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Professional Technical Report on

Vehicle Exhaust Control Using SIMULINK

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Contents

Chapter 1

Introduction

Engine exhaust systems for automobiles are designed to ease the flow of exhaust gases of combustion leaving an internal combustion engine, thereby achieving optimal power output.Generally, engines on road-going cars are designed to meet high power requirements only at higher ranges of rpm. This gives the car better performance on highways and low- traffic roads. But for local commuting - which includes driving on busy streets and narrow roads - involving operating in low-to-medium rpm for significant periods of time, car performance would get slightly degraded.engine exhaust systems have been specifically designed to help in such scenarios.

Motor vehicle emissions contribute to air pollution and are a major ingredient in the creation of smog in some large cities. A 2013 study by MIT indicates that 53,000 early deaths occur per year in the United States alone because of vehicle emissions.[2] According to another study from the same university, traffic fumes alone cause the death of 5,000 people every year just in the United Kingdom.

Petrol and diesel vehicles are main modes of transportation, which are responsible for todays world becoming global. The two fuels when burnt in internal combustion engines provide the power for motion at the same time, exhaust gases are released in atmosphere. The composition of the exhaust gases may contain very small percentage of components, which are unacceptable as they can cause harm in human beings as well as the environment. Therefore, it is matter of concern to monitor exhaust gases as per existing government regulations also.

In most petrol engines, the fuel and air are usually mixed after compression. The pre-mixing was formerly done in a carburetor, but now it is done by electronically controlled fuel injection, except in small engines where the cost/complication of electronics does not justify the added engine efficiency. The process differs from a diesel engine in the method of mixing the fuel and air, and in using spark plugs to initiate the combustion process. In a diesel engine, only air is compressed (and therefore heated), and the fuel is injected into very hot air at the end of the compression stroke and self-ignites.

The presented project report deals with a simulation model of a Vehicle exhaust system developed using SIMULINK libraries.

Chapter 2

Exhaust Gases and Various Exhaust Regulations

Exhaust gas or flue gas is emitted as a result of the combustion of fuels such as natural gas, gasoline, petrol, biodiesel blends,] diesel fuel, fuel oil, or coal. According to the type of engine, it is discharged into the atmosphere through an exhaust pipe, flue gas stack, or propelling nozzle. It often disperses downwind in a pattern called an exhaust plume.

2.1 Exhaust gas

The largest part of most combustion gas is nitrogen (N2), water vapor (H2O) (except with pure-carbon fuels), and carbon dioxide (CO2) (except for fuels without carbon); these are not toxic or noxious (although carbon dioxide is a greenhouse gas that contributes to global warming). A relatively small part of combustion gas is undesirable, noxious, or toxic substances, such as carbon monoxide (CO) from incomplete combustion, hydrocarbons (properly indicated as CxHy, but typically shown simply as "HC" on emissions-test slips) from unburnt fuel, nitrogen oxides (NOx) from excessive combustion temperatures, and particulate matter (mostly soot).

2.2 Exhaust emissions legislation in Europe

Conventional vehicles still determine the look of our roads and with good reason. Modern vehicles are extremely clean, use the energy of their fuel frugally and convert raw energy into the necessary propulsive power in extremely efficient ways. The Euro VI standard has been binding on heavy commercial vehicles since 2014 for reducing exhaust emissions. From September 2015 onwards, the Euro 6 exhaust emissions standard will be binding on all newly registered cars. This means pollution emissions can be reduced by about 95 percent compared to Euro 0. NOx and particulate emissions have been reduced particularly markedly over recent years: 80 percent NOx reduction and 50 percent particulate reduction from trucks in the last level alone (i.e., compared to Euro V). As far as cars are concerned, the 80 percent particulate reduction has already been implemented with Euro V. In Euro 6, it is now the NOx emissions above all that are being reduced by a further 56 percent.

Euro exhaust emissions limits are closely linked to the underlying New European Driving Cycle, NEDC for short. In future, the WLTP (Worldwide Harmonized Light Vehicles Test Procedures) will form the legal basis for Euro exhaust emissions legislation. The RDE legislation (Real Driving Emissions) is an addition to Euro exhaust emissions legislation directed towards areas of driving and parameters that lie outside the type test procedure. RDE regulates any kind of driving under any conditions.

The automotive industry is tackling this challenge of reducing exhaust emissions by developing new exhaust post-treatment systems. The VDA assumes that the RDE legislation will mean that the majority of diesel vehicles will have to be equipped with additional NOx post-treatment technology in future. The EU Commission is planning to introduce legislation for new vehicle types from September 2017 onwards, and for all new vehicles from September 2018. The RDE law is expected to be approved at the end of 2015. As a result, the automotive industry does not have adequate time to prepare for the technical implementation and retrofitting additional exhaust post-treatmenttechnologies to ongoing series production. As a result, the planned date of introduction for ongoing series production in September 2018 must be regarded as particularly critical. The planned introduction of RDE legislation at the present time must be reconsidered under the aspect of a cost-benefit ratio instead. Consequently, the VDA proposes that the regulation should be introduced from September 2017 onwards with a higher limit value (conformity factor), and that this factor should be tightened up five years after publication of the law.

