Car Engine Dynamics and Fuel Consumption Simulation

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1 Introduction

This document outlines the formulas used to simulate the dynamics and fuel consumption of a car engine. The model considers the engine angular velocity, fuel consumption rate, fuel efficiency, power output, torque, and time-varying factors such as gas valve open level and load torque.

2 Formulas

2.1 Fuel Consumption Rate

The fuel consumption rate, $\dot{m}(t)$, depends on the time-varying gas valve open level, $V(t)$, and the engine angular velocity, $\omega(t)$:

$$\dot{m}(t) = k_{\text{fuel}} \cdot V(t) \cdot \omega(t) \tag{1}$$

where k_{fuel} is a proportional constant for the fuel consumption rate.

2.2 Fuel Efficiency

The fuel efficiency, $\eta_f(\omega(t))$, is a function of the engine angular velocity, $\omega(t)$:

$$\eta_f(\omega(t)) = \eta_{\max} \cdot \left(1 - e^{-\alpha \cdot (\omega(t) - \omega_{\text{opt}})^2}\right) \tag{2}$$

where $\eta_{\max}$ is the maximum fuel efficiency, α is a constant, and ω_{opt} is the optimal angular velocity for maximum efficiency.

2.3 Power Output

The power output, $P(t)$, is determined by the fuel consumption rate and the fuel efficiency:

$$P(t) = \dot{m}(t) \cdot \eta_f(\omega(t)) \tag{3}$$

2.4 Total Torque

The total torque produced by the engine, $T_{\text{total}}(t)$, is related to the power output and angular velocity:

$$T_{\text{total}}(t) = \frac{P(t)}{(2\pi \cdot \omega(t)/60)} \tag{4}$$

2.5 Internal Friction Torque

The internal friction torque, $T_f(t)$, as a function of angular velocity is given by:

$$T_f(t) = k_{\text{friction}} \cdot \omega(t) + c_f \tag{5}$$

where k_{friction} is the internal friction coefficient and c_f is a constant representing static friction.

2.6 Net Torque

The net torque, $T_{\text{net}}(t)$, is the difference between the total torque, internal friction torque, and load torque:

$$T_{\text{net}}(t) = T_{\text{total}}(t) - T_f(t) - T_{\text{load}}(t) \tag{6}$$

2.7 Angular Acceleration

The angular acceleration, $\alpha(t)$, is determined by the net torque and the engine's moment of inertia, I:

$$\alpha(t) = \frac{T_{\text{net}}(t)}{I} \tag{7}$$

2.8 Update Angular Velocity

The angular velocity is updated using the angular acceleration over a small time step, dt:

$$\omega(t + dt) = \omega(t) + \alpha(t) \cdot dt \tag{8}$$

3 Conclusion

These formulas provide a comprehensive model for simulating car engine dynamics and fuel consumption, considering the time-varying nature of the gas valve open level and load torque. Adjust the constants and functions based on empirical data or specific engine characteristics for more accurate simulations.