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Design and Analysis of Cost reduced Diesel Exhaust Aftertreatment system against Flex Module

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Abstract : This research paper represents Designing of Cost reduced Diesel Exhaust Aftertreatment system against existing Flex Module aftertreatment system.
Methods represents the steps to design new cost reduced Aftertreatment system. Study involves how new design is still meeting existing space claim and meeting all performance requirements. Simsolid software were used to calculated Modal and Static structural analysis to compare both the designs & ARAI test facility has been used to validate new deign meets Emission compliance as per BS6 Limit for MHCV Norms.
Keywords: Cost reduced Aftertreatment system, Packaging Space claim.

I. INTRODUCTION

Aftertreatment is the key elements which treats Engine out Exhaust gas to Emission compliance exhaust gas Out from Aftertreatment system.
For Emerging market Cost is big driver for selling any new product or sustaining existing production due to heavily competition in market, This results, any system we sold to market should be lesser in cost and shall be competitive in price selling to OEM's. Since current system (Flex ATS system) costs more due to design and Manufacturing complexity.

II. OBJECTIVE

1) To design new Aftertreatment system which fits on OEM space claim and meet all emissions requirement: - New design shall fit on existing space claim on OEM Chassis by making sure we shall meet all BS6 Emission Legislation's limits
2) System should meet existing Vibration requirements: - New Design should be capable of meeting India Road Load Vibration conditions based on current offering to OEM.
3) System should meet Temperature requirements: - Since New design should be fitted at different chassis boundary/location, new Downpipe is longer by 0.6~0.8m from baseline, hence newly designed downpipe shall meet Temperature drop requirement.
4) To design new ATS system with lesser in cost: - Newly proposed design should be lesser in cost by 5~7% & shall have ease in assembly and manufacturing.

III. METHODOLOGY

1) *Application Study:* Check already available, Bench marking options for Same range of Engine rating
2) *Literature Survey:* Review what is already being available in market and come up with what is missing and can be invented
3) *Study Of Existing Available Aftertreatment System And Material Properties:* Look for existing available options available
4) *Preparing Design and Theoretical Calculation:* Once concept design is fixed, work on theoretical calculations before going for Analysis
5) *Preparing 3D Models using CAD Software:* Prepare 3D model using Creo for Analysis and detail design
6) *Finite Element Analysis on ATS System:* Prepare model for ALD calculations
7) *Material Optimization for ATS system:* Optimize material based on application
8) *Results:* Review cross functionally among team for Final result
9) *Comparison of Results for Best Space Claim:* Optimize/Rerun result in case of any issue.
10) *Preparation of the Report:* Prepare final report and publish REPORT.

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IV. LITERATURE & PATENT REVIEW

The aftertreatment system or exhaust gas processer plays a very important role in the automotive exhaust systems. A review of the literature survey related to finding cost reduction opportunity based on material change, design modification and commonization technique. In this literature different cost reduction opportunity techniques were taken into consideration, based on system understanding, design change, material change, standardization, modularization.

Following papers are refer for study of aftertreatment system and their configuration.

1) United States Patent by Zoran et.al .[1] (Cummins Emission Solutions , Inc).Presented in his research about single module Integrated system. Therefore, in this paper study of single module configuration is done. In single module DOC, DPF & SCR housing in the single module and aligned with the single centreline axis. The selective catalytic reduction system may also include a diesel particulate filter disposed within the single housing and having a DPF centre axis aligned with the single centre line axis.
2) For the material study AK steel [2] reference is used for finding the Mechanical Properties, chemical properties, thermal properties and cost of the material. various parameters are considered for selection of material like weldability, corrosion resistance, machinability and availability of material. AK steel price sheet is used for the cost prediction and also the exhaust comparator sheet is used for the PUGH matrix concept selection process.
3) Peter Thorne, Camacho [3] presented in his paper about commonization, standardization and modularization for cost reduction. How to reuse the physical items, information items, architectures and knowledge since various parameter.
4) K. C. Vora, A. S . Patil and V. G . Halve [4] Presented SAE paper on A system approach to automotive exhaust development. In this paper system requirements are discussed for the development of cost-effective exhaust system. This paper reviews the requirements, design considerations and developments in the field of exhaust systems for automotive application. Also discussed various tool like DFMEA and DVP which leads to achieve performance, quality and durability of the system.
5) United states patent by Harrison et al.[5] on exhaust gas after treatment assembly contain aftertreatment assembly and their mounting position. It contains switchback configuration of ATS. Mounting location of DOC, DPF ,SCR and AMOX is explained in detail. As per research exhaust after treatment system is disclosed including Such amount and at least two exhaust gas after treatment components chosen from the group including a particle filter (PF), a muffler, a heat source for PF regeneration, a Selective Catalytic Reductor (SCR) and a mixing chamber, at least one of the components being positioned in the first mounting position and the at least one other component being positioned in the second mounting position, fluidly connected to the first component.
6) Yoel Emun, Joseph Kish and Hatem Zurob [6] Presented SAE paper on Comparative Corrosion Evaluation of Ferritic Stainless Steels Utilized in Automotive Exhaust Applications. In this paper include corrosion evaluation of different grades of ferritic stainless steel. As per the result of acid condensate test Type 409 has least corrosion resistance compared to Type 439 and Type 436 because of its chromium contained.
7) S. N. Thakur and J. R. McMillen, M. L. Holly, P. K. Samal [7] presented SAE paper on High Temperature Oxidation/Corrosion Performance of Various Materials for Exhaust System Applications. In this paper test is done on sample SS409 and Mild steel with powder metallurgy and stamped formed material. SS409 with PM formed retain 99% of the original material stock thickness. It reduces by 30 % in case of stamped SS409.In case of mild steel 50 to 90 % reduction of mass due to corrosion and Microhardness also reduced by 40 %.
8) Peter Heuser, Stefano Ghetti, Devising Rathod, Sebastian Petri and Sascha Schoenfeld [8] presented SAE Paper on Bharat Stage VI Solutions for Commercial Engines for the India Market. In this paper discussed major engineering challenges for the OEMs in terms of system complexity, reliability, costs, and development effort for BS VI conversion. It includes different layout of ATS for BS VI System also the model-based calibration for the optimized system.
9) Jyotirmoy Barman, Prateek Arora, and Kumar Patchappalam [9] Presented SAE Paper on Technology Challenges and Strategies for BS-VI in Commercial Vehicles. The changes in emission norms and testing cycles have been discussed with the possible concerns that are required to be addressed for the transition from BS-IV to BS-VI. In this paper include various strategies for achieving BS VI emission norm with optimized cost of the system.
10) Matthew Baus, Anthony Cook and David Schaller [10] Presented SAE Paper on Integrating New Emissions Engines into Commercial Vehicles: Emissions, Performance & Affordability. The purpose of this is to provide a comprehensive exposure to the numerous tasks and challenges associated with changes to diesel engines and related vehicle systems imposed by regulatory mandates. It includes various configuration layout and their mounting orientation for various application. It includes various case study on vehicle packaging limitations, aftertreatment control, product management and aftertreatment configuration.

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11) Robert L. Chance , Ronald G. Ceselli [11] Presented SAE Paper on Corrosiveness of Exhaust Gas Condensates. It includes evaluation of corrosiveness of Mild steel, Type 1 aluminized steel and stainless steel by use of anodic polarization measurements and a cyclic immersion procedure. Therefore, as per test Acid condensates are generally more corrosive than alkaline condensates towards metals of the exhaust system. Stainless steel is generally the most corrosion resistant material and Plain carbon steel is the least resistant material towards acid condensates and is susceptible to pitting corrosion in some alkaline condensates.

V. SYSTEM REQUIREMENT

Following parameters or criterions are considered while optimizing cost

1) *Weight:* weight should be within acceptable limit.
2) *Space Claim* - Represents width and height of concepts.
3) *Structural Integrity* – system able to with stand rotating bending forces and vibration forces during operation.
4) *Manufacturability* - Represents capability required for manufacturing of individual components. Parameter is based on assumption of existing capabilities and design complexity.
5) *Serviceability:* Exhaust AT assemblies requires removal and servicing of an AT element, e.g. a particulate soot filter element and/or a catalyst element.
6) *Design Complexity* - Represents cumulative effect of component manufacturability, ease of assembly, no of components etc.
7) *Ease of Assembly* - Represents the capability required for assembling the parts or no of constraints for assembly. Parameter is based on existing capability and observations from CAD model/Design.
8) *Component Cost* - Represents cost to be incurred for individual components. Accounts for manufacturability, tooling cost, etc.
9) *Form/Fit/Function*- Represent simple design, should have ease in fitment and meet functional requirement
10) *Durability /Reliability* – Represent new design should be meet Min. warrantable life and shall have no failure until life of vehicle
11) *Legal compliance & Safety*- Represent New design should meet legal compliance requirement & shall meet all safety requirement
12) *Aesthetic*- Represent Part should look good and eye easing

VI. CONCEPT DESIGN AND VERIFICATIONS

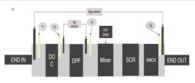
In this section we will talk about different steps we followed for concept selection and verifications. An exhaust aftertreatment system comprising of DOC, DPF, Mixer and SCR.

To design new After treatment system we need space claim from OEM chassis, Flow and Engine rated condition. New design should meet same/improved Emission limits and passes all structural design requirements.

1) *Brainstorming:* A group of people were called and given ask to share concept based on input conditions to reduce cost of overall system. Various ideas were generated and proceeded for further evaluation
2) *Concept selection using Pugh Matrix tool:* All the ideas were added in sheet and compared with baseline design

Concept selection for FM to SM Project





Criteria/Concept	Concept: Datum	SISO System	EISO Flex	EIEO SM	Sangam System
Overall Length	S	+	-	+	+
Space claim needs	S	+	-	+	+
Back pressure	S	-	S	+	S
Temp Drop across System	S	S	S	+	S
Emission Limit	S	S	S	S	-
Manufacturablity	S	+	S	+	+
Cost of Manufacturing/Capex Needs	S	+	-	+	S
Time to Implement	S	S	-	+	-
	S				
	S				
	S				
	S				
	S				
Total Σ +	0	4	0	7	3
Total Σ –	0	1	4	0	2
Total Σ S	13	3	4	1	3
Total	0	3	-4	7	1
Rank	4	2	5	1	3

Finalized EIEO Design has taken for further concept verifications



Existing Design of ATS



New Design of ATS

3) Ideas Evaluation & Verifications

a) Modal Analysis: Modal analysis were performed to check vibrational frequency. First modal frequency for new design is 406.02 Hz whereas for Flex Module it is 382.06 Hz which is improved design as compared to Flex system

b) Static Structural Analysis: Static structural analysis were performed with 10G inertial loading in X, Y&Z directions individually and max stress value is compared with the yield limit of the material. It has been observed that New Design experiences lesser stress than Flex Module.

c) PSD Test: New design verified using Single Axis shaker test using RLDA vibration profile and test has been passed.

d) Emission Verification: New design were verified using Medium Heavy commercial vehicle BS6 Emission transient cycle (WHTC) and this meets emission requirements.

VII. CONCLUSION

Newly designed Diesel exhaust Aftertreament system meets all requirement which includes lesser in cost, complexity, Improved in structural performance, Meeting in lesser packaging space claim and finally product offering will be cheaper b/n 5~7% from baseline.

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VIII. ACKNOWLEDGEMENT

Although it was not easy to complete this project unless I got great company support from Cummins Technology India private Limited Pune & my Industrial guides Mr. Aashish Wadke and Mr. Rajesh Yeole has guided for overall execution.

