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Effects of Lubricant Temperature in a Motorized Engine

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Abstract: This paper explains the effect of various lubricant and engine temperatures on the intake mass air flow, engine noise and lubricant pressure behaviour of a motor-driven spark ignition engine. The lubricant pressure, engine noise and mass air flow changes were recorded under a steady state operating condition with an increased engine speed in which both the volume and temperature of the lubricant remained unchanged for each sets of test. The engine was driven by an electric motor at a wide-open throttle and a constant speed ranging from 500 to 3000 rpm with 500 rpm increment. The lubricant and cooling water were set at 32°C (unheated) and 90°C (heated) for each run. In general, the pressure of the lubricant was found to decrease for either increased engine speed or lubricant temperature. It was found that high lubricant viscosity produced high overall engine friction and resulted to a higher engine noise. Heated lubricant started off with a very low pressure with 0.996 bar compared to unheated lubricant with 2.497 bar in 500 rpm. Unheated engine lubricant recorded a peak noise of 107.2 dB at 1500 rpm before it dropped momentarily before increased linearly beyond this speed. The findings in this work are useful for researchers in the field of automotive technologies, environmental and triblogies.

Key words: Viscosity · Lubricant pressure behaviour · Engine noise · Intake air flow · Motorized engine

INTRODUCTION

Liquid viscosity is a measure of fluid resistance to flow when is acted upon by an external force; such as pressure differential or gravity. For a given mass of liquid, smaller sized droplets (lower viscosity) yield a greater total surface area than larger ones, thus possesses lower static pressure [1]. Oil viscosity can be affected by a number of external factors. The most prominent factor is due to the change in temperature during machinery operation. A lubricant viscosity will decrease with an increase in temperature and will increase with a temperature reduction. The Viscosity Index (VI) is an arbitrary scale used to measure a fluid's change in viscosity across temperature variance. Oil with high VI experiences smaller decreases in viscosity as the working temperature increases than an oil with a lower VI [2]. Oils with viscosity of 10 cs at 100°C and a VI of 100 will have a viscosity of approximately 10,000 cs at 0°C. Thus, the change of only 100°C in temperature can cause to a thousand-fold change in viscosity [3]. The viscosity of lubricants increases markedly with increased pressure. The viscosity of the lubricant measured in the film of hydrodynamic bearings is many times greater than its viscosity measured at atmospheric pressure [4].

Generally, the temperature of a standard spark ignition engine is considerably high and the viscosity of the lubricant is highly depended on the operating temperature. A standard water cooled engine should operate with a cooling system temperature between 80°C and 90°C. Considering that the oil operating temperature should be 10°C to 15°C above the coolant temperature, the oil operating temperature should be within 90°C to 105°C [5].

In general, the noise emitted by operating engine is controlled and reduced for the sake of the passenger's comfort. The noise level of an engine will rise as the engine speed increases due to many factors. The major part of the noise produced is mainly caused by the engine structure and noise reduction can be achieved by more rigid and flexible structural modification [6]. Oguchi [7] studied the noise generated by the impact of the piston on the cylinder wall known as piston slap noise. Also, noise is generated by impacting bodies due to the high

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surface accelerations during the contact period [8]. All of these sources suggested that higher engine speed resulted in high surface acceleration and structural vibration, thus causing higher noise level. Research done by Ian [9] concluded that a drop in lubricant viscosity lowers the engine's friction thus reduces the engine noise.

This paper explains the lubricant pressure behaviour, intake air flow and engine noise variation of a motor-driven spark ignition engine that operated with normal operating temperature and in unheated condition. The results of this study are useful for researchers in a field of automotive technologies, environmental and triblogies.

MATERIALS AND METHODS

Engine Specification: A 1.6 litre with a dual overhead camshaft (DOHC) and a multiport fuel injection (MFI) gasoline engine (Proton Campro 1.6) was used and driven by an electric motor. The specifications of the engine, intake valve and exhaust valve were listed in Table 1, 2 and 3.

