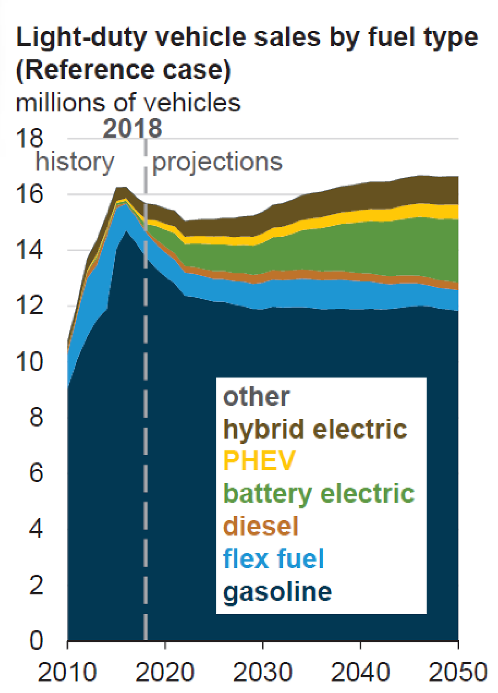
Performance Evaluation of Spark Plugs in Gasoline Engines

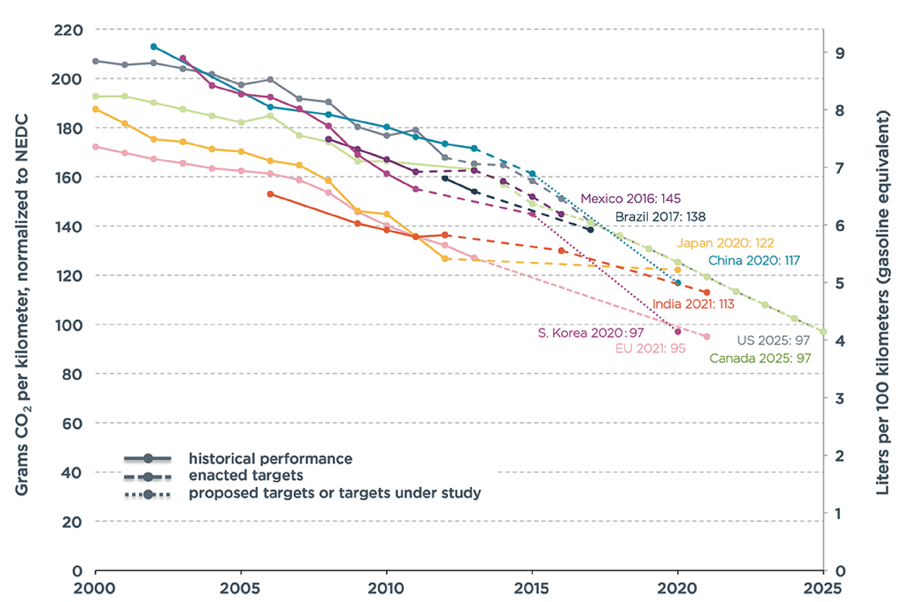
Centre for Mechatronics and Hybrid Technology
Mechanical Engineering, McMaster University
Mehdi Sadeghkazemi

EECOMOBILITY (ORF) & HEVPD&D CREATE

END OF ICE AGE?

According to the recent report of the U.S. Energy Information Administration (Annual Energy Outlook 2019 with projections to 2050), the Internal Combustion Engines (ICEs), especially gasoline engines, will maintain their significant market share through 2050. Surviving in today's market with the stringent emission and fuel economy legislations is a tough challenge for ICEs. Hence, a continuous improvement is required to meet all the standards and customer expectations. Part of this improvement is done through the ignition system design and optimization.