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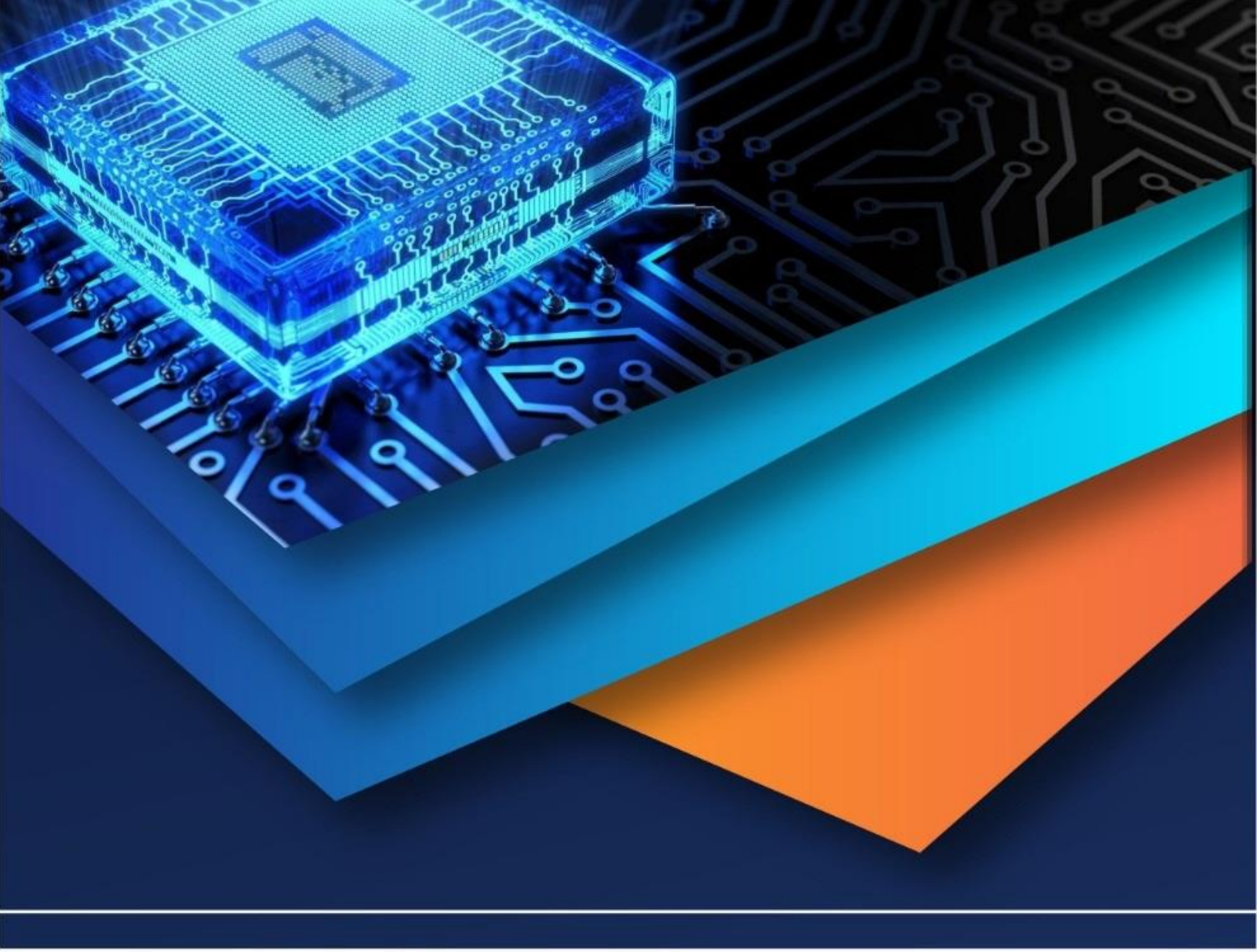
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