Evaluation of emission control technologies on the vehicle performance and its effects on NVH performance

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Abstract-Effect on the environment of any activity is given a lots of concern. Emission from vehicles has also been brought into the limit of standard defined by the Indian government authorities since 2000, known as Bharat stage (BS). At present BS IV has already applied and by 2021 BS VI will come into action. So, the automobile manufacturers are working on it to bring their vehicle emission under this limit. The main object products in the diesel engine exhaust are nitrogen oxide (NO_x), particulate matter (PM), carbon monoxide (CO) and hydrocarbons (HC). There are several technologies which are used to meet this legislation, either by making changes in engine design or by using some chemical reaction agents (after treatment technologies) in the exhaust system to convert production to less harmful ones.

All these technologies has some of the positive or negative effects on the vehicle performance as well as on the NVH performance of the vehicle. This effect is seen due to the change in fuel injection system, hindering the exhaust gas flow or utilisation of fuel for conversion of exhaust products. Magnitude of these effect depends on the type of technology and the level up to which it is used. In this report, the author has tried to quantify these effects for a technology consisting a common rail diesel injection (CRDi) engine with a pair of diesel oxidation catalyst (DOC)/Oxycat on a passenger vehicle of Force Motors Limited.

Effect on vehicle performance is evaluated by creating at two different 1D equivalent models of the vehicle consisting all the sub assemblies, one with BS III engine and peripherals while another with the BS IV engine and peripherals. Results of the models were compared and effects were quantified. The NVH performance is calculated by using the LMS Virtual.Lab software. Initially, equivalent 3D FEM acoustic model of the exhaust system with or without after treatment technology is created in the HyperMesh software and noise transmission loss is compared after applying the appropriate boundary condition to accommodate practical conditions in the model. For vibration effects, the full exhaust system 3D model is created on HyperMesh and using the Optistruct software the modal analysis is done in order to check the coupling of exhaust natural frequencies with engine's operating frequencies.

1.INTRODUCTION

1.1. OVERVIEW

Compression Ignition engines are one of the most efficient power generators among all the IC engines. Furthermore, less fuel cost makes it even more desirable option for the consumers. But the harmful effects of its emissions on the environment has compelled the Indian government to impose restrictions on the amount of harmful products that can be emitted. These standards are known as Bharat stage. As the diesel engine owns most of the commercial vehicle segment of the automobile industry, it has prompted the OEMs and their service providers to work on strategies to reduce these emissions [16]. This research has resulted in numerous technologies that can help meet the emission standards.

The technologies that help emission reduction affect the other performance parameters of the vehicle. Few examples include making changes in the fuel injection system or using catalytic converter which converts the harmful emission to less harmful products or filter which restricts the flow of larger particles directly into the atmosphere. These processes have an effect on the vehicle performance parameters like maximum speed, acceleration, gradeability, fuel economy, etc. as well as noise and vibration performance of the vehicles. The magnitude of these effects depends on the type and extend upto which the technology is incorporated into the existing system. To meet the requirements of the stringent forthcoming norms, it is necessary to use a combination of multiple emission reduction technology simultaneously [27]. Thus, quantifying the effects of such technologies gains utmost importance prior to their selection. In this endeavor to meet the

challenges posed by the upcoming tougher emission regulations, Force Motors Limited (FML) is taking efforts to make the use of the best technology available in the market currently.

This project aims to quantify the effect of implementation of CRDi technology in a four cylinder engine and pair of diesel oxidation (DOC) filter on the vehicle performance and NVH performance. In this report an efficient modeling procedure for quantifying the effect is also shown.

DOC is the oxidation catalyst which converts incompletely combust carbon monoxide and hydrocarbon to carbon dioxide and water which are less harmful products for the environment. DOC consists of a metal or ceramic core/substrate which has a number of channel, from where the exhaust gases flows. The substrate is doped with some precious material (platinum in this case) which act as a catalyst for the conversion reaction. Amount of doping affects the conversion rate and cost of the converter. The substrate is responsible for maximum effects on the vehicle performance as well as on the vehicle noise. Due to the flow of exhaust gas through the channel, its flow may get restricted which will create a back pressure on the engine due to which the fuel economy as well as maximum velocity and acceleration make get affected. Flow through channel also affects the distributive effect of the noise. This may lead to increase or decrease in the transmission loss of noise depending on the size of the channel.