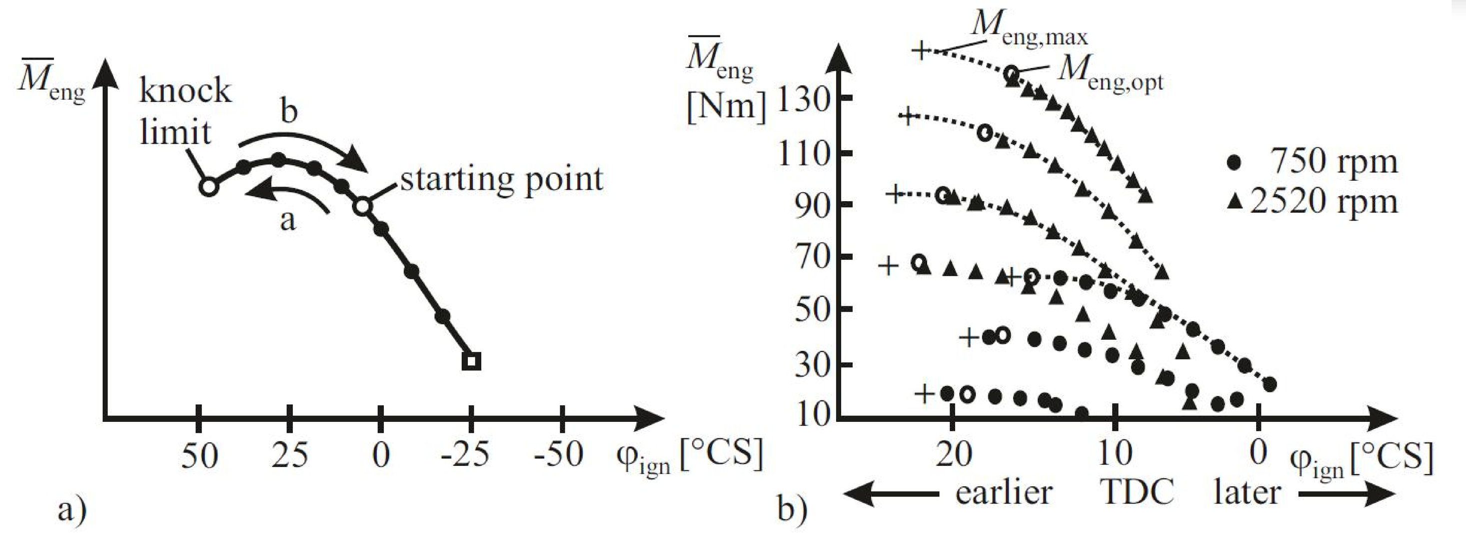




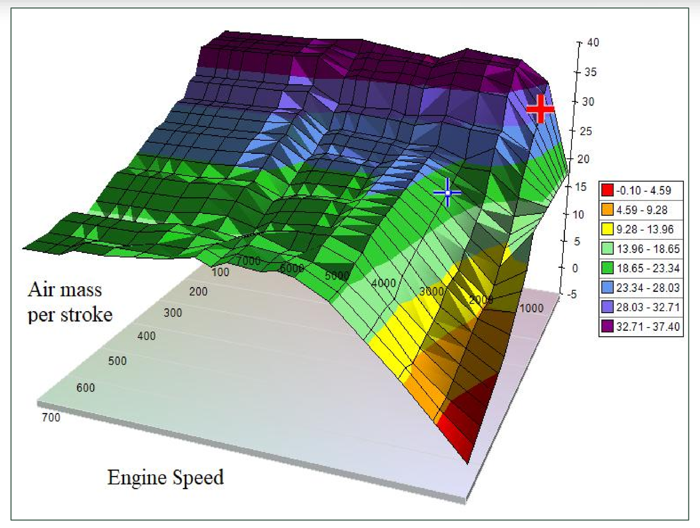
SIGNIFICANCE OF THE IGNITION SYSTEM

Ignition system is a significant part of the control system in gasoline engines because of its connection to engine management objectives especially those related to performance, emission and engine protection. The ignition advance with reference to Top Dead Centre (TDC) is constrained by knock and exhaust gas temperature limits as well. A compromise is required to take into account the effects of these objectives and constrains when optimizing the ignition timing. The feedforward ignition control contains the dynamics of all the mentioned attributes to keep an appropriate ignition advance for each engine speed and load condition. The feedback ignition control works according to the knocking condition of the engine, i.e. when knock is detected by engine knock sensors, the engine control unit retards the ignition timing until the knock condition disappears. Its is also possible to move the in-cylinder pressure peak to the optimized position in the crank domain by means of feedforward and feedback ignition timing control.

DEPENDENCY OF ENGINE EMISSION AND PERFORMANCE TO IGNITION TIMING

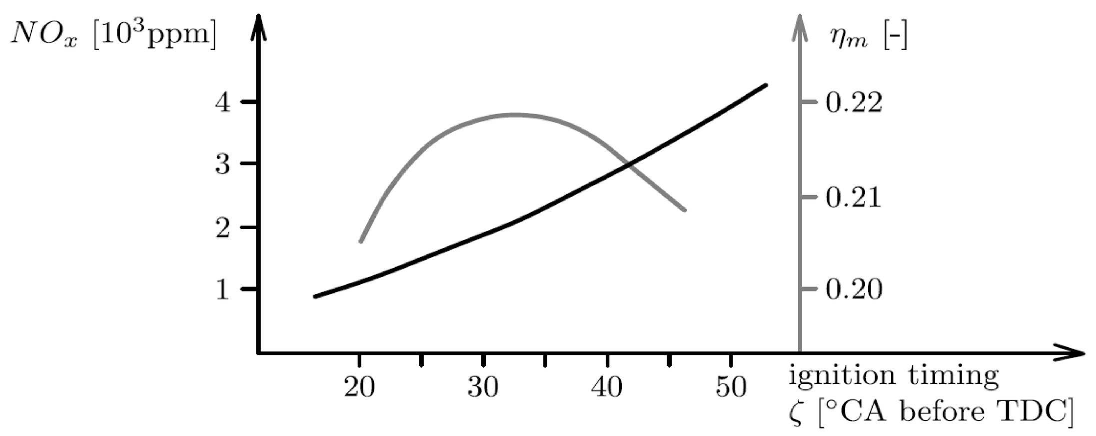


Dependency of engine torque to ignition timing (a), Optimal versus maximum achievable engine torque (b)



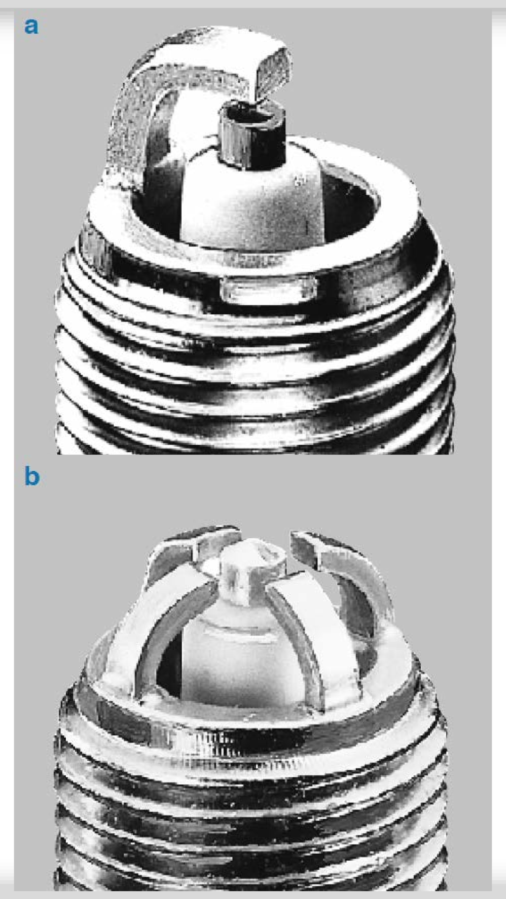
A typical feedforward ignition timing map

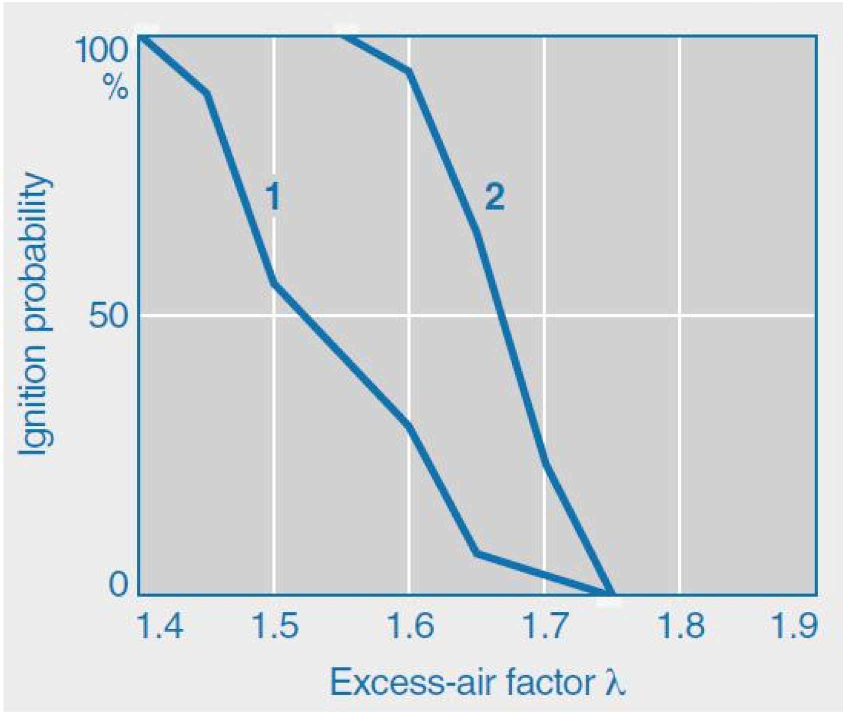
There are optimum points for both of the engine torque and emission values (especially Nox) that are dependent to the ignition timing as indicated in the figures. These optimums are functions of engine operating points and the ignition system design and can be located by the optimization techniques, which is the objective of this research for different spark plug designs.



