World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:13, No:04, 2019

Predictive Semi-Empirical NOx Model for Diesel Engine

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Abstract : Accurate prediction of NOx emission is a continuous challenge in the field of diesel engine-out emission modeling. Performing experiments for each conditions and scenario cost significant amount of money and man hours, therefore model-based development strategy has been implemented in order to solve that issue. NOx formation is highly dependent on the burn gas temperature and the O₂ concentration inside the cylinder. The current empirical models are developed by calibrating the parameters representing the engine operating conditions with respect to the measured NOx. This makes the prediction of purely empirical models limited to the region where it has been calibrated. An alternative solution to that is presented in this paper, which focus on the utilization of in-cylinder combustion parameters to form a predictive semi-empirical NOx model. The result of this work is shown by developing a fast and predictive NOx model by using the physical parameters and empirical correlation. The model is developed based on the steady state data collected at entire operating region of the engine and the predictive combustion model, which is developed in Gamma Technology (GT)-Power by using Direct Injected (DI)-Pulse combustion object. In this approach, temperature in both burned and unburnt zone is considered during the combustion period i.e. from Intake Valve Closing (IVC) to Exhaust Valve Opening (EVO). Also, the oxygen concentration consumed in burnt zone and trapped fuel mass is also considered while developing the reported model. Several statistical methods are used to construct the model, including individual machine learning methods and ensemble machine learning methods. A detailed validation of the model on multiple diesel engines is reported in this work. Substantial numbers of cases are tested for different engine configurations over a large span of speed and load points. Different sweeps of operating conditions such as Exhaust Gas Recirculation (EGR), injection timing and Variable Valve Timing (VVT) are also considered for the validation. Model shows a very good predictability and robustness at both sea level and altitude condition with different ambient conditions. The various advantages such as high accuracy and robustness at different operating conditions, low computational time and lower number of data points requires for the calibration establishes the platform where the model-based approach can be used for the engine calibration and development process. Moreover, the focus of this work is towards establishing a framework for the future model development for other various targets such as soot, Combustion Noise Level (CNL), NO₂/NOx ratio etc.

Keywords : diesel engine, machine learning, NO_x emission, semi-empirical
Conference Title : ICAE 2019 : International Conference on Applied Energy
Conference Location : Tokyo, Japan
Conference Dates : April 22-23, 2019