2.LITERATURE REVIEW

1. Harkonen, M., Rajan, B., Trigunayat, A., and Jagtap, N.,published there work on the "Optimization of Diesel Oxidation After-Treatment Systems for Indian Market Scenario," under the SAE Technical Paper 2015 [7].The paper provides a brief description of the various emission control technologies and the scope of their application in Indian market scenario. Author has studied the various problems in current Indian automobiles and fuels which create a hindrance in achieving the BS IV and above norms. Author has also shown some case studies which shows importance of keeping the catalyst close to the engine or influence exhaust gas temperature on the conversion efficiency of DOC. An another case study is also shown which describe the influence of precious metal, wash coating and canning of the DOC on the vehicle emissions. Author has also described the effect of sulphur present in the fuel on emission control technology's efficiency and durability.
2. Paper describes the majorly present emission control technologies in after treatment category and their application in Indian market. Parameters of after treatment technology's structure which should be defined and have major influence on after treatment conversion efficiencies are specified in the work. As the case study's configuration of emission technology is similar to this target project configuration, hence the paper helps in understanding the advantages of various components in the configuration. Description about the internal parts of DOC are given, which helps in understanding the functioning of DOC.
3. Santha, S. and Solanki, N., worked on the topic "Automotive Exhaust Muffler Design, Development and Study on Attenuating Whistling Noise," and published it under SAE Technical Paper 2013 [21]. Through this paper the authors describe the procedure to evaluate the root cause of noise problem in full vehicle with the help of colour map and playback post, processing, effect of perforation holes shape and their pitch on the noise dissipation performance of the muffler. Comparison between the shape Optimisation and use of absorbing material like E-glass fibre is also shown in the paper. According to the author, absorbing material should be used for noise attenuation because optimising this shape for noise attenuation may result increase of back pressure which causes the decrement in the fuel economy, with absorbing material will also increase the manufacturing cost but won't have much increase in back pressure with the required noise attenuation.

   The paper infers that neither the shape nor the size of the perforation has much effect on noise attenuation. But the ratio of acoustic space and the structural space has more influence on the noise attenuation. If the size and the pitch of the perforation is modelled such that it is equivalent to the practical conditions then more accurate results can be obtained. Furthermore, paper also gives an emphasis on modelling the absorbing

properties of the emission control technology in the FEA model

4. Yadav, P., S., Gaikwad, A., A., Kunde, S., A., Karanth, N., V., worked on the topic "Prediction of Muffler Radiated Noise for a Diesel Engine", and published it in SAE Technical Paper 2011 [3]. Through the paper the author wants to show an easier procedure to model no source using the volume velocity and impedance for an exhaust muffler in this paper the author has modeled the muffler using the boundary element method and the inner perforation is modeled using the transfer admittance boundary condition option of LMS Virtual lab software first or model is verified by evaluating the transmission loss of the muffler as the transmission loss does not depend on the source modeling it is effective way to determine the accuracy of the mathematical model for predicting the transmission loss of the muffler unit normal velocity is applied at the inlet and impedance equal to the characteristic impedance of normal is applied at the outlet the obtained transmission loss is correlated with the practically tested transmission loss after obtaining the required correlation the model is taken for noise source modeling after providing the calculated volume velocity and source impedance the sound pressure is evaluated at the muffler outlet according to the author even the noise radiated at the exhaust manifold is not required to be measured to calculate the source noise is the procedure explained in the paper is followed and even the required accuracy can be achieved
5. Lavrentjev, J., Rammal , H., Tiikjo, H., presented their work on "The Passive Acoustic Effect of Automotive Catalytic Converter",in the SAE Technical Paper-2011 [12]. In this paper, the author has performed experiments for evaluating the transmission loss of the catalytic converter containing substrate of different material and working in different operating conditions like different speed and temperature. In order to provide the different operating conditions, the author has allowed the mean flow of air through the catalytic converter, at different speed and temperature. The author has used to material for the substrate core, ceramic and metals and three mean flow conditions for testing the two catalytic converter at 0 metres per second at 20 degree Celsius, 60 metres per second at 20 degree Celsius and 60 metres per second at 200 degree Celsius were used as the mean inflow and the transmission loss was evaluated with the reflective dissipative and transmission coefficients. It was observed through the experiments, that the transmission loss of ceramic core was significantly more than the metallic Core due to 4 times more porosity of the ceramic core which results in increase of dissipative characteristics. It was also observed that the operating conditions do not have much effect on the overall transmission loss of the catalytic converter. From the transmission loss graph it can be concluded that the maximum transmission loss is obtained between 1000 and 1400 Hertz of about 6 to 8 decibels.

3.OBJECTIVE

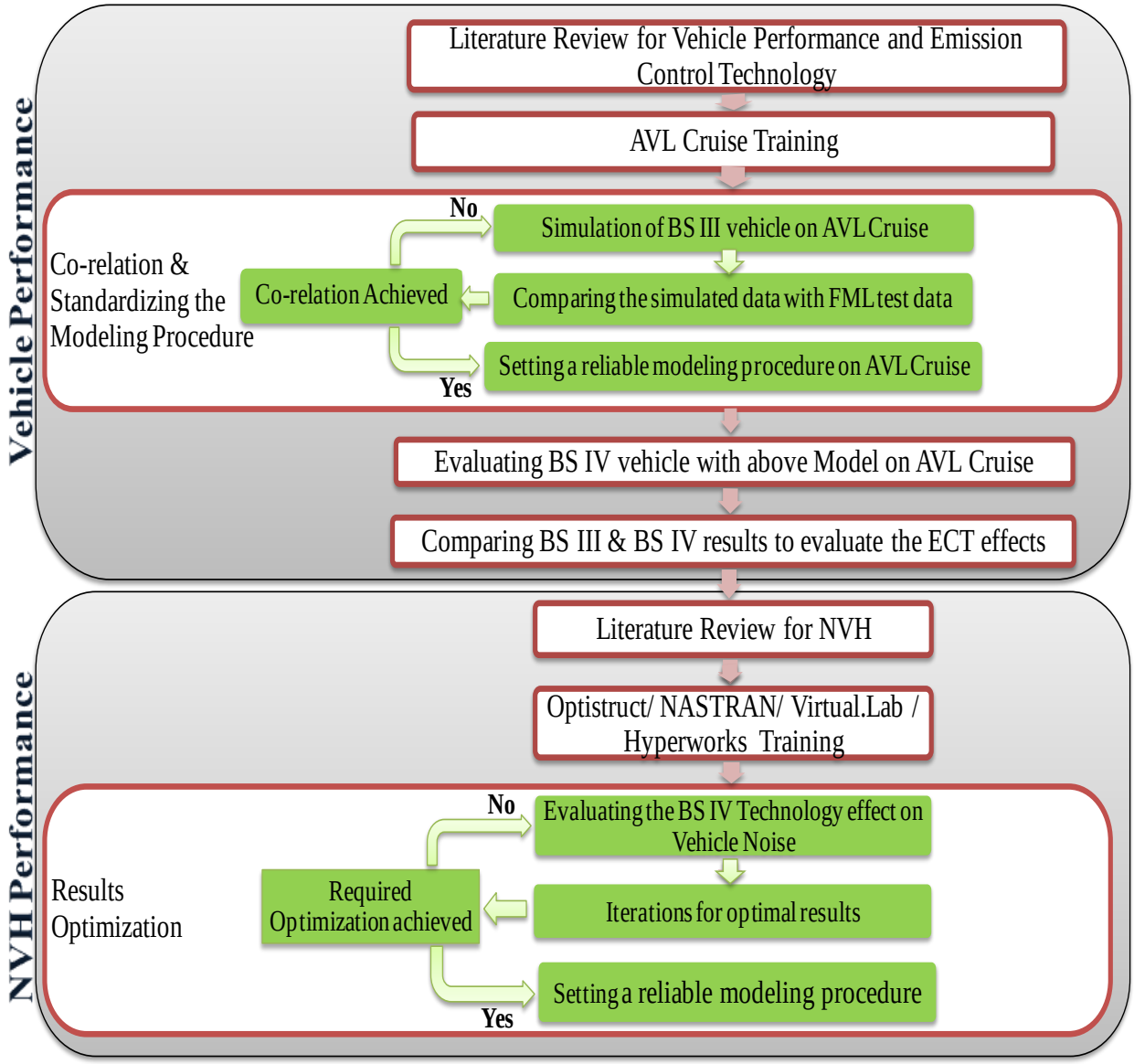
The main objective is to evaluate the effect of emission control technology on vehicle performance and its effect on NVH performance.

4.METHODOLOGY

The overall purpose of this project is to evaluate effect of emission control technology on the vehicle performance and NVH performance on an 14 seater passenger vehicle of Force Motors. Author started firstly with making a 1D model of the full vehicle which was already existing vehicle. The model was created on a AVL Cruise software. By simulating the vehicle performance and correlating it with the practical testing results, validation of the vehicle model and inputs was obtained. As the target vehicle is a future concept, it was necessary to obtain the required correlation between the two results. After obtaining the required correlation, the part load data of BS III technology engine was replaced with the BS IV technology engine part load data in order to incorporate the emission control technologies characteristics in the vehicle model. Comparison of the BS III and BS IV simulated results provides the effect of emission control technology on vehicle performance.

After this the complete exhaust system model (containing the emission control technology) was created in Altair Hypermesh and the modal analysis

was performed on the model, in order to check the coupling of exhaust system with any of the engine operating frequency. This avoid the chances of occurrence of resonance in the vehicle which would result in high vibrations. Then the acoustic cavity of the exhaust system has to be modeled in Altair HyperMesh and its acoustic response is evaluated in LMS Virtual.Lab. Finally by plotting the noise transmission loss over the acoustic cavity of the exhaust system with and without emission control technology the effect of emission control technology on the NVH performance of the vehicle will be obtained.



4.1. Modeling of BSIV Technology Vehicle

Since the project aims to evaluate the effect of emission control technology on vehicle performance, all the other vehicle sub-assemblies has to be kept same. In order to incorporate the effect of emission control technology in the AVL Cruise model, the part load data taken from the testing, where again evaluated on the CRDi engine by applying back pressure at exhaust, equivalent to the DOC back pressure. This helped in involving both technologies effective in the AVL Cruise model. Furthermore in order to evaluate the emission composition at the exit of tail pipe the raw engine emission maps were provided in the engine emission maps and the details of DOC were provided by using the Exhaust System (special module of AVL Cruise).

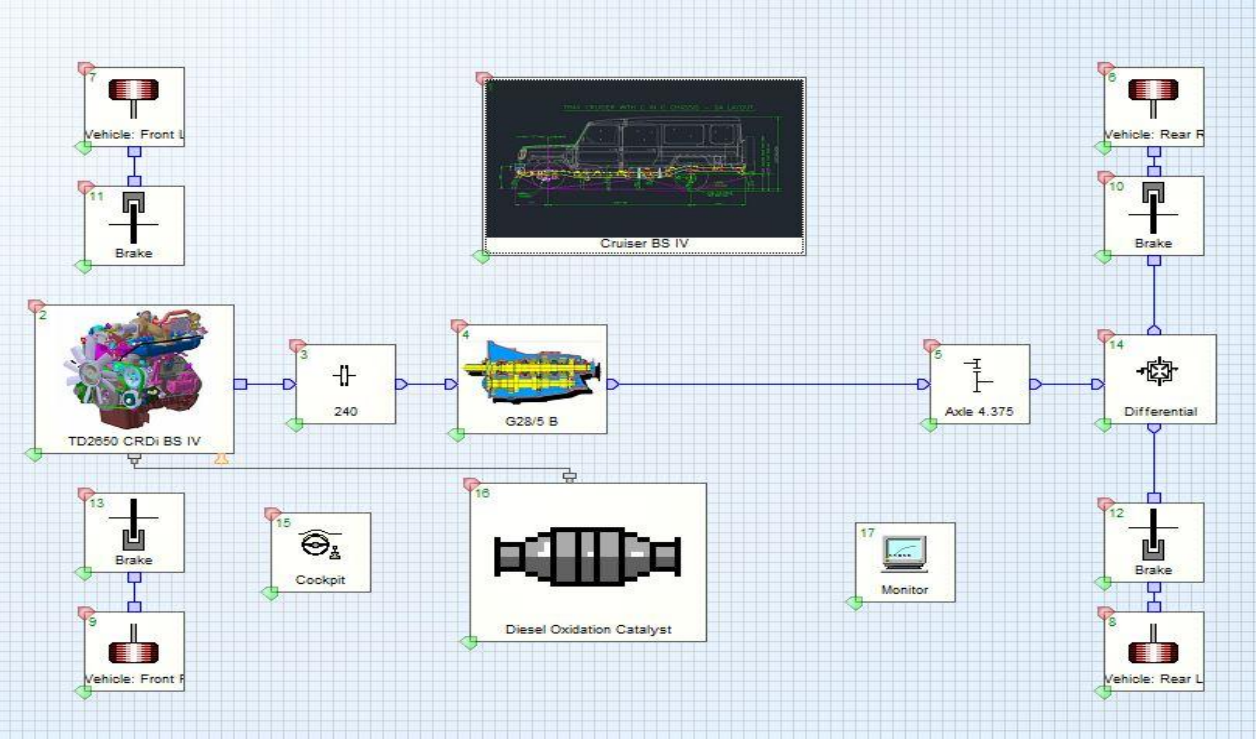
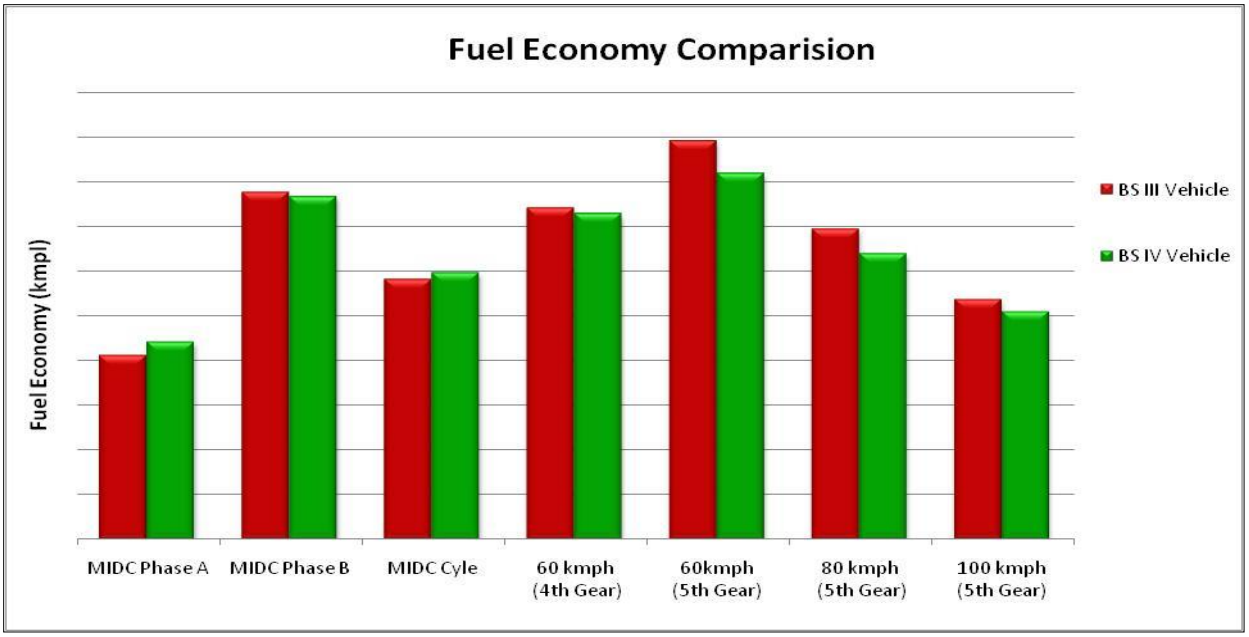


Figure BS IV Technology Vehicle 1D Model on AVL Cruise

5.RESULTS

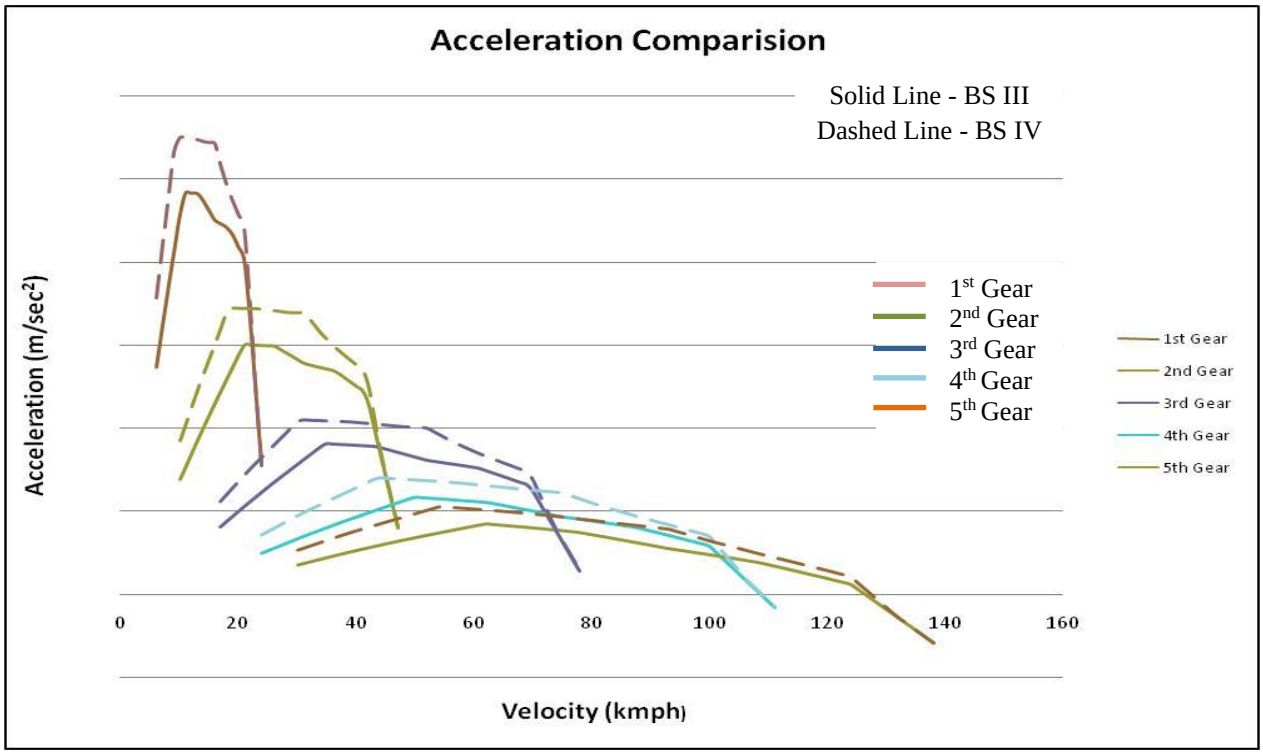
Underneath results are obtained after the simulation of the BS IV vehicle on AVL Cruise. Results shows the comparison of the BS III vehicle and BS IV vehicle, performance parameter, signifying the effect of emission control technology on the vehicle performance.