Dependency of NOx emission and engine efficiency to ignition timing

THE TWO DIFFERENT SPARK PLUG DESIGNS





Effect of spark plug design on spark plug efficiency and ignition probability, a: Conventional b: New design

METHODOLOGY

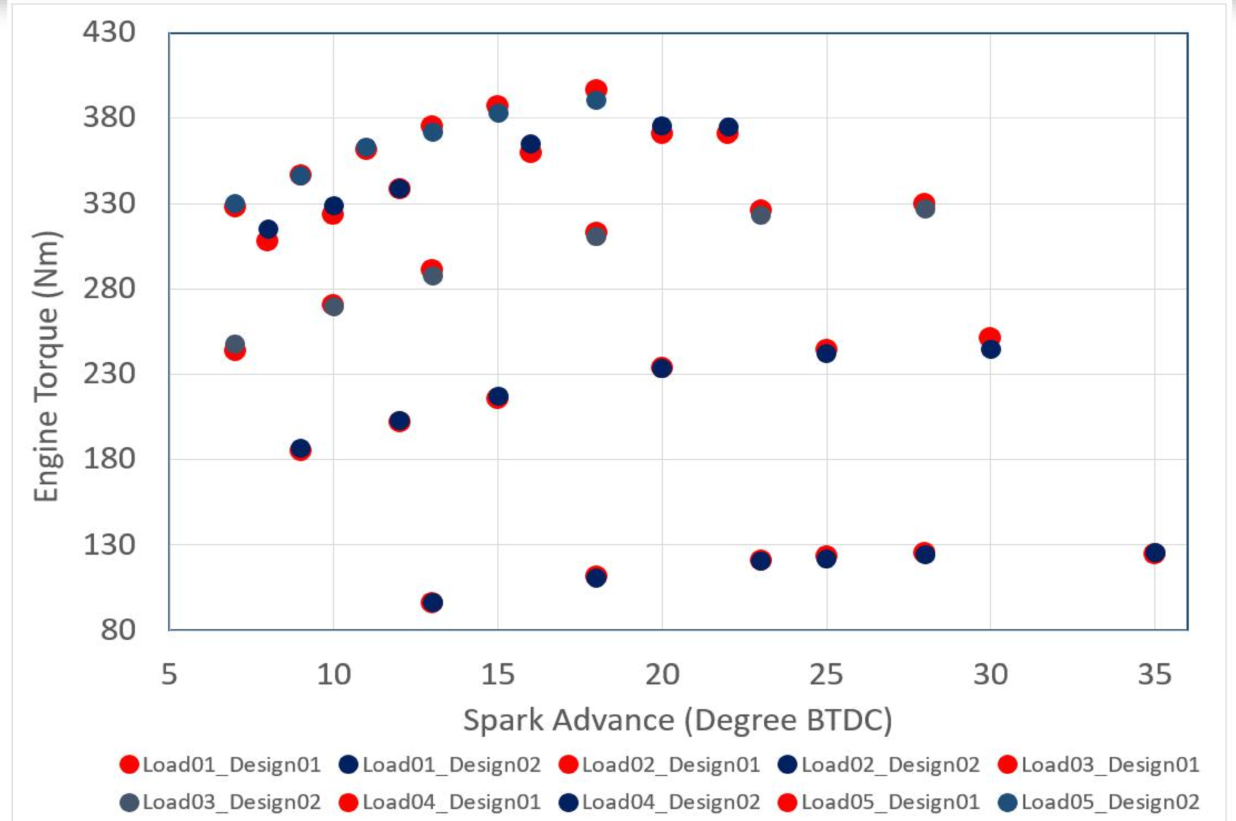
There are different approaches of ignition map optimization varying from **conventional trial and error** to the novel **model based** approaches. The Model Based approach is used in this research.

