Knock Characterization and Study

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Objectives:
Study the phenomena that determine knock in spark-ignition engines

Engine Setup:
Mercury Marine 40 hp, 3 cylinder, spark-ignited engine with vertical shaft

**Mercury Marine 40 hp, 3 cylinder, spark-ignited engine with vertical shaft**

- **Power @ Propeller**: 40 HP, 29.4 kW
- **Max Speed**: 5500-6000 RPM
- **Cylinder Configuration**: In Line
- **Displacement**: 747 cc
- **Bore & Stroke**: 65 & 75 mm respectively
- **Cooling System**: Water-Cooled
- **Ignition System**: ECM 555 Digital Inductive
- **Exhaust System**: Through Propeller
- **Lubrication System**: Integrated Wet Sump
- **Fuel/Ethanol Tolerance**: 10%
- **Fuel/Alcohol Tolerance**: 85 Octane
- **Fuel Induction System**: 2-Valve per Cylinder, Single Overhead Cam (SOHC)
- **Pressure Sensing System**: Kistler 6125B pressure transducer, Kistler 5010B charge amplifier
- **Data Acquisition System**: NI-PCI-6143 S series DAQ, preceded by 2 Analog 50kHz filters
- **Data Acquisition Frequency**: 200 kHz

Current Work

- Mean power spectral density was used to establish the pass-band for the digital filters
- 4 filters were used to digitally filter the pressure signal
- Filter 4 is a band-pass filter with a dynamic band of 3 kHz centered at the most energetic frequency

![Power Density vs. Frequency](image1)

![Power Density vs. Frequency](image2)

- The commonly used method of TVE usually predicts the knock onset late
- **KO_{TVE}** was developed based on SER (Single Event Rate)

Current Work Continued

Major knock intensity metrics fall into one of the following 8 major categories

- Frequency domain
- Time domain
- Pressure
- Heat release
- Single value
- Average value

Main Examples

- **MAPO**: Time domain, Pressure, Single value
- **SEPO and AEPO**: Time domain, Pressure, Average value
- **SEHRO and AEHRO**: Time domain, Heat release, Average value
- **AEFD**: Frequency domain, Pressure, Average Value

![Frequency Domain vs. AEPO](image3)

AEFD = \( I_{AEFD} = \int_{\Delta\vartheta} P(t) dt \)

- The heat release calculation done for the knock intensity purposes is usually based on:

Heat release, Integration Interval

AEHRO = \( \frac{1}{\Delta\vartheta} \int_{\Delta\vartheta} [x(t)]^2 dt \)

- The difference between AEPO and AEFD is that AEPO is calculated for a time window \( \Delta\vartheta \) whereas AEFD encompasses the entire cycle.
- It was verified that equation 15 was satisfied if the integration limits for AEPO are extended to encompass the entire cycle.
- The reason for the modest spread between the two methods is mainly because of the cycle-to-cycle variation in pressure oscillations’ duration; therefore, a cycle with oscillations that last much longer than 7° CA would have a greater AEFD/AEPO ratio than a cycle with oscillations that last significantly within the 7° CA window.

Results

- **Single Value vs. Integral Value Methods**
  - The use of a single-value method for knock detection, e.g., MAPO, is susceptible to bias because of destructive and constructive interference of the harmonic waves.
  - The maximum possible value caused by constructive interference of all contributing waves is unlikely to occur because of the decaying nature of the autoignition waves.
  - The acoustic power of the pressure signal is equal to the sum of the powers of the individual harmonic waves, which correspond to the sum of squares of the amplitudes of the basic harmonic waves. Therefore, many combined signals with the same maximum amplitudes might have very different total powers.

Results Continued

- **Heat Release Rate Methods**
  - The heat release calculation done for the knock intensity purposes is usually based on:

Heat release, Integration Interval

\( \Delta\vartheta \)

- The fact that the pressure is not uniform under the conditions of knock immediately violates the thermodynamic equilibrium assumption that is inherent in the above equation.
- The results are not independent of the pressure-based metrics and do not, therefore, provide new insight. Therefore, a strong correlation exists between AEHRO and AEPO.

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