

EFFECT OF GASKET OF VARYING THICKNESS ON SPARK IGNITION ENGINES

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ABSTRACT

In the study of Toyota, In-line, 4 cylinders, spark ignition engine using gaskets of varying thicknesses (1.75mm, 3.5mm, 5.25mm, 7mm and 8.75mm) between the cylinder head and the engine block, the performance characteristics of the engine was investigated via the effect of engine speed on brake power, brake thermal efficiency, volumetric efficiency and exhaust temperature. To evaluate the performance characteristics for definite gasket (GK) thickness, the engine was operated between 200 – 4000 rpm, under steady state condition. The investigation reveals worsening engine performance with increasing gasket thickness though with improved volumetric efficiency for any given speed range.

KEYWORDS: Brake thermal efficiency, volumetric efficiency, Exhaust temperature

INTRODUCTION

Gaskets have wide industrial applications, such as, in automobile engines. In spite of the fact that the top surface of an engine cylinder block and the lower surface of an engine cylinder head may be smooth to the eye, the two surfaces never fit together closely enough to prevent leakage. Therefore, a gasket must be inserted between them to effect a seal. Various head gasket designs are in use, and these include metal head gaskets, fibrous head gaskets, sandwich type head gaskets having a metallic core and asbestos-bonded layers laminated to the core, chemical formulations containing polytetrafluoroethylene, silicone, nitriles, neoprene, polymeric resins etc. Sandwich-type gasket assemblies have sufficient resiliency to seal the cylinder head and sufficient heat resistance, especially when armored, to withstand the high temperature and pressure of the combustion chamber. Nunney (1998) affirmed that asbestos gaskets are becoming increasingly rare due to health concerns.

The gasket must seal against air, coolants, combustion and engine oil at their respective peak operating temperature and pressure and must be able to withstand the dynamic and thermal forces that are transmitted from the head and block, hence sharing the same strength requirements as other combustion chamber components as presented by Bickford (1997). The materials used and design employed must be thermally and chemically resistant to the products of combustion and the various chemicals, coolants and oils used in the engine, therefore avoiding a variety of problems that may occur, ranging from compression loss, which leads to power reduction or rough engine, to exhaust gases being forced into the cooling system, leading to engine overheat and increased engine wear due to the mixing of motor oil with antifreeze.

Furthermore coolant can leak into the cylinders, causing the exhaust to issue steam as revealed by Nunney, (1998), hence damaging the catalytic converter. If a very large amount of coolant does this, hydro-lock may occur, causing extensive engine damage.

Past studies of spark ignition engine were mostly centered on combustion systems as presented by Liberman (2008), Morel and others (1981), while Karlowitz (1974) revealed those centered on emissions control. Those that showed the fuel property effects on combustion and emissions were investigated by Johnson (2005), Kataoka and others (1993), Kahraman and others (2009), Blackmore and Thomas (1977), Owen and Colen (1990), while the works of Hosseini and others (2008), Nunney (1974) centered on engine and component designs. Eastwood (2000), Maus and others (1999) investigated the after-treatment devices in contrast to the engine control study of Kunihiro and others (2005), while Daniels and Braun (2006), Skjoedt and others (2008) systematically investigated the engine tribology. This experimental study, therefore, is a step further in establishing the influence of gasket thickness on brake power, brake thermal efficiency, volumetric efficiency and exhaust temperature for specific speed range of the engine.

EXPERIMENTAL METHODOLOGY

The experiment was conducted using a four-cylinder engine manufactured by Toyota with the specifications given in Table 1. The engine with all the necessary accessories, such as, fuel pump, oil sump, exhaust manifold, ignition coil, fan, fan belt, air cleaner, carburetor, etc was solidly mounted on a test rig. A systematic diagram illustrating the experimental layout of the engine is given in Figure 1.

With all the necessary accessories on the engine fitted firmly, the cooling system (radiator) was connected to the engine through water hose with water as the coolant. The inlet and outlet water hose together with the exhaust pipe were perforated in circular shape, so as, to accommodate the temperature sensor (thermometers)

necessary for reading the temperatures of the cooling water and the exhaust gas.