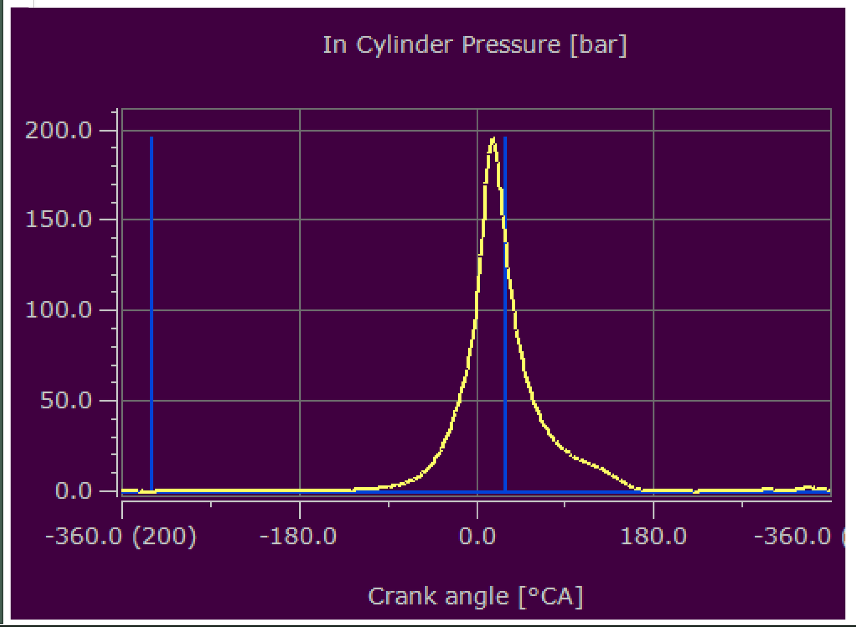
Design of Experiment (DoE): Engine tests will be done in selected points in the engine operating region covering engine speeds of 1000 to 3000 rpm and engine loads of 10 to 100%. All the effective engine parameters are monitored/controlled during the experiments so that the pure effects of ignition timing could be recognized for the two different designs. Engine torque, emission, fuel consumption and in-cylinder pressure are the main parameters under study. The new **Gen3 Ford Coyote engine** is used in this research at CMHT engine dyno lab.

Engine modeling: The statistical engine modeling approach is applied to the test data of the experimental part of this research to build models of engine performance, emission and fuel consumption. Main focus will be on Neural Network and Gaussian Process engine modeling methods.

Ignition Timing Optimization: The optimization part of this research is done with the aid of the Model Based Calibration (MBC) toolbox of MATLAB, which is developed to deal with the engine optimization problems. The optimization algorithm is the multi-objective Genetic Algorithm (GA), which returns the Pareto Fronts of the different objectives, while considering the constrains of engine knock and exhaust temperature. Comparing the Pareto Fronts of each spark plug design tells us which one is better in what operating point of the engine.

INITIAL RESULTS





Name	Cyl 1
APMAX [°CA]	16.6
ARMAX [°CA]	8.2
IMEPN [bar]	37.0
KFRQ [%]	52.0
KINT [bar°CA]	3.3
KPEAK [bar]	0.6
KPEAK_STAT [bar]	0.9
KRAT [None]	1.3
PMAX [bar]	195.7
PMAX_AVG [bar]	182.5
RMAX [bar/°CA]	7.7

McMaster University | University of Windsor | Western | CMHT Centre for Mechatronics and Hybrid Technologies | Ontario Research Fund | NSERC CRSNG

We acknowledge the support of the Ontario Research Fund: Research Excellence Program.

We acknowledge the support of the Natural Sciences and Engineering Council of Canada (NSERC), which invests annually over $1 billion in people, discovery and innovation.