Analysis of Combustion Knock Metrics in Spark-Ignition Engines

Document Number: 2006-01-0400

Date Published: April 2006

Author(s):
Jeffrey D. Naber - Michigan Technological Univ.
Jason R. Blough - Michigan Technological Univ.
David Frankowski - Motorola Automotive
Monroe Goble - Motorola Automotive
John E. Szpytman - Motorola Automotive

Abstract:
Combustion knock detection and control in internal combustion engines continues to be an important feature in engine management systems. In spark-ignition engine applications, the frequency of occurrence of combustion knock and its intensity are controlled through a closed-looped feedback system to maintain knock at levels that do not cause engine damage or objectionable audible noise.

Many methods for determination of the feedback signal for combustion knock in spark-ignition internal combustion engines have been employed with the most common technique being measurement of engine vibration using an accelerometer. With this technique single or multiple piezoelectric accelerometers are mounted on the engine and vibrations resulting from combustion knock and other sources are converted to electrical signals. These signals are input to the engine control unit and are processed to determine the signal strength during a period of crank angle when combustion knock is expected. As the accelerometer detects a number of sources of vibrations in addition to the desired vibration from knock, the signal quality varies significantly from engine to engine, cylinder to cylinder, and over the operating conditions of the engine.

To evaluate the effectiveness and accuracy of knock detection via accelerometers, a reference system is commonly employed. One of the most common reference metrics is the signal strength of the combustion pressure over the appropriate frequency range as measured with in-cylinder pressure transducers.

This analysis examines both cylinder pressure and accelerometer-based knock intensity metrics, where the pressure-based knock intensity metric is used as the reference measure. Distributions of the knock metrics over a number of engine cycles for various engine speeds, loads, cam timings, and knock levels are measured and fit to a log-normal model distribution. The log-normal model is shown to provide a good fit to the measured distribution and also captures the

characteristics of the distribution to include skewness and peakness. In addition the accelerometer intensity metric is correlated to the reference pressure intensity metric. The result of this correlation provides the coefficient of determination, which is used as a measure of the accelerometer intensity metric's ability to indicate knock. The effects of the distribution of the pressure intensity metric on the coefficient of determination are examined by analyzing subsets of the distribution