Table 1: Engine Specification

Engine	Specification
Manufacturer	Toyota Motor Corporation
Model	4K ,In line, 4 Cylinder, OHV
Type	Spark ignition
Capacity (cc)	1,290
Bore x stroke (mm)	75 x 73
Cylinder number	4
Maximum power (kW)	86
Maximum torque	12.7kgfcm
Compression ratio	9:1
Compression Pressure(kPa)	1,180

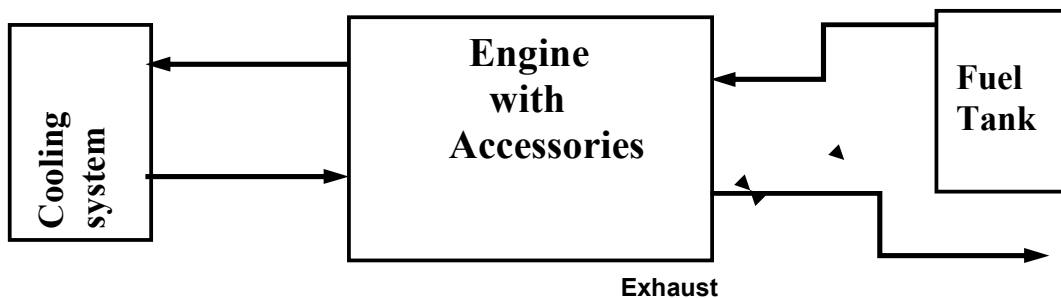


Figure 1: Experimental Layout

Another component specially constructed for this experiment is the fuel system (tank) having a volume of 16.8 cm x 10.5 cm x 20 cm, connected to the engine with fuel solenoid in place to cut off fuel supply when necessary. Furthermore, the fuel tank had necessary arrangement in place to record the mass flow rate of the fuel at any given time. With exhaust manifold properly fixed and the extension directed well away from the setup, the influence of the product of combustion on the experiment was minimized. To ensure close to stoichiometric air/fuel mixture, the air was properly filtered through the air cleaner before mixing with the supplied fuel to the carburetor and finally into the combustion chamber.

Before running the engine, a 4 liter SEA 40 oil lubricant, for effective lubrication of the engine parts, was poured in the oil sump to gauge and new oil filter, plugs, fuel pump and a 64 Ah battery fitted and then, 'test-run' for about 20 minutes to ensure proper connection and functionality of all the components. The engine with 1.75mm gasket was then set at 200 rpm and allowed to run for 5 minutes followed by the readings of the water inlet, outlet exhaust temperatures and the mass flow rate of the fuel (m_f). Further readings were taken by varying the speed of the engine at intervals of 200 rpm up to a maximum of 4000 rpm. The same procedure was repeated for gasket thicknesses of 3.5mm, 5.25mm, 7mm and 8.25mm.

From the dimension of the fuel tank, the volume flow-rate (V_f), hence mass flow rate ($m_f = \rho_f V_f$), of the fuel was computed at any given time interval (Δt). The brake power (BP), brake thermal efficiency (η_b) and volumetric efficiency (η_v) were then evaluated using standard expressions of Nunney (1974).

DISCUSSION OF RESULTS

As shown in Figure 2, the brake power is directly proportional to the speed of the engine with slight increase in the constant of proportionality with increasing gasket thickness, which implies that for any given speed, there is increase in the brake power for increasing gasket thickness. The corresponding adverse effect of this phenomenon is represented in Figure 3, where the superiority of the normal (1.75mm) gasket with higher brake thermal efficiency for any given speed is clearly illustrated. For all tested head gaskets, the brake thermal efficiency decreases with increasing engine speed, which implies that less mass flow-rate of fuel is required to run the engine with 1.75mm gasket.

Because volumetric efficiency is the ratio of air induced, measured at the free air condition to the swept volume of the cylinder and given that the swept volume is virtually the same for all the tested head gaskets, the volumetric efficiency of the engine with 1.75mm gasket should be less for any given engine speed due to the

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increase in volume of air induced with increasing gasket thickness, as illustrated in Figure 4. The figure also shows continuous increase in volumetric efficiency with increasing engine speed for any given head gasket. As represented in Figure 5, the exhaust temperature is seen to vary almost linearly with the engine speed for the 1.75mm head gasket. Furthermore, the figure also represents the departure from linearity for increasing gasket thickness, which is an indication of the possible difficulties associated with the use of gaskets with thicker material.

