Engine Friction Model and Error Analysis

Nabil G. Chalhoub, Associate Professor
Naeim A. Henein, Professor
Hassan Nehme, Ph.D. Candidate

Mechanical Engineering Department
Wayne State University
Detroit, Michigan 48202

Walter Bryzik

U. S. Army Tank-Automotive RDE Center, AMSTA-R
Warren, MI 48397-5000, U.S.A.

May 26, 1999
Goal

A reliable method for determining the instantaneous engine frictional losses under transient and steady-state operating conditions.
Scope of the Work

• Focus on improving the \((P - \omega)\) method.

• Error Analysis:
  - Identify the reason for obtaining positive numerical values for the engine frictional losses.

• Methods for improving the accuracy of the \((P - \omega)\).

• Experimental validation of the theoretical results.
Detailed model capable of capturing the rigid and Flexible motions of the crank-slider mechanism.

Sources of Error
- Role of structural deformations in the prediction of the instantaneous engine frictional losses.
- Effects of the system nonlinearities.

Improvements of the Method
- Estimation of the structural deformations to correct for the measurements of the rigid body motion of the crank-slider mechanism before the data can be used in the \((P - \omega)\).
- Improve the accuracy of the \((P - \omega)\) method by including the structural deformations in its formulation.
A model describing the frictional losses along with the rigid and flexible motions of the crank-slider mechanism.

$(P - \omega)$ method based on the rigid body model of the crank-slider mechanism
Instantaneous Frictional Torque
From the Current Formulation
\[
\omega_{\text{Cont}} = \omega_{\text{rigid}} + \left( 1^{\text{st}} + 2^{\text{nd}} + 3^{\text{rd}} \text{ elastic modes} \right)
\]
Instantaneous Frictional Torque
From the (P-W) Method

\[ \omega_{Cont} = \omega_{rigid} + 1^{st} + 2^{nd} + 3^{rd} \text{ elastic modes} \]

\[ \omega = \omega + \sum_{i=1}^{3} \phi_i(z_1=0) \dot{q}_i(t) \]
\( P - \omega \) Method (Modified)

\[ \omega_{\text{treated}} = \omega_{\text{rigid}} + (2^{\text{nd}} + 3^{\text{rd}} \text{ elastic modes}) \]

\[ \omega_{\text{treated}} = \omega_{\text{rigid}} + (3^{\text{rd}} \text{ elastic mode}) \]
Instantaneous Frictional Torque
From the Modified (P-W) Method

\[ \omega_{\text{cont}} = \omega_{\text{rigid}} + 3^{\text{rd}} \text{ elastic modes} \]

\[ \omega_s = \omega + \phi_3(z_1=0)\dot{q}_3(t) \]

![Graph showing instantaneous frictional torque over engine cycles](image)
Power Spectrum of $\omega_{\text{contaminated}}$

Frequency
P-W method

$T_{\text{friction\_actual}} (\cdot), T_{\text{friction\_estimated}} (\cdot)$

Cycle

4 4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 5
Estimation of the structural flexibility of the crank-slider mechanism

\((\theta, \omega, \dot{\omega})_{cont}\)

- \(P_{gas}\)
- \(T_{load}\)

\((\theta, \omega, \dot{\omega})_{corrected}\)

- \(P_{gas}\)
- \(T_{load}\)

\((P - \omega)\) Method

- \(T_{f_{est}}\)

\(q_f\)
Improvements of the Method (Continued)

- Modify the model that considers the combined rigid and flexible motions of the crank-slider mechanism to include the hydrodynamic lubrication regime of the piston assembly.

- Consider the effects of the piston secondary motions such as piston slap and piston tilting.

- Experimental validation of the theoretical results.