THE MEASUREMENT OF COMPONENT FRICTION LOSSES IN A FIRED ENGINE, PART 1 (EXPERIMENTAL METHOD)

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ABSTRACT

The direct relationship of frictional loss and fuel economy in an internal combustion engine has resulted in increasing interest in understanding the performance of the engine at the component level. Also for the development of new engine lubricants it would be better to have an in-depth analysis of the interaction of lubricants with each individual engine component under fired conditions.

With the advances in data acquisition system and sensor technology, extensive study of the main engine components i.e. valve train, piston assembly and engine bearings has been possible resulting in the development of a versatile engine friction measurement system. Total engine and component friction measurement was carried out on a single cylinder Ricardo Hydra gasoline engine under fired conditions at various lubricant temperatures, engine speeds and loads. The engine was fitted with more than fifty different sensors and to sample/log data from such a large number of transducers, an advanced high-speed synchronised data acquisition system was designed/developed. Experiments are reported for total and component friction at a range of engine operating conditions with SAE 0W20 and friction-modified SAE 5W30 lubricants. The effect of lubricant temperature and engine speed on not only component friction but also total engine friction has been analysed.

2. TOTAL AND COMPONENT FRICTION

Total engine and component friction measurement was carried out on a single cylinder Ricardo Hydra gasoline engine under fired conditions at crankcase lubricant inlet temperatures of 24°C, 40°C, 60°C and 80°C. The friction was measured at engine speeds of 800rpm (¼ load), 1500rpm (½ load) and 2000rpm (½ load) using an SAE 0W20 lubricant and a friction-modified SAE 5W30 lubricant. Results are presented in part 2. The design of the single cylinder Ricardo Hydra gasoline engine is based on a real engine, a GM 2.0 litre Cavalier engine.
The Ricardo Hydra engine is a four valve engine having direct-acting overhead camshafts acting on flat faced, hydraulic lash adjusted bucket followers driven by a toothed timing belt. Direct and instantaneous measurement of valve train friction torque is carried out using specially designed camshaft drive pulleys incorporating torque sensing, see figure 1. The torque transducer is a two-part construction with instrumented central hub and toothed pulley gear. The torque sensing system was specially designed to integrate seamlessly into the original engine drive train arrangement and to be capable of evaluating both inlet and exhaust camshafts. The camshaft torque transducer signal conditioning, calibration and post processing details can be found in [1].

Instantaneous and average piston assembly friction measurements have been carried out on a single cylinder gasoline engine using the IMEP (indicated mean effective pressure) method, which was found to be a powerful tool to monitor piston assembly performance at realistic engine speeds and loads without any major engine modifications. The forces acting on the piston assembly were carefully determined by measuring the cylinder pressure, crankshaft angular velocity and strain in the connecting rod. The difference between the resulting gas pressure, inertia and connecting rod axial forces acting on the piston yields the piston assembly friction. To achieve this with confidence, an advanced instrumentation, telemetry and data acquisition system was designed and developed, giving special attention to the synchronisation and simultaneous sampling of analogue and digital channels. The details of the piston assembly friction measurement technique, instrumentation and calibration can be found in [2].

The total engine friction loss in a fired engine is measured by using the information of cylinder pressure and piston displacement thus generating a PV (pressure-volume) diagram. The total engine friction loss can be derived from the indicated diagram and the engine brake torque measurement as,

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\text{Total friction} = \text{indicated work} – \text{pumping work} – \text{brake work}
\]

By measuring simultaneously the camshaft assembly friction, piston assembly friction and total engine friction, engine bearing friction power loss is calculated as all the auxiliaries are independently and externally driven. The Ricardo Hydra engine has two main bearings and a big-end bearing. The advantage of using a single cylinder engine is that the load sharing issue between main bearings is easily resolved with each bearing carrying half the load of the cylinder pressure and inertia.

3 DATA ACQUISITION SYSTEM

In order to measure total engine friction, component friction and various engine parameters an advanced data acquisition system based on a 933 MHz Pentium III PC was developed using high-speed National Instruments data acquisition hardware. Labview was used to control the data acquisition DAQ operations. Synchronised measurement of a number of analogue and digital channels was paramount for the piston assembly friction measurement and bearing friction [2]. A summary of the flow of information required to measure component and total engine friction is shown in figure 2.

4 RESULTS

The experiments were performed in four sets, obtaining measurements at four different speeds at each temperature using SAE 0W20 and friction-modified SAE 5W30 lubricants. The detailed results are discussed in the second part of this paper showing the capability of this system. Figure 3 is taken from the results section (part II) showing the measured parameters. This system can be used as a powerful tool for studying the effect of different lubricants on each of the main components of an engine. It can be used to validate complex engine friction models and various materials and engine component design.

Figure 2. Engine friction data flow chart

Figure 3. Total engine and component friction at an engine speed of 800rpm, ¼ load, SAE 0W20 no FM

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