2.3 Vehicle emissions

Vehicle emissions control is the study of reducing the motor vehicle emissions – emissions produced by motor vehicles, especially internal combustion engines.Emissions of many air pollutants have been shown to have variety of negative effects on public health and the natural environment.Emissions that are principal pollutants of concern include:

Hydrocarbons – A class of burned or partially burned fuel, hydrocarbons are toxins.Hydrocarbons are a major contributor to smog, which can be a major problem in urban areas.

Carbon monoxide (CO) – A product of incomplete combustion, carbon monoxide reduces the blood's ability to carry oxygen; overexposure (carbon monoxide poisoning) may be fatal.

Nitrogen oxides (NOx) – Generated when nitrogen in the air reacts with oxygen at the high temperature and pressure inside the engine.NOx is a precursor to smog and acid rain. NOx is a mixture of NO, N2O, and NO2. NO2 is extremely reactive.

Particulate matter – Soot or smoke made up of particles in the micrometre size range: Particulate matter causes negative health effects, including but not limited to respiratory disease and cancer.

Sulfur oxide (SOx) – A general term for oxides of sulfur, which are emitted from motor vehicles burning fuel containing sulfur.

Volatile organic compounds (VOCs) – Organic compounds which typically have a boiling point less than or equal to 250 Â°C; for example chlorofluorocarbons (CFCs) and formaldehyde.

2.4 Method

2.4.1 The Air-Injection System

Air injection is a method of reducing exhaust emissions by injecting air into each of the exhaust ports of an engine so that air mixes with the hot exhaust and oxidises HC and CO forming H2O and CO2 .During the early days of emisÂsion control, it was an easy task to meet the required emission standards through air injection. Early air injection systems used many hoses and tubes placed across the engine so that it became inconvenient to work on the engine, and hose failure due to engine heat also became common.
Manufacturers use different names for their air injection systems, for example American Motors call it Air Guard, Chrysler names it Air Injection System, Ford calls it Thermactor Air Injection System and General Motor names it Air Injector Reactor (AIR). Irrespective of the name, all systems are simple and basically the same. A belt-driven air pump supplies fresh air to the injector nozzles installed in the exhaust manifold or cylinder head, so that air mixes with the hot exhaust leaving the engine. This helps the oxidation process necessary to reduce HC and CO emissions.

2.4.2 The Exhaust Gas Recirculation (EGR) System

A widely adopted route to reduce NOx emissions is Exhaust Gas Recirculation (EGR). This involves recirculating a controllable proportion of the engine's exhaust back into the intake air. A valve is usually used to control the flow of gas, and the valve may be closed completely if required.

The substitution of burnt gas (which takes no further part in combustion) for oxygen rich air reduces the proportion of the cylinder contents available for combustion. This causes a correspondingly lower heat release and peak cylinder temperature, and reduces the formation of NOx. The presence of an inert gas in the cylinder further limits the peak temperature (more than throttling alone in a spark ignition engine).The substitution of burnt gas (which takes no further part in combustion) for oxygen rich air reduces the proportion of the cylinder contents available for combustion. This causes a correspondingly lower heat release and peak cylinder temperature, and reduces the formation of NOx. The presence of an inert gas in the cylinder further limits the peak temperature (more than throttling alone in a spark ignition engine).

Chapter 3

SIMULINK Model

3.1 Features

It is a simplified SIMULINK model to display exhaust gases in a petrol engine.It Focusses on keeping A/F Ratio closer to ideal.Controls fuel nozzle diameter for this, Air diameter has been kept constant for that particular case to be able to show fuel nozzle area control for achieving the desired.

It Uses feedback loop to show effect of Exhaust control.It Shows With and without feedback loop effect is available through manual switch as we wanted to show both the effect of using feedback on Exhaust gases and when no feedback is present in the same model. ideal A/F ratio.

3.2 Assumption

The following assumptions were made before beginning the modelling to keep the system in SIMULINK simple and easy to understand:

Chemistry or Complex equations of combustion in an Engine has been ignored. Instead, suitable percentages of exhaust gas formations have been used in the form of 1D lookup table to mimic the amount of exhaust gas formed based on a captured A/F ratio.

The objective of the project is to demonstrate an exhaust system capable of controlling the output using an active feedback meaning that the corrections in values are immediately applied when the feedback is ON.

Data used to model the system is appropriately assumed to seem realistic enough since access to those real values is a part of engine and exhaust design which is beyond the scope of this study.

Therefore, we emphasize on displaying the logic used to develop the system and not on the accuracy of the values available as output.