5.1. Effect on Fuel Economy –



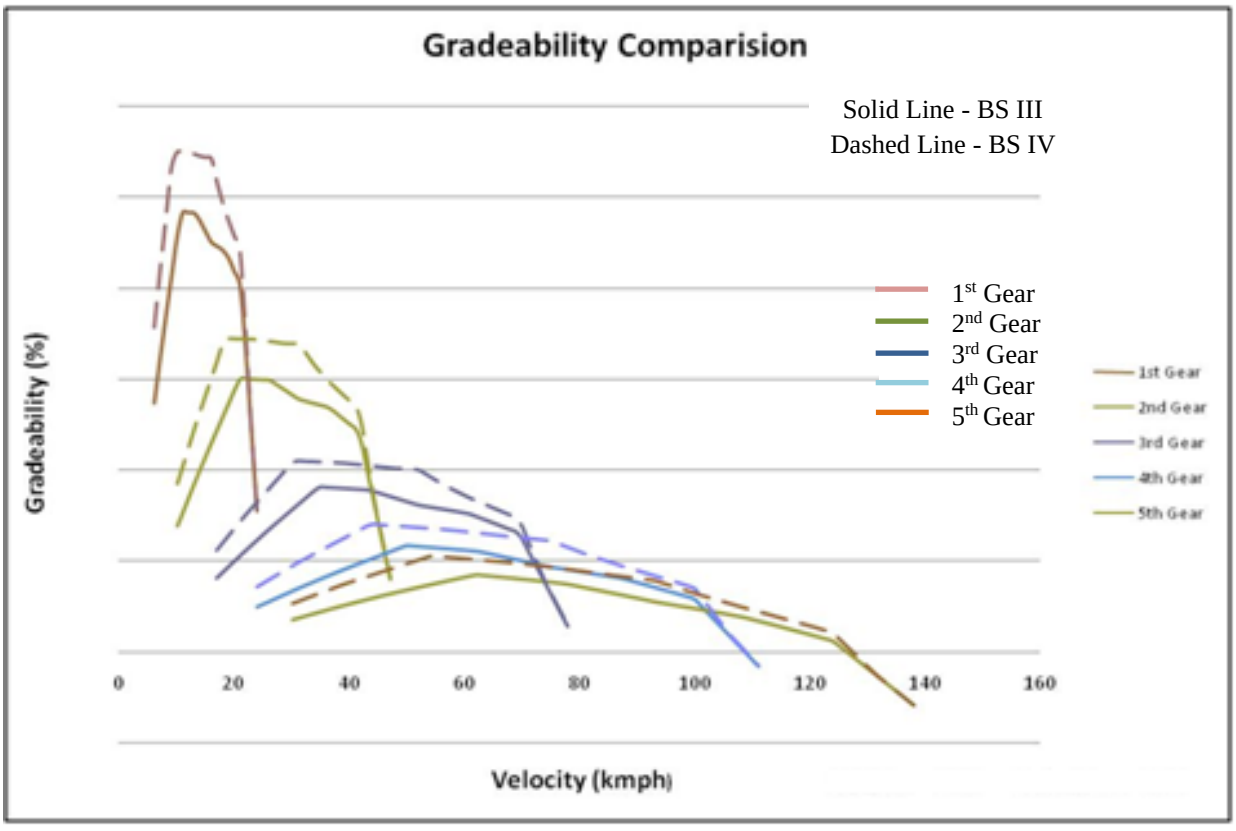
Graph 4.1 1 Effect of ECT on Fuel Economy

