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Critical Weld Length Durability For Hanger Rod In Exhaust System

Mylaudy Dr. S.Rajadurai[1], R.Kavin[2], A.Prabhakaran[3]

[1]Head, Research & Development / Sharda Motor Industries Ltd,
Mahindra City, Tamil Nadu, India

[2]Assistant Manager, Research & Development / Sharda Motor Industries Ltd,
Mahindra City, Tamil Nadu, India

[3] Senior Engineer, Research & Development / Sharda Motor Industries Ltd,
Mahindra City, Tamil Nadu, India

Abstract

This paper reveals the methodology adopted to address the design, development and validation of different types of weld length of exhaust hanger rods. Traditional methods dictates full seam weld in the hanger rod along with its connecting geometry. Going apart from the traditional way, we validated different types of weld lengths for single geometry hanger rod. One by one hurdles are cleared by using virtual simulation and experiments. To initiate the development stage basic dynamic stiffness of hanger rods are analyzed with respect to Sharda motor standard targets. Later it is verified using dynamic loads (Average road load data for the particular geometry in different conditions) and it is correlated with testing.

Keywords: *Hanger Rods, Eigen frequency, Road Load Data Acquisition, Root Mean Square, Experimental validation.*

1. Introduction

A vehicle exhaust system composed manifold bellow,catalyst,hangers,resonator and pipeline assembly. The fundamental function of exhaust system is to carry the exhaust gas from the engine to tail pipe and also reduce the sound of the expelled exhaust gas to an acceptable limit. During the initial stage of the exhaust system design, Exhaust hangers plays a vital role in automobiles exhaust after treatment system. It not only grasps the exhaust system to chassis. It helps to diminish the vibration through the rubber isolator. But the design of the hanger rods and identification of the hanger location are crucial role in exhaust development. The exhaust system endures the engine vibration as well as road surface induced vibration. The problem of mechanical vibration for an automotive exhaust hangers are investigated using the modal analysis. By using the finite element mathematical model is possible to calculate vibration, Eigen frequency and mode shape. Ideