Table 2: Variations of temperature with respect to time at different locations of the engine

Sl No	Left Side ^{o}C		Right Side ^{o}C		Exhaust Port ^{o}C	
	Top	Bottom	Top	Bottom	Top	Bottom
1	89.3	96.3	79.3	74.8	94.2	112.5
2	94.6	105.6	85.2	82.5	94.6	112.8
3	98.3	105.7	90.9	84.4	95.8	115.6
4	105.9	113.2	92.7	85	98.2	116.4

Table 2 provides a temperature profile around the engine cylinder. The motorcycle had not been washed in a long time, and there was a fair amount of dust accumulation around some of the fins. The head gasket has also deteriorated and hence a little engine oil had leaked from around the head. Yet, the temperatures were fairly consistent, with the maximum fin temperatures obtained around the exhaust port situated at the front of the engine.

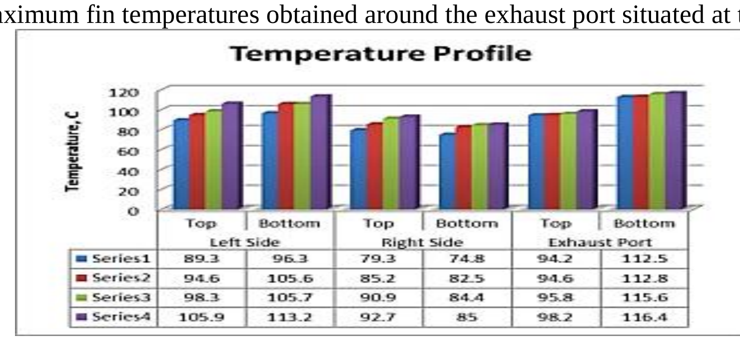

Fig 5: Plots of Variations of temperature with respect to time at different locations of the engine

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After obtaining a basic thermal behavior of the engine under static conditions, fuel efficiency tests were conducted.

As it is impossible to understand the actual flow of fuel from the metal fuel tank, it was initially replaced by a metered jar, and then the jar was replaced by a glass burette to get accurate fuel consumption statistics with respect to time and engine temperature.

Readings of temperature and the time taken for consumption of 1cm^3 of petrol were gathered.

As the motorcycle has a carbureted engine, the amount of fuel that collects in the float chamber of the carburetor was neglected for the sake of simplicity, and only the decrease in the volume of petrol in the burette with respect to time was taken as the final reading. Three trials were conducted with adequate time in between trials for the engine temperature to come back close to room temperature.

Table 3: Time taken for 1cc petrol consumption and corresponding temperatures at fins at different locations of the engine

Sl No	Time in secs	Left Side ^oC		Right Side ^oC		Exhaust Port ^oC	
		Top	Bottom	Top	Bottom	Top	Bottom
1	28.86	95.3	98.4	82.3	73.7	89.8	108.8
2	28.9	99.5	105.4	89.1	75.9	93.5	110
3	24.31	104.8	118.8	92.8	81.2	97.3	124.8
4	24.06	112.5	121	96.3	84.2	100	126.6

In Table 3, it can be observed that the maximum time for 1cc of fuel consumption (minimal fuel consumption, or best mileage) was obtained right after the warmup had been done. As the fin temperature increases, we can see a corresponding decrease in the time taken for 1cc of fuel consumption, which means more fuel was consumed as the engine overheated. More trials could have been carried out, but the engine had already overheated by that point in time, and throttle response had dulled.

After these trials, a normal table fan was used at a distance of 1m from the front wheel to simulate air flow over the fins. The speed of the fan was 780rpm, diameter of 300mm and air flow of around 40CMM.

The motorcycle was warmed using the same procedure as mentioned earlier and trials were carried out.

The fan was turned on after trial 4 and the following results were obtained.

Table 4: Time taken for 1cc petrol consumption and corresponding temperatures at fins at different locations of the engine, with fan

Sl No	Time in secs	Left Side ^oC		Right Side ^oC		Exhaust Port ^oC		%age differences wrt to least time
		Top	Bottom	Top	Bottom	Top	Bottom	
1	28.5	86.4	77.3	75.6	75.3	75.4	108.4	NA
2	32.06	89.6	83.1	79.5	77.6	76.5	116.6	NA
3	26.31	92.5	84.4	81.9	79.3	78.2	121.1	NA

4	21.15	94.3	91.1	85.2	84.2	85.1	123.4	0.00
5	23.25	85.4	82.6	84.8	85	68.6	122.2	9.93
6	25.45	84.5	82.4	85.9	87.9	64.7	117.9	20.33
7	26.92	83.2	84.8	84.8	86.3	63.4	116.2	27.28

In Table 4, it can be seen that the best fuel efficiency is obtained in the 2nd trial, beyond which the time taken for fuel consumption decreased rapidly. The fan was turned on after trial 4, and as can be seen, the fuel efficiency increased steadily. Figure 6 shows the percentage increase in time taken for 1cc of fuel consumption after the fan was used. The times rose steadily from 9.93%, 20.33% up to 27.28%.

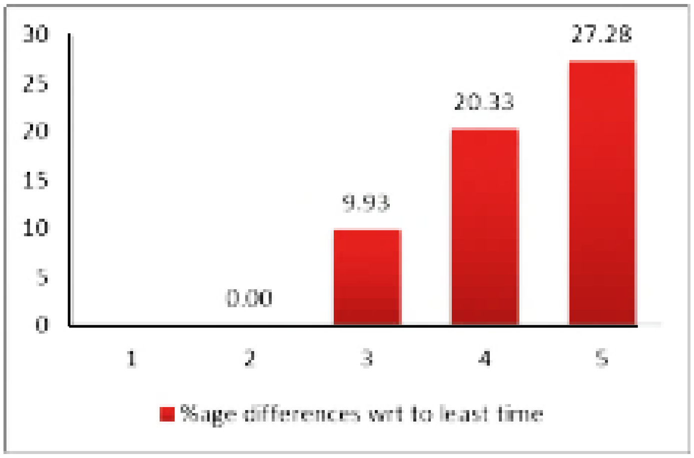

Fig 6: Percentage increase in time taken after least time, with fan

For the second trial and for all trials onwards, a proper warmup routine was followed to simulate the motorcycle's running.

V. CONCLUSIONS AND FUTURE WORK

From Tables 3 and 4, the optimum temperature for the engine can be concluded to lie between 110 – 120^{o}C near the exhaust port.
The aim of further experimentation would be to bring the time taken for fuel consumption close to the 30 second mark by maintaining the optimum operating temperature for the engine. Methods for keeping the temperature constant will need to be explored.

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Author 1:

Name: Mr Mallya Ananth Mohan

Email address: ammallya.mech@sode-edu.in

Postal Address: Senior Assistant Professor,
Department of Mechanical Engineering,
Shri Madhwa Vadiraja Institute of Technology and Management,
Vishwothama Nagar, Bantakal
Udupi – 574 115, Karnataka, India

Tel: +91 820 2589182, +91 820 2589183

Author 2:

Name: Dr Narasimha Krishna Bailkeri

Email address: nkbailkeri@nitte.edu.in

Postal Address: Professor,
Department of Mechanical Engineering,
Nitte Mahalinga Adyanthaya Memorial Institute of Technology, Nitte, SH1, Karkala Taluk,
Udupi – 574110, Karnataka, India

Tel: +91 8258 281263, +91 8258 281264