These values could easily be changed if and when actual data might be made available. Figure 3.1 shows a sample calculation that we performed in MS Excel for a pedal displacement of 10mm with other assumed values and found the A/F ratio to

Pedal Position	10	mm
Valve area opening, air	95	%
Valve area opening, fuel	100	%
diameter, air	50	mm
diameter, fuel	4	mm
no of fuel jets	4	

AIR INTAKE		
Air flow velocity	2	m/s
Air inflow valve area	0.0019	m2
Air flow volume	0.004	m3/s
Air density	1.292	kg/m3
Air mass flow	0.005	kg/s

FUEL INTAKE		
Fuel valve velocity	0.010	m/s
Fuel inflow valve area	0.00001	m2
Total area	0.00005	m2
Volumetric flow rate, fuel	0.0000005	m3/s
Gasoline density	719.7	kg/m3
Fuel MFR	0.00036	kg/s

Calculated AIR FUEL RATIO (AFR)	14.0
Type of Mixture	**RICH**

Figure 3.1: Sample Calculations for Designing

be 14.0 i.e. RICH.

3.3 Block Diagram

Figure 3.2 shows the block diagram of Exhaust control system. It Consist of Five major blocks :

- Acceleration Input : Input to the system which determines the speed of the engine and also the factor how much control is needed .
- Fuel Intake Control : This block control the rate of flow of fuel so as to control the combustion process.
- Air Intake Control : Oxygen is important in burning process . This Block control the flow of air into the system.
- Exhaust Control : It is one of the important block in this design. It is generally used in feedback loop to control the air to fuel ration.
- Exhaust Decomposition : This block is used to decide the various component of air depend on air fuel ratio.

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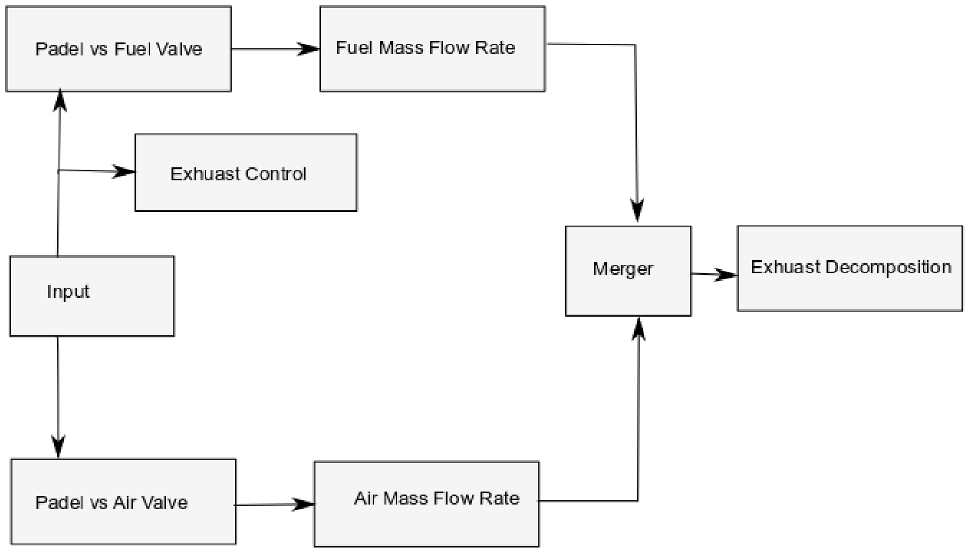

Figure 3.2: Block Diagram

3.3.1 Fuel Intake Control

Figure 3.3 shows simulink model block for Fuel Intake control also known as Fuel Mass rate control.Let Fuel mass flow rate is R,Fuel volume is V, Fuel Value density is D,Fuel Valve Area is A,Fuel Velocity is v and Fuel Value Diameter is d then following gives the equation for Fuel Intake or Fuel Mass Rate Control.

- R = V x D
- V = A x v
- A = (Pi/4) x d*d

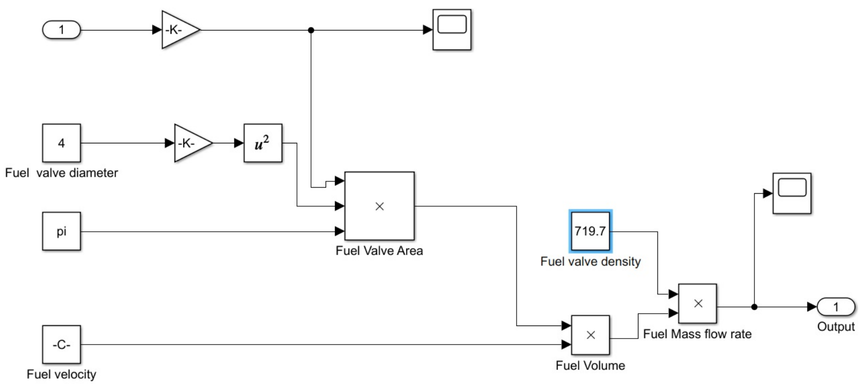

Figure 3.3: Fuel Intake Control

3.3.2 Air Intake Control

Figure 3.4 shows simulink model block for Air Intake control also known as Air Mass rate control.Let Air mass flow rate is R,Air volume is V, Air Value density is D,Air Valve Area is A,Air Velocity is v and Air Value Diameter is d then following gives the equation for Air Intake or Air Mass Rate Control.