5.2. Effect on Vehicle Acceleration –

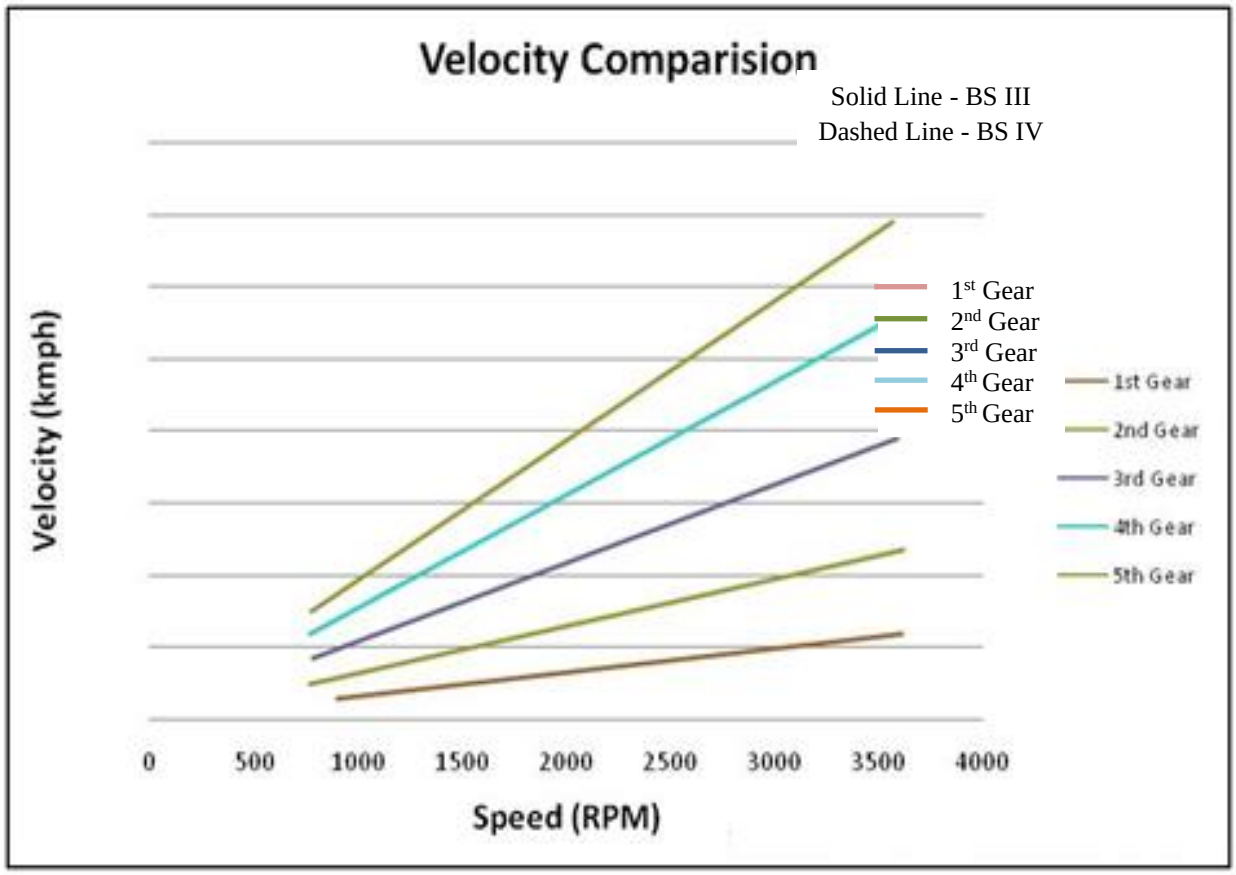


Graph 4.2 1 Effect of ECT on Vehicle Acceleration

5.3Effect on Vehicle Gradeability-



5.3. Effect on Maximum Velocity-



From the above results, no change in max velocity has been observed, as there is no change in the powertrain of the two vehicle. This similarity is kept in order to evaluate the effect of emission control technology only. There has been a significant increase in the acceleration and gradeability with a minute decrement in the fuel economy, this supports the above explanation discussed in CRDi advantage.

Validation of the 1D full vehicle model with the practical testing results gives the following accuracy of the modeling and simulation procedure :

Parameters	Accuracy (%)
Max Speed	98.33
Acceleration	95.14
Fuel Economy	90.95

6.CONCLUSION

By the using the above modeling procedure 90% accuracy is obtained, through this we can conclude that the above explained modeling procedure can be used in Force Motors Limited for the evaluation of vehicle performance of future vehicle. As well as from the comparison of the BS III and BS IV vehicle simulation results it is concluded that the change of BS III to BS IV technology is helping in increasing the vehicle performance of the vehicle with a minute drop in the fuel economy.

7.FUTURE SCOPE

FEM model of the exhaust system has to be analyzed in the LMS Virtual. Lab for the evaluation of the noise transmission loss about the assembly.

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