Table 1: Specifications of Engine Model

Parameters	Units	Specifications
Number of cylinders	-	4
Displacement	cc	1597
Firing order	-	1-3-4-2
Bore	mm	76
Stroke	mm	88
Bore spacing	mm	82
Connecting rod length	mm	131
Piston compression height	mm	26
Compression ratio	-	10:1
Valve centre distance	mm	34
Intake valve inclination	°	21.5
Intake valve diameter	mm	30
Exhaust valve inclination	°	20.5
Exhaust valve diameter	mm	25
Hyd. Tappet diameter	mm	32
Maximum torque	Nm @ rpm	148 @ 4000
Maximum power	kW @ rpm	82 @ 6000

Table 2: Intake Valve Specifications

Parameters	Unit	Specifications
Maximum lift	mm	8.90
Valve length	mm	115.11
Diameter	mm	31
Valve open	°	12 BTDC
Valve close	°	48 ABDC
Lift duration	°	240

Table 3: Exhaust Valve Specifications

Parameters	Unit	Specifications
Maximum lift	mm	8.70
Valve length	mm	115.11
Diameter	mm	25
Valve open	°	45 BBDC
Valve close	°	10 ATDC
Lift duration	°	240

Motorized Engine Testing: Tests were carried out to measure the mass air flow entering the cylinder, lubricant pressure behaviour and sound level for the engine. The engine was run at steady state conditions with wide open throttle (WOT) at constant speed ranging from 500 to 3000 rpm with 500 rpm increment. The lubricant and cooling water were set at 32°C (unheated) and 90°C (heated) for each test runs. 20W-50 motor oil was used for the engine oil. The mass flow rate of air entering the intake manifold was measured using the Bosch AMF sensor and the noise level of the engine was measured using a sound level meter. One pressure sensor (Kistler type 6125B) was installed on top of one of the engine cylinders and another pressure sensor was installed into the oil filter adapter to measure the lubricant oil pressure. The pressure data was sent to the Dewetron DEWE5000 combustion analyzer. The sound level measuring setup for this experiment complied with the noise test distance and orientation method of National Stationary Exhaust Noise Test Procedures for In-Service Motor Vehicles, Australia with a standard of ISO 5130.

RESULTS AND DISCUSSIONS

Mass Air Flow: Figure 1 shows the mass air flow behaviour for increased engine speed and lubricant temperature. The mass air flow for both lubricant temperatures display a similar trend of increase as the engine speed was increased. There are no significant correlation between intake air flow and lubricant temperature. The engine ran by a combustion draws more air through the intake system compared to a motor-driven engine. Therefore, there were a huge different between calculated and measured mass air flow. However, as the engine speed reached higher than 2000 rpm, the mass air flow experienced a decrease in trend for both lubricant temperatures. This decreasing trend occurred due to the inefficiency of the intake valve event and is commonly experienced by a non-vvt engine. As concluded by Duckworth [10], the early intake valve open (IVC) in medium speed and late intake valve close (IVC) in high