- R = V x D
- V = A x v
- A = (Pi/4) x d*d

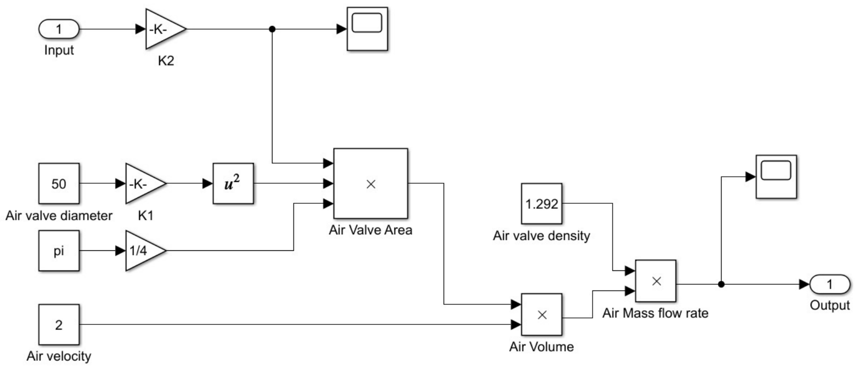

Figure 3.4: Air Intake Control

3.3.3 Exhaust Control

It can be connected via a manual switch to the system. This block is mainly responsible foe the control of Air to fuel ration to an ideal value that is 14.7 . It takes fuel rate as input and gives Air to fuel ration as output . Figure 3.5 shows the block diagram used in simulink .

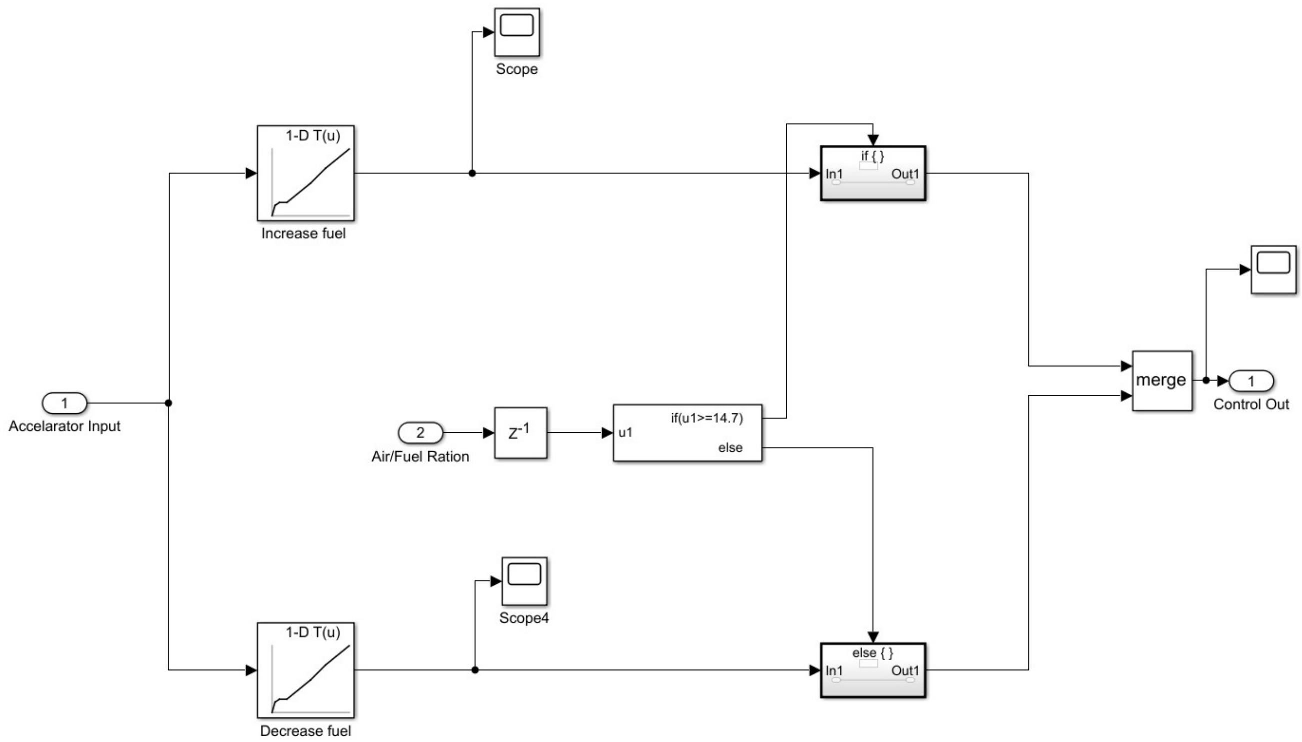

Figure 3.5: Exhaust Control

3.3.4 Exhaust Composition

This is one of the important block of exhaust control system .As there are many standards for the vehicle exhaust control . It not only deoends on the country locatoion but aslo the type of vechile .So this block gives general feature for setting value to various type of gases .Figure 3.6 shows the simulink

