APPLICATION NOTE

A NEW KNOCK DETECTION TECHNIQUE

Accufiber has developed a new method of detecting knock conditions in an internal combustion engine. An Accufiber optical Fiber Thermometer (OFT) mounted in the spark plug or the cylinder head monitors flame propagation within the cylinder. When knock occurs, the flame propagation speed across the cylinder increases and the shape of the OFT signal changes. The OFT signal associated with the arrival of the flame at the sensor becomes more abrupt and is of shorter duration. Higher frequency fourier components are generated in the OFT signal.

The fourier components are found to be multiples of the combustion frequency and provide a simple knock signature which is free from the effects of engine vibration. Comparison of the relative amplitudes of the fundamental (1st order) combustion frequency and the higher harmonics (2nd, 3rd, 5th etc.) show that the relative amplitudes of the higher order terms increase by approximately an order of magnitude when knock occurs. Several common wave analysis techniques can be used to obtain the fourier components of an OFT signal and detect the presence of knock.

The use of OFT sensors to measure the velocity of the flame front within cylinders has been reported some time ago.[1,2] If the distance between two sensors is known, the time required for the flame to travel between the sensors can be used to estimate the flame velocity component normal to the two sensors. While such "time of flight" measurements are straightforward, during each engine cycle the combustion front can travel along a much different path and can arrive at either sensor first. The use of simple time delay measurements to characterize the average flame propagation velocity can lead to ambiguous results. The present method of knock detection is based on the shape of the OFT signal. It is independent of the path of the flame with the cylinder and is only dependent on the speed and duration of the combustion within the cylinder.

A simple example of the technique is provided from knock data reported earlier.[3] A 3.78 liter, V6, 8:1 C/R carburated General Motors engine was operated in a chassis dynamometer near 2000 RPM under normal conditions and with the timing advanced to produce knock. The engine conditions are listed below:

	Normal Conditions	Knock Conditions
Torque	75 ft lbs	85 ft lbs
RPM	2090 RPM	1840 RPM
Speed	30 MPH	30 MPH
Vacuum	-3 in. Hg	-6 in. Hg
Timing	-18 deg BTDC	-36 deg BTDC
Dwell	30 deg	28 deg

The OFT sensor was located approximately 0.375 in. from the cylinder wall near the exhaust valve.[1] A 12 bit digitizer recorded the data in 0.05 ms time increments. The digital temperature resolution was 0.045°F; temperature signal-to-noise ratios were approximately 36,000/1 for a bandwidth of 10KHz.

The sensor signal was compensated for the thermal lag of the sensor and the heat flow to the sensor was recorded.[1] Typical heat flow waveforms are shown in Figure 1, where it is seen that there is a qualitative change in the shape of the waveform when knock occurs. The leading edge is more abrupt and heating of the sensor occurs over a shorter period of time. FFT analyses of these data provide the power spectral density functions shown in Figure 2. It is observed that when knock occurs, the relative value of the 2nd order term increases fourfold, while the relative values of the 3rd and 5th order terms increase tenfold. Notice that the amplitudes of the higher order terms are compared with the amplitude of the 1st order combustion frequency to eliminate any dependence on the absolute amplitude of the waveform on engine operation. The combustion frequency is equal to one half the engine RPM and is obtained from independent RPM measurements.

There are many methods of obtaining the fourier components of the heat flow wave, including tunable digital filters, dedicated FFT integrated circuits and FFT algorithms within the engine microprocessor. Accufiber has filed for a patent describing the sensor designs and associated analog and digital circuits. A control signal which is a function of the relative amplitudes of the fundamental