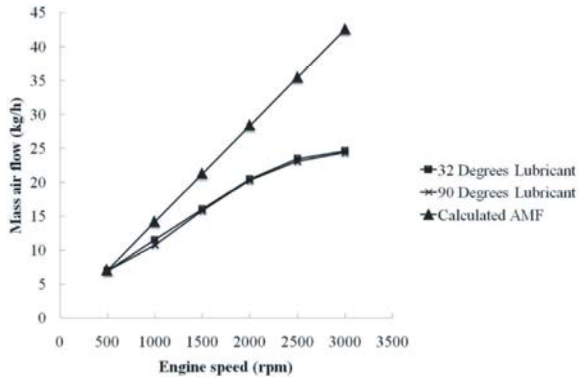

Fig. 1: Mass air flows in various engine speed and lubricant temperature

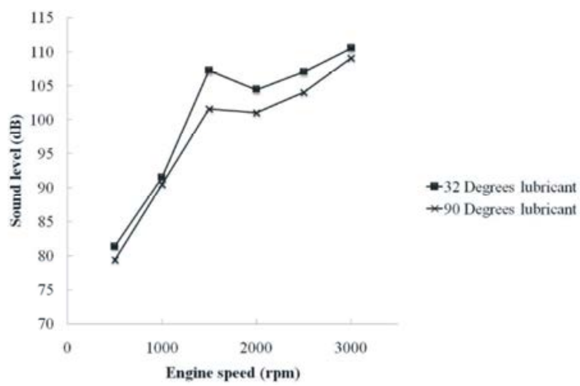

Fig. 2: Engine noise in various engine speed and lubricant temperature

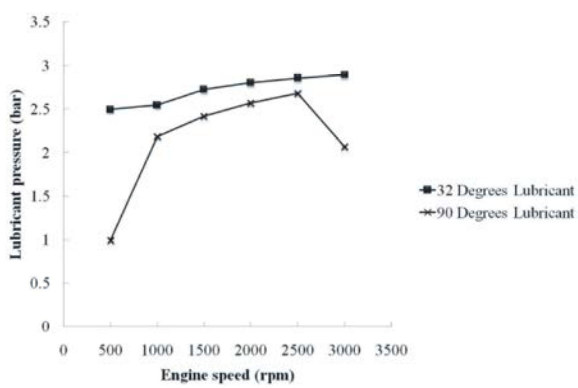

Fig. 3: Lubricant pressure in various engine speed and temperature

speed is proven to increase and retain the linearity of the trend of mass air flow entering the cylinder, thus improves volumetric efficiency [11].

Engine Noise: Figure 2 illustrates the engine noise due to increased engine speed and lubricant temperature. The engine operation produced unstable noise in unheated condition which recorded a peak noise of 107.2 dB in 1500 rpm and dropped momentarily before increased linearly beyond this speed. When the lubricant was in low temperature, it has a higher viscosity and higher engine friction. Thus, this results in more noise being generated than its normal operating temperature. Therefore, by elevating the lubricant temperature, the engine friction can be reduced and ultimately reduces the noise generated by the engine [9].

Lubricant Pressure Behaviour: Figure 3 shows the lubricant pressure behaviour across various engine speed and temperature. The engine oil pressure rose as the engine speed was increased. Unheated lubricant possessed higher pressure value and continued to rise almost linearly as the speed increased towards 3000 rpm. The heated lubricant started off with a very low pressure with 0.996 bar compared to unheated lubricant with 2.497 in 500 rpm and began to drop as the engine speed reached beyond 2500 rpm. This trend is due to the high temperature of the lubricant that lowered its viscosity, thus resulting a lower pressure. Heated lubricant recorded a peak value of lubricant pressure with 2.68 bar in 2500 rpm before it began to drop. In low speed, the heated and the unheated lubricant pressure difference was large. Heated lubricant provided lower resistance between the engine moving parts due to low viscosity. Therefore, a pre-heated engine is proven to operate with higher stability in either idle or low speed state. Higher engine speeds caused the pump to run faster and pushed more oil through the engine and because of the variances in high temperature (oil thinning) and the engine upon cold engine start up, the leakage from the bearings are higher than the pump's delivery rate causing a drop in oil pressure value [12].

CONCLUSIONS

This study had demonstrated that the engine noise and the engine oil pressure were strongly dependent on the operating temperature of the oil and the engine speed. There are no significant correlation between intake air flow and lubricant temperature. The high viscosity of lubricants in low temperature caused higher engine friction and noise. The engine that operated with unheated lubricant recorded a peak noise of 107.2 dB at 1500 rpm and dropped momentarily before increased linearly beyond this speed. The engine that operated with heated lubricant started off with a very low pressure with 0.996 bar compared to unheated lubricant with 2.497 in

500 rpm. This suggests that an engine needs to be in high temperature to operate optimally. Oil thinning (low viscosity) increased the bearing leakage rate higher than pump delivery rate in high speed causing a drop in pressure value.

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