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A Review:
Modelling and simulation of spark ignition engines

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Abstract — This paper assimilates the performance and the trends in spark ignition engines and to increase their efficiency in terms of Fuel-Air ratio (FAR) using adaptive control method, maintaining the FAR (Fuel-Air Ratio) by Three Way Catalyst (TWC). High performance robust controllers are introduced for meeting the objectives of the vehicle. Mechanical configurations such as the Electronic Fuel Injection (EFI), Drive by Wire Technology (DBW) , Variable Valve Timing (VVT). Zero Dimensional models are used to analyse the performance of the SI engines.

Keywords— Variable Can Timing, Electronic Fuel Injection, Fuel–Air Ratio, Zero –Dimensional.

I. INTRODUCTION

Spark ignition engines are also known as gasoline engines have emerged with a lot many recent trends and technologies with respect to conventional methodologies. The key objectives of SI engines are to improve their efficiency in terms of fuel economy and optimize and reduce the exhaust emissions. To maintain the Fuel-Air Ratio (FAR) several adaptive control methods are used for time delay systems. The determination of the point at which the fuel air ratio must be maintained is done by Three -Way Catalyst (TWC) in order to remove the excess of pollutants with higher efficiency. Three – Way Catalyst are refined with the laid foundation that they are thermally stable. This enables us to mount them directly on the exhaust manifold. Since a rapid engine start-up strategy catalyst operating temperature is achieved once the engine gets started , it is very easy to have extremely low emissions. Several computer models are used to test the performance of Three-Way Catalysts (TWC) layouts.

Adaptive controller designs are incorporated amalgamating feed forward direction as one of the designs while the other incorporating feed forward adaptation as well as feedback adaptation. The Adaptive Posicast Controller (APC) is used for the purpose. For the modelling and proper simulation of spark ignition engines high performance robust controllers are used to meet the objectives of the vehicle. Introducing design parameters and several mechanical configurations. The recent technologies introduce Electronic Fuel Injection (EFI), Drive by Wire Technology (DBW), Variable Can Timing (VCT) are such system technologies that has improved the overall performance of the vehicle. Control systems play an integral role in regulating the devices and they are settled as in two types of configurations. One of them is the open loop control systems, closed loop control systems. The Air-Fuel Ratio forms an important measure for issues such as anti – pollution and performance tuning reasons.

A Proportional – Integral – Derivative (PID) controller is commonly used in control systems. It helps in calculating the erroneous value measuring the difference between the desired set point and the measured process variable. The controller specifically attempts to optimize the error over time by element to a new value. For proper simulation, simulation models are used for spark ignition engine. A single zone zero dimensional model is used where in the Double Wiebe function is used which applies the Least Square method and it was known that the Double Wiebe function model fits better than the single Wiebe model. New fuel injection technologies have been introduced for spark ignition engines such as the Homogenous Charge Compression Ignition (HCCI) , Gasoline Direct Injection (GDI).

These current technologies produce less emission as compared to the other conventional models. The only disadvantage with these is that they are costly and less economical. As compared to the other technologies such as the Computational Fluid Dynamic Model (CFD) , Simulink are easy to use , take less computational time and quite easy to handle.

II. FUEL-AIR RATIO

The Fuel-Air Ratio can be defined as the mass ratio of air to fuel present in an internal combustion engine. A stoichiometric mixture has enough air to burn the available fuel completely but the only bottleneck it serves is that the stoichiometric mixture unfortunately burns very hot and eventually damages the engine components. It is generally used under light load conditions. This can somewhere reduce the fuel economy. In order to improve the fuel economy, engines are equipped with sensors in order to measure

the amount of un-burnt fuel. The Fuel-Air Ratio (FAR) control is one of the important aspects of gasoline engines. It has always been associated with numerous issues and challenges and extensive research has made it possible to introduce many controllers based on model based control approach. Fuel-Air Ratio also uses an automatic model which is also called as the Adaptive Posicast Controller (APC) which is an adaptive controller for time delay systems. Non– Linear feed forward controllers; feedback linearization, observer based controllers etc. are also some controllers which have significantly improved the functioning of the spark ignition engines.

Three Way Catalyst (TWC) is known to be one of the most quintessential technologies used to control the emissions. A Three Way Catalyst usually operates in a closed loop system and is made up of ceramic or a metallic substrate incorporating an active coating which is rich in alumina and is also made up of a number of oxides in a combination such as palladium, platinum and rhodium. It mainly consists of oxygen sensors which help in regulating the Air-Fuel Ratio (FAR).

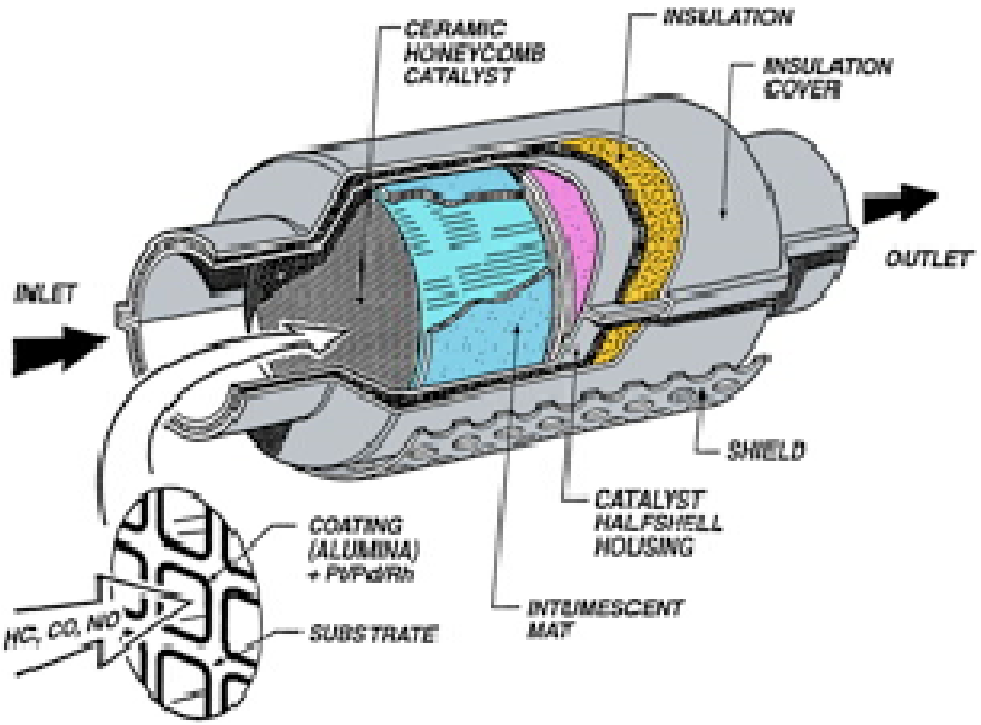

Figure 1. Three Way Catalyst (TWC)

A Three Way Catalyst (TWC) also had its distinguishable features with different properties. As compared to the conventional catalysts, thermally durable catalysts have been introduced that help in increasing the life of the catalyst. Diesel Oxidation Catalyst (DOC) are also one of the key technologies which serve to be better than the Three Way Catalyst (TWC) approach in a way that they have made it possible to have reduced or minimized contents of sulphur in emissions. DOC has also resulted in the substantial reduction of CO and HC emissions and hence produce less emissions as compared to Three Way Catalyst (TWC) approach. These are some of the primary reasons why we consider Diesel – Oxidation – Catalyst (DOC) better than the Three -Way – Catalyst (TWC).

The conventional fuel injection systems used carburettors for the purpose but now the current technology uses electronic fuel injectors which have replaced the carburettors in such a way that they provide excellent throttle response allowing smooth engine operation. It also helps in making the engine more efficient. The Drive by Wire technology (DBW) has now formed an integral part in automotive industries. It has allowed us to supplant the use of mechanical linkages and mechanical control systems with electronic systems making use of mechatronic actuators. It allows us to make our systems more durable and largely inclined to safety. It also works on reducing the overall weight of the system making it easy to use.

The only disadvantage with this technology is that it makes the development cost high. It somehow makes the system grow complex to ensure the system to be safe. However these systems with such technologies fall under the category of Safety Critical Systems

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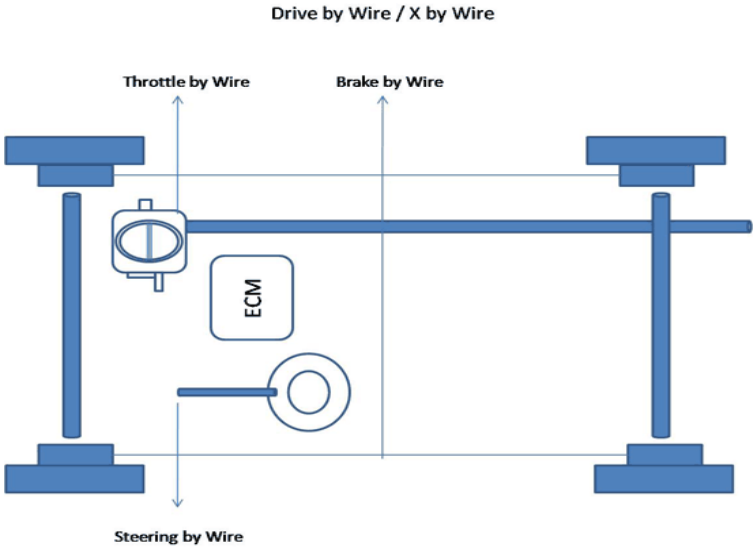

Figure 2. Drive by Wire Technology (DBW)

The Drive by Wire technology is categorized into its main two parts:

A. Brake by Wire Technology

The Brake by Wire technology enables and provides us the power to control the braking system in automobiles by means of electrical circuits. This technology proves to be very successful as it helps in replacing the conventional use of pumps , hoses , fluids , belts, traditional mechanical and hydraulic control systems etc. This technology exists as Electronic – Brake – System (EBS) , which assures that the system provides electronic activation of almost all the braking system components. The key advantage of using the EBS system over the conventional braking system is that it purely enhances the accuracy and the precision of the braking system and overall minimizes and reduces the distance of the braking which is also known as braking distance.

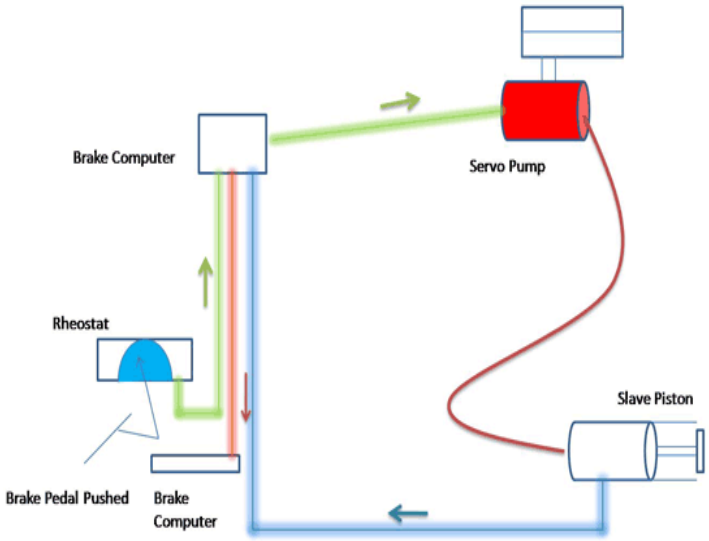

Figure 3. Brake By Wire Technology.

B. Electronic Throttle Control

The Electronic Throttle control is one such concept whose technology aspect is based on replacing the mechanical linkage in the automotives. The ETC also helps in providing the ease with which the driver can execute gear changes and work on the changes of

the torque.

Figure 4. Electronic Throttle Control.

III. VARIABLE VALVE TIMING

Variable Cam Timing (VVT) provides with excellent torque capacity, greater power with reduced fuel consumption and hence with lower emissions. The variable Valve Timing is used to overcome the engine deficiencies, thereby dynamically altering the valve's opening and closing for optimal performance at any speed.

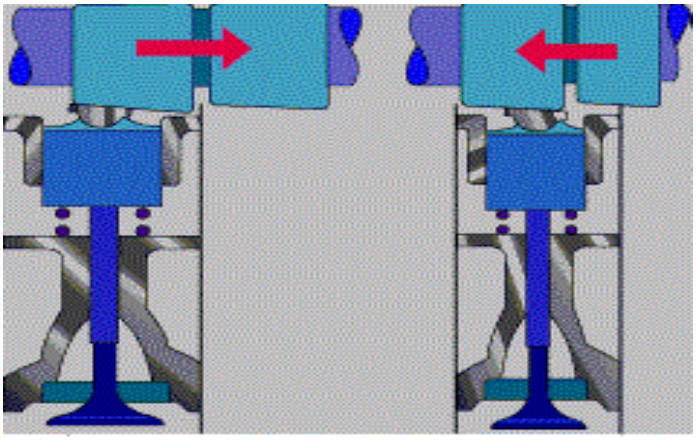

Figure 5. Variable Valve Timing (VVT)

IV. CONCLUSION

A single Zero Model presents to be a good interface to the user for any parametric study. CFD & Simulink provides results that are close to each other with experimental brake power.

The adaptive control method used for maintaining the Fuel-Air Ratio (FAR) gives good and effective results. The Three Way Catalyst (TWC) method involving the catalyst working in a closed loop system . It was noticeable that the Diesel Oxidation Catalyst (DOC) was better than the conventional catalysts used and ensured that the vehicle produced less emissions as compared to the other catalysts used.

Spark Ignition engines have come up with a lot many new configurations and with many such replacements that have contributed towards the betterment of the operation of Spark Ignition engines. Electronic fuel injectors are known to be tested on uncountable samples and it was known that it absolutely worked accordingly in place of carburettors. The Homogenous Charge Compression Ignition (HCCI) and the Gasoline Direct injection (GDI) are some of the examples which have had a great essence in the automotive

industries.

The Drive-By Wire (DBW) technology allowed us to make our systems more safe and more easy to use and handle. To increase the torque capacity of the vehicle we have incorporated the new technology Variable Valve Timing (VVT) which is quite successful in overcoming the bottlenecks and the setbacks of the system.

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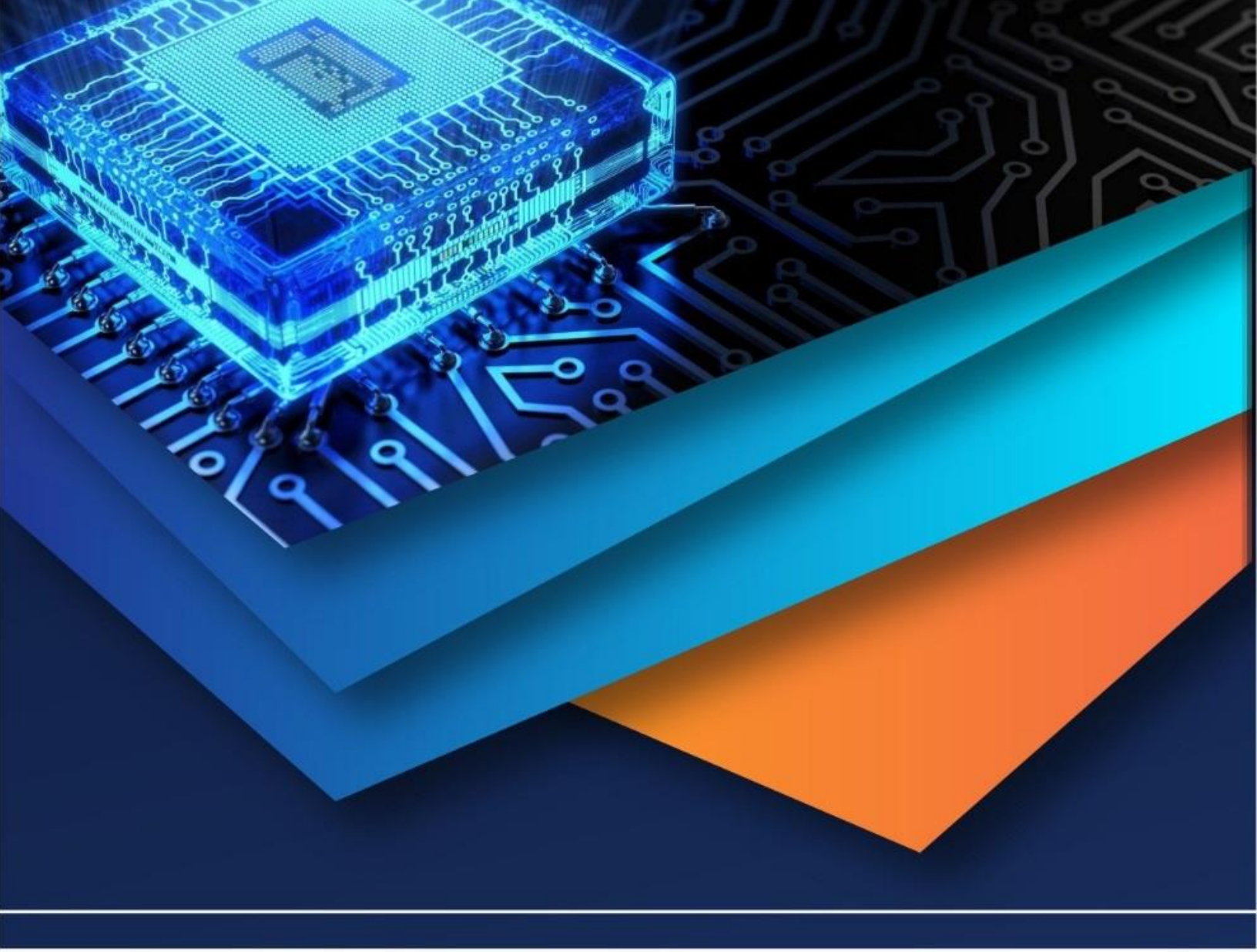

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