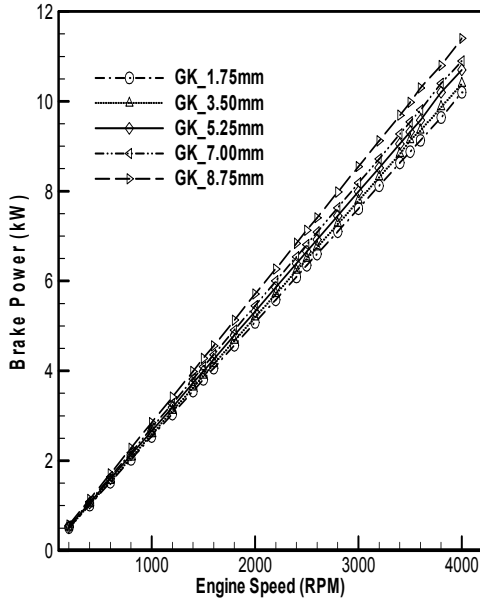


Figure 2: Effect of Speed on Brake Power.

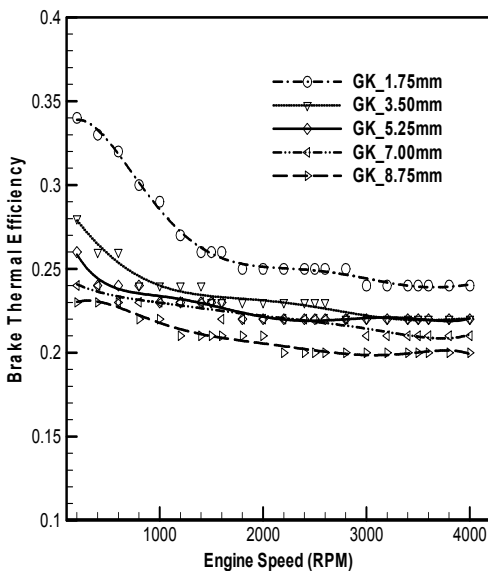


Figure 3: Effect of Speed on Brake Thermal Efficiency.

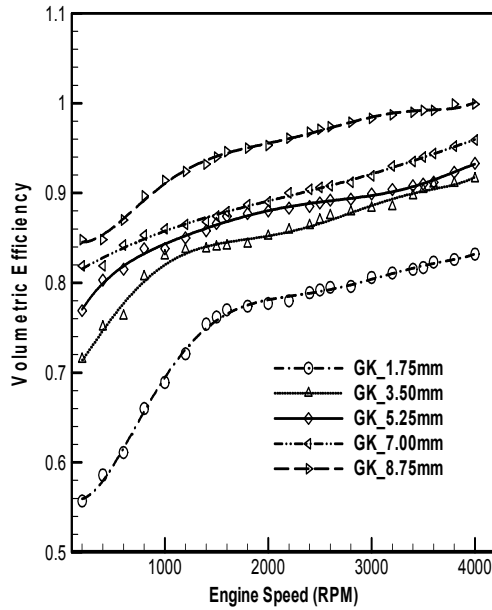


Figure 4: Effect of Speed on Volumetric Efficiency.

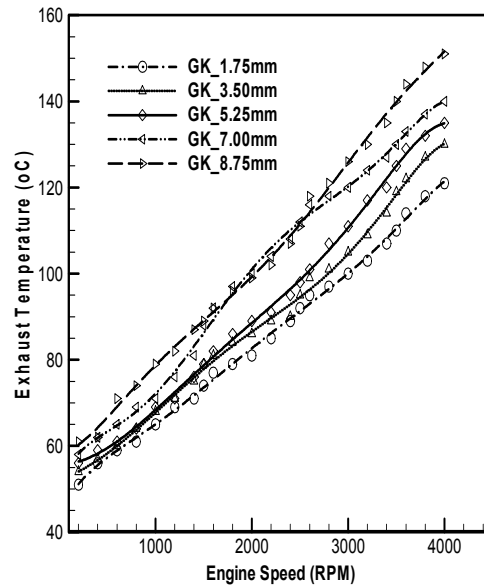


Figure 5: Effect of Speed on Exhaust Temperature

CONCLUSION

Increasing the gasket thickness has both favorable and adverse effect on the performance of the engine with the latter outweighing the former. Therefore, the most common misconception of having to select head gasket of thicker material is been laid to rest.

As discovered, the thicker the material, the more likely the material being contained can ‘weep’ through the pores of the gasket material, with possible different effect on some materials than the others. A rule of

thumb is to have the material thick enough to compensate for any surface irregularities and to permit for some compression and necessary resiliency to seal the cylinder and sufficient thermal and chemical resistance required in the vicinity of the combustion chamber.

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