

Idle Combustion Stability Modeling

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ABSTRACT

Idle Combustion Stability has previously been difficult to predict prior to prototype engine development. This paper describes an empirical modeling approach to predicting upfront idle combustion stability. The model outputs are the combustion torque harmonic magnitudes and %LNV.

The paper describes the modeling methodology and provides correlation results for different engine configurations.

INTRODUCTION

Idle Powertrain NVH is the potential new car or truck buyer's introduction to Powertrain NVH, and the vehicle owner's reminder at the start of each new trip. The perception of idle NVH is transmitted not only to the customers' ears but also to the hands through the steering wheel vibration, to the feet through the floor board and pedal vibration, and to the torso through the seat track vibration. Low vibration inputs from all of these locations transmit a message of Powertrain quality and confidence. The delivery of these low vibrations requires good idle combustion stability.

The metrics that describe combustion stability, Standard Deviation of Indicated Mean Effective Pressure (SDIMEP) and the Percent Lowest Normalized Value (%LNV) were described in [1], and Combustion Torque Harmonics in [2,3]. These metrics can be measured once the engine is produced [4,5,6], but the Engine Development and Powertrain NVH teams need to know up-front in the design process prior to hardware that a proposed design will deliver on these metrics. An analytical prediction of idle combustion inputs is required to move the use of the vehicle level prediction tools [6] earlier in the development process.

MODELING METHODOLOGY

PARAMETER RELATIONSHIPS

The relationship of the fundamental metrics, SDIMEP, %LNV, Combustion Torque Harmonics was described in detail in [3] will be summarized here.

Standard Deviation of Indicated Mean Effective Pressure (SDIMEP)

SDIMEP is the fundamental parameter of idle combustion stability. It defines the statistical distribution of the primary work done by the combustion event. The total work done by the combustion event is described by the mean torque (0th order Combustion Torque Harmonic) or the NMEP. The SDIMEP will vary depending on the combustion system and the engine load, which can be measured by the IMEP. The relationship between IMEP and SDIMEP was first pointed out in [1]. The plot in [figure 1](#) shows a typical scattering of data with over 50 engines and more than 100 data points.

The general trend of the SDIMEP vs. IMEP data is given by the line plotted through the data. This line will be used as the fundamental statistical underpinning of the combustion model presented. This line follows the recognized relationship of SDIMEP vs. engine load; SDIMEP will decrease with increasing engine load and increase with decreasing load. The increase with load will flatten out with ever increasing load and the rate of decrease becomes increasing greater with lower load. A second order function is used to represent this relationship.

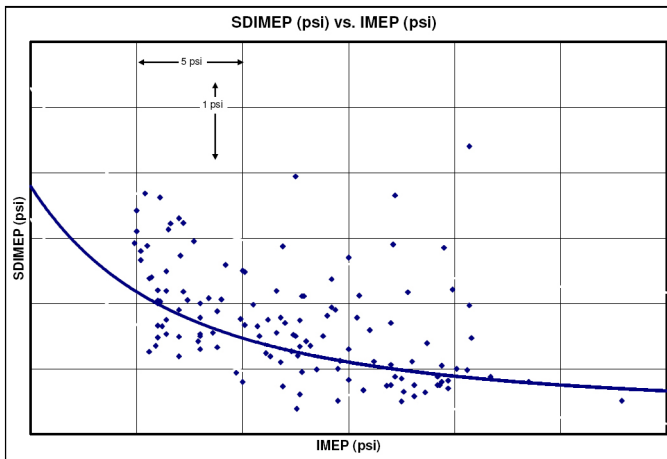


Figure 1. SDIMEP vs. IMEP Relationship

There is still a significant scatter in the data at any given IMEP point. The model will account for this factor by using the SDIMEP at a standard idle load. It is intended that this factor will allow the model user to account for variables that impact the combustion stability like combustion chamber shape, compression ratio, spark plug location, fuel injector location, fuel injection spray pattern, etc. The use of this variable allows the user to adjust the tract along which SDIMEP varies with IMEP. Two extreme cases are shown in [figure 2](#) with the dotted lines giving a high and a low combustion stability trend.

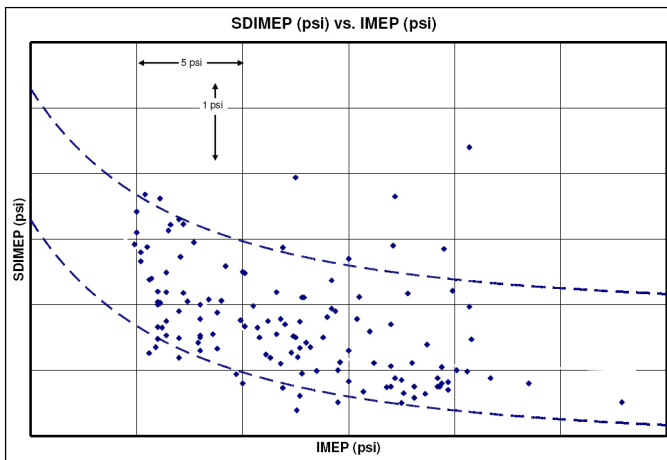


Figure 2. SDIMEP vs. IMEP Relationship Adjustments for Range of Combustion Stability

Idle Load

The Idle Load is the total work done by the combustion event. This work is quantified by the mean torque. The 0th order Combustion Torque Harmonic, Engine Load, and mean torque will be used interchangeably in this paper.

The load model starts with a regression analysis curve fit to convert from 0th order Combustion Torque to IMEP. The data from an engine running at approximately the center of the SDIMEP - IMEP map shown in [figures 1](#) and [2](#) was used to generate the regression. The regression analysis results in a linear relationship that gives a 94% R^2 correlation. The data, which contains over 2000 points, and the linear regression line are shown in [figure 3](#).

Using definitions given in [3] and approximations for friction load ($IMEP = BMEP + \text{friction}$) and the difference between Engine Load and Brake Torque; equations for Engine Load, BMEP, IMEP and Engine Displacement can be shown. These relationships will be used in the model.

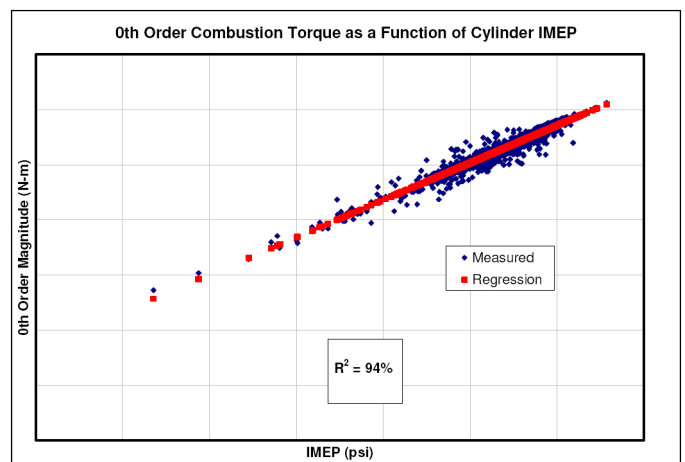


Figure 3. Engine Load vs. IMEP Relationship

INITIAL MODEL

The model as currently defined is capable of processing inputs:

- Engine Displacement (bore, stroke, and # of cylinders)
- Engine Idle Load in Torque or BMEP
- Engine SDIMEP at a base engine load into an IMEP value and the corresponding SDIMEP.

A cycle by cycle, cylinder by cylinder population of data for multiple cylinders can now be generated by assuming a normal distribution population for the entire data population and breaking the data up into the number of cylinders desired. A portion of a larger population is shown in [table 1](#).