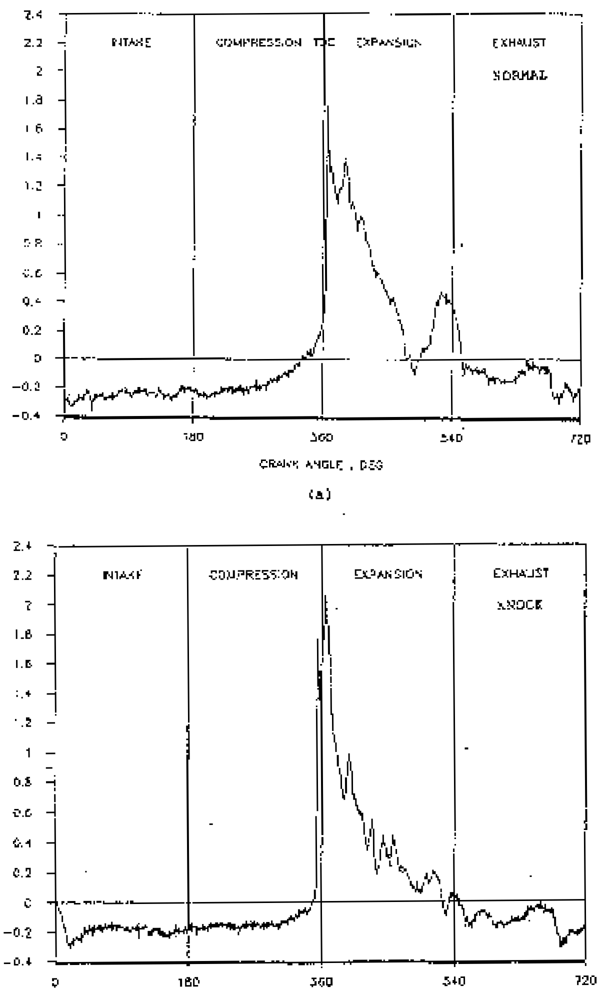

Figure 1. Single Engine Cycle Heat Flow Waveforms, a) Normal Conditions

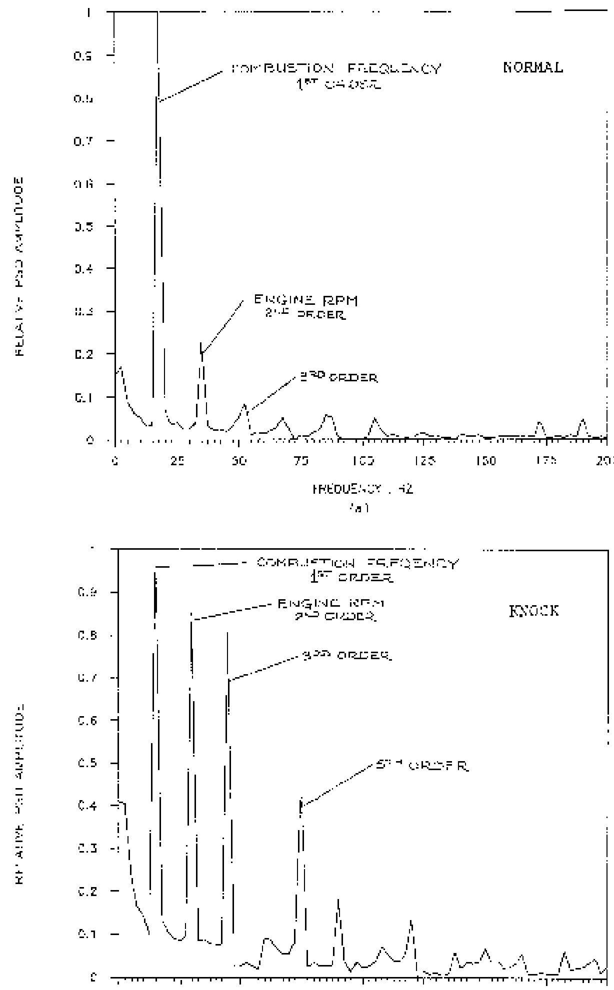

Figure 2. Comparison Heat Flow. a) Normal Engine Operation at 2090 RPM b) Knock at 1840 RPM.

combustion frequencies and the higher harmonics can be used to adjust the engine operation to eliminate knock. All the elements of the technology are inherently inexpensive and a practical engine knock sensor and detection system will be developed in response to market demand.

At the present time, in order to introduce the technology to the engine development and test community, an engine knock detection package has been assembled for use with external real time wave analysis equipment or the Accufiber EAS100 Engine Analysis Software. Typical experimental arrangements are shown in Figure 3. The OFT engine sensor can be introduced into the cylinder using an engine insert[4] or an instrumented spark plug. [5] Either an analog compensation circuit and a real time FF7' spectrum analyzer can be used to obtain instantaneous Power Spectral Density functions or the data can be digitized and analyzed of f line using EAS100 software[6] to compute the heat flow to the sensor and the FFT of the heat flow signal.

Please contact the Accufiber factory for additional details and technical assistance.

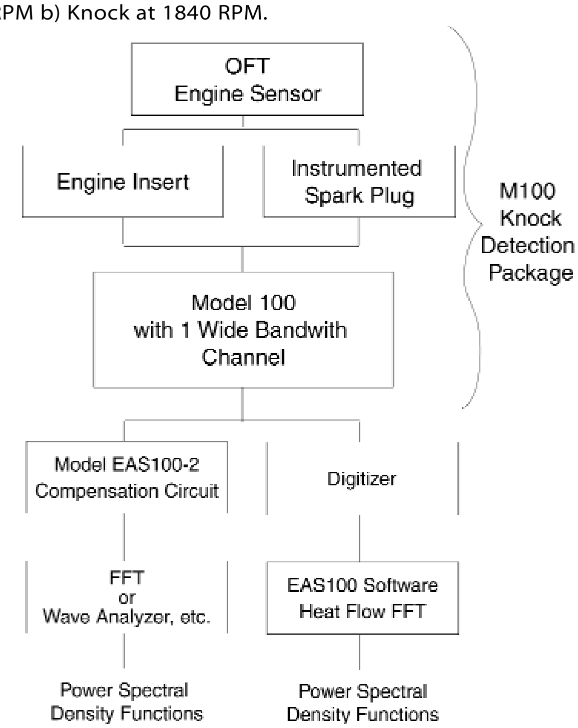

Figure 3. Engine Test and Development Alternatives for OFT Knock Detection.

REFERENCE

[1] Dils, R.R. and Moore, M.P., "An Introduction to Optical Fiber Thermometer Measurements in Automotive Engines," Advances in Instrumentation, Volume 41, ISA 86, Houston, TX, p 1159, 1986.

[2] Accufiber Application Note EAS100-A1, see page 9 and Figure 6, February 1988.

[3] Accufiber Application Note EAS100-A5 "Sensor Temperature and Heat Flow Measurements During Knock," February 1988.

[4] Accufiber Application Note EAS100-02, "Installation of Optical Fiber Thermometers for In-Cylinder Measurements", February 1988.

[5] Accufiber Application Note EAS100-A8, "Instrumented Spark Plug",

[6] Accufiber Application Note EAS100-A2, "An Introduction to EAS100 Heat Transfer Analyses", February 1988.