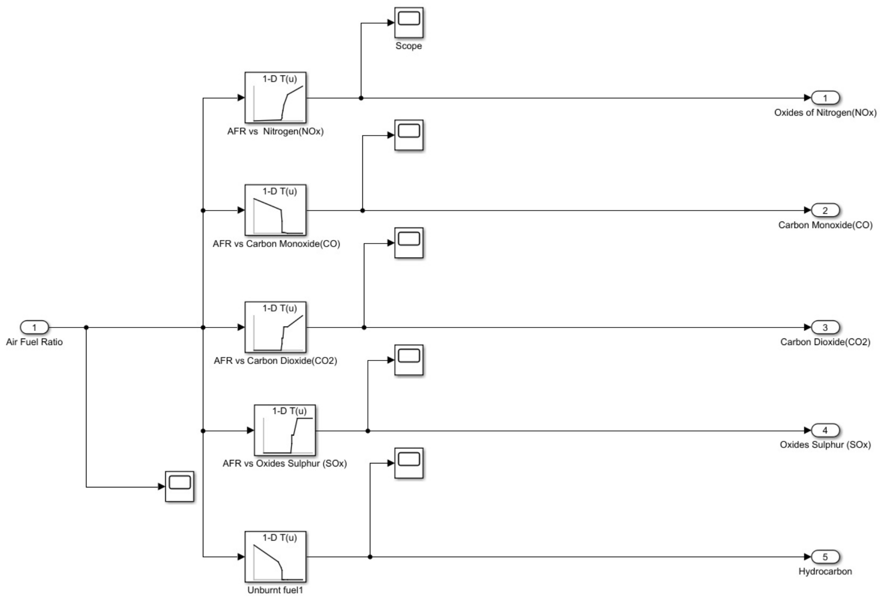

Figure 3.6: Exhaust Composition

3.3.5 Complete System

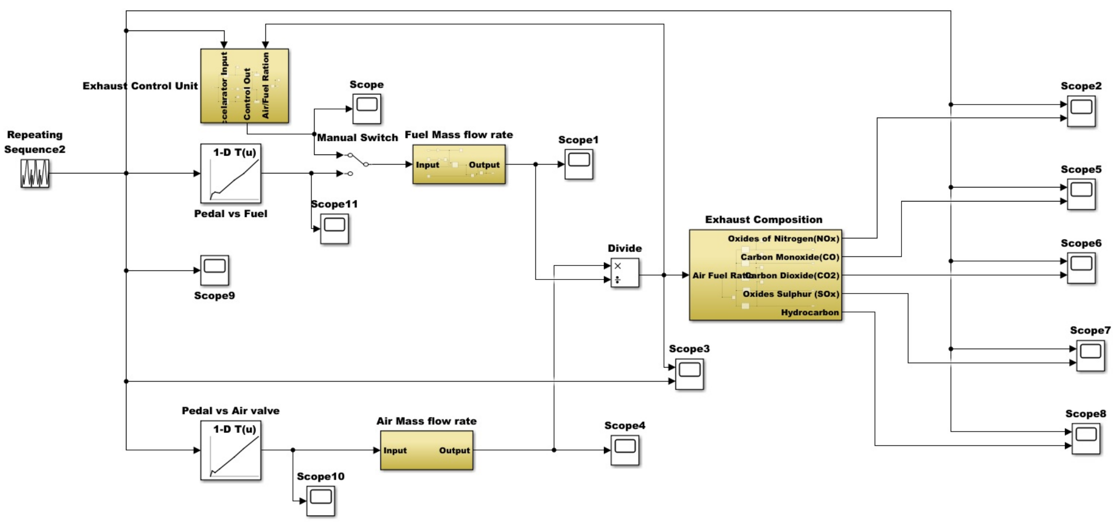

Figure 3.7: Complete System

3.4 Simulation Results

3.4.1 Air Fuel Ratio

Fig shows 3.8 the Air Fuel Ratio of designed simulink model . It can be observe that if exhaust control system is not used Air to fuel ratio is unpredictable.Ideal value for A/F is 14.7 which is achieved by model.

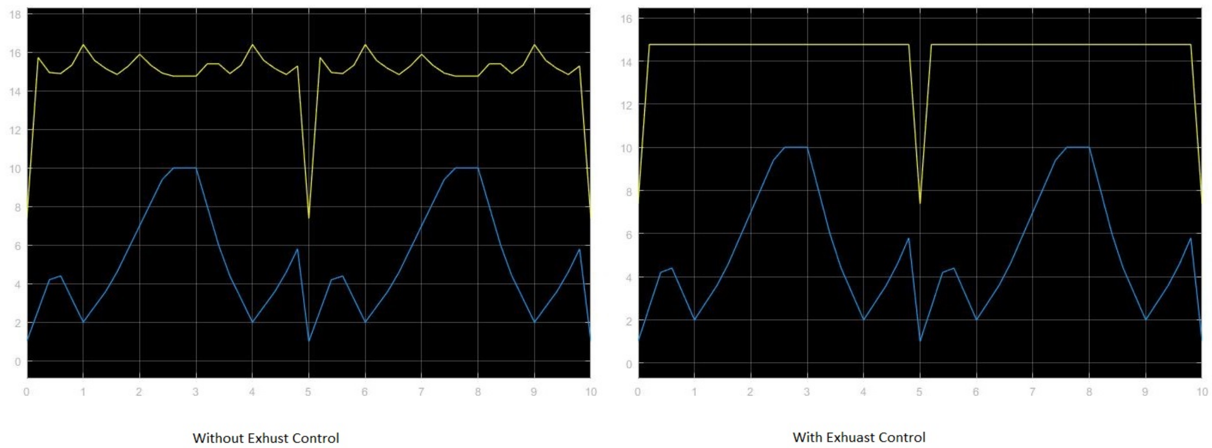

Figure 3.8: Air Fuel Ratio

3.4.2 Oxides of Nitrogen(NOx)

Fig shows 3.9 the presence of Oxides of Nitrogen(NOx) in designed system. It can be observe that if exhaust control system is not used Oxides of Nitrogen (NOx) is uncontrollable .Ideal value for Oxides of Nitrogen(NOx) could be approximately 16 percentage which is achieved by model.

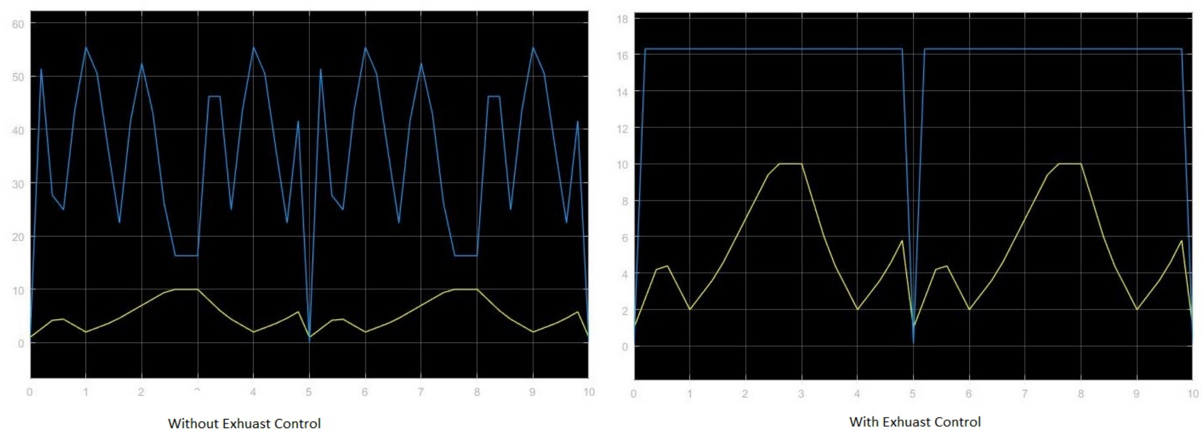

Figure 3.9: Oxides of Nitrogen(NOx)

3.4.3 Carbon Monoxide(CO)

Fig shows 3.10 the presence of Carbon Monoxide(CO)) in designed system. It can be observe that if exhaust control system is not used Carbon Monoxide(CO) is uncontrollable .Carbon Monoxide(CO)is harmful for human health.So this gas should be reduce to zero.

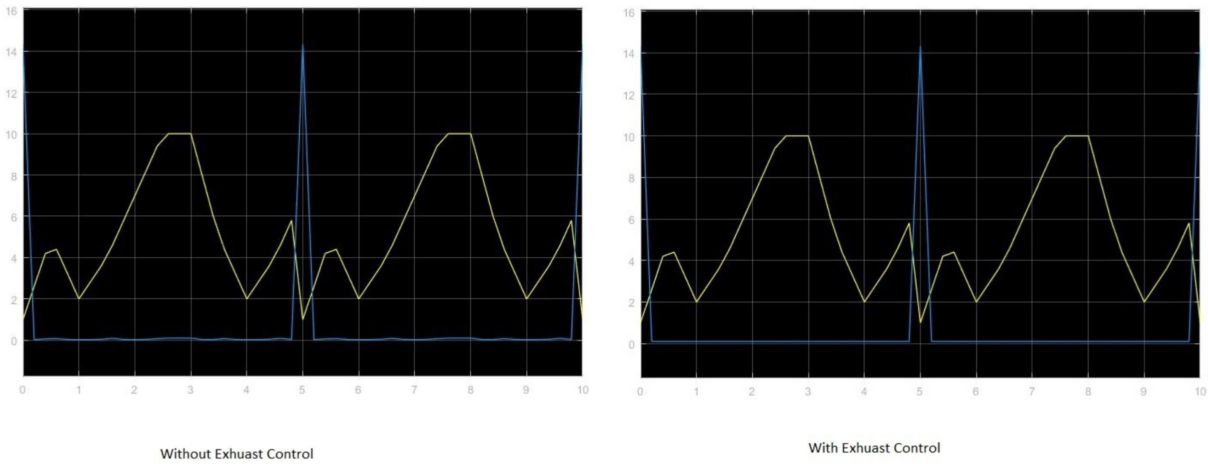

Figure 3.10: Carbon Monoxide(CO)

3.4.4 Carbon Dioxide(CO2)

Fig shows 3.11 the presence of Carbon Dioxide(CO2) in designed system. It can be observe that if exhaust control system is not used Carbon Dioxide(CO2) is uncontrollable .Ideal value for Carbon Dioxide(CO2) could be approximately 14.7 percentage which is achieved by model.

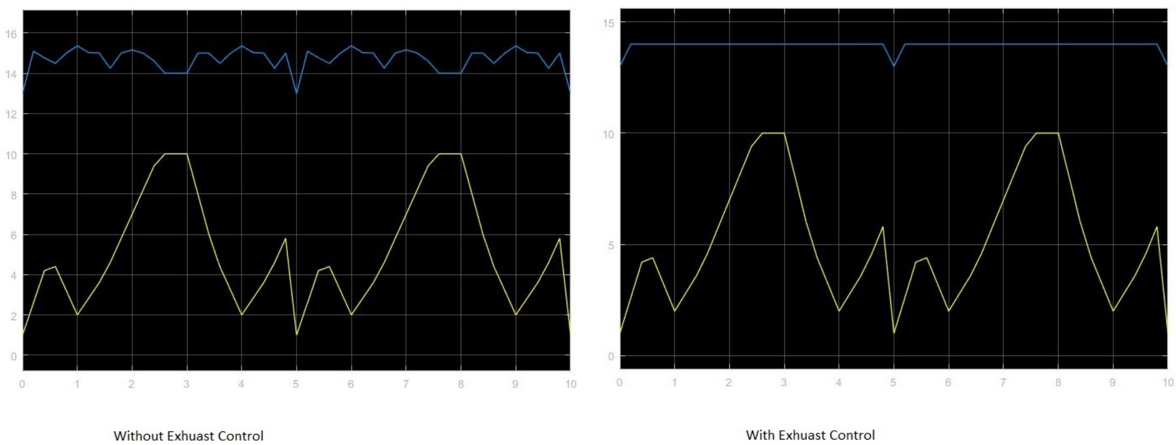

Figure 3.11: Carbon Dioxide(CO2)

3.4.5 Oxides of Sulphur (SOx)

Fig shows 3.12 the presence of Oxides of Sulphur (SOx) in designed system. It can be observe that if exhaust control system is not used Oxides of Sulphur (SOx)) is uncontrollable .Ideal value for Oxides of Sulphur (SOx) could be approximately 13 percentage which is achieved by model.

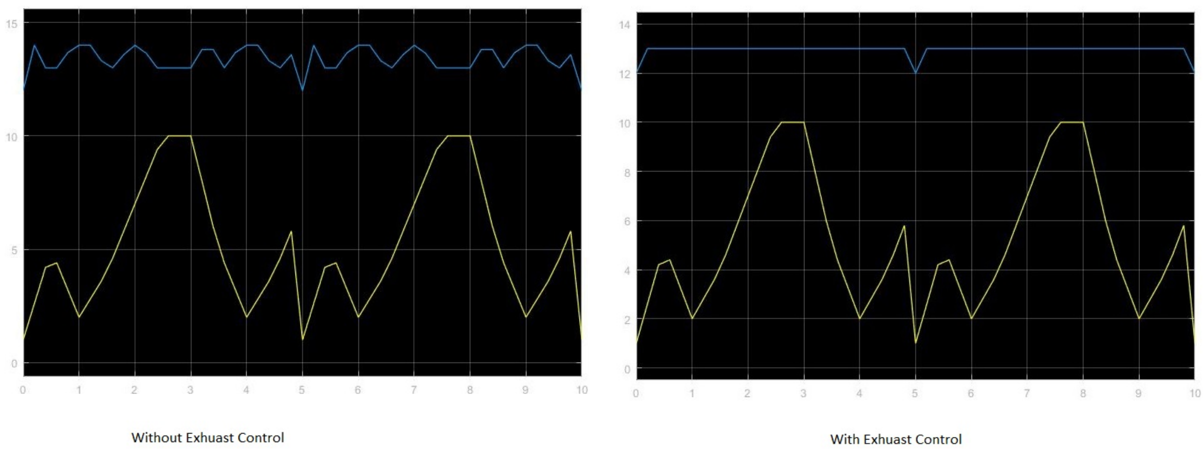

Figure 3.12: Oxides Sulphur (SOx)

3.4.6 Hydrocarbon

Fig shows 3.13 the presence of Hydrocarbon in designed system. It can be observe that if exhaust control system is not used Hydrocarbon is uncontrollable Hydrocarbon is harmful for human health.So this gas should be reduce to zero.

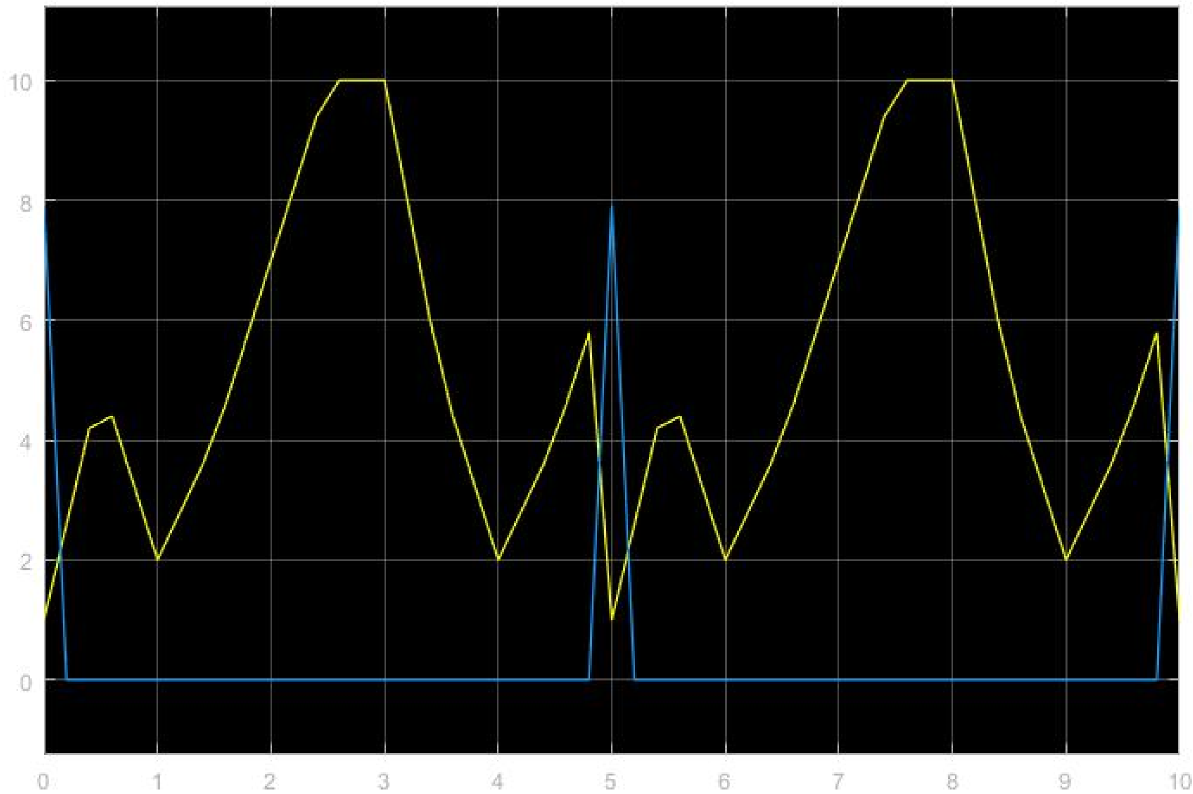

Figure 3.13: Hydrocarbon

Chapter 4

Conclusion

The Vehicle Exhaust Control model was successfully developed in SIMULINK using MATLAB 2018a version. The developed model was simulated for t=5s for a given repeated sequence input of accelerator pedal displacement values between 0 to 10 mm with default simulation settings and the transfer function estimated for the feedback loop was found to be a single value of -1.845 for the static gain linearization using Linear analysis option in SIMULINK. The model is able to exhibit control over the Fuel input for different values of A/F Ratio as calculated in the model at each time t (s). Also, the exhaust composition plots for all the gases NOx, CO and SOx show correct trends when plotted and compared for both feedback and no feedback simulations.

Since the model is a simplified version of an important vehicle system it can be developed further to implement more elements and subsystems to replicate the actual physical system even more closely.Catalytic converter with Oxygen sensor could be implemented as additional element in the model as a technique to control exhaust system.

Currently this model relies on assumed data based on concepts in textbooks and literature available for research on the internet. However, access to real life data and lab test data can assist in improving and fine tuning the model.The model could also be tested by controlling Air quantity instead of Fuel as employed currently which might be a challenge as the air quality depends on the environment and might vary in some conditions.

Chapter 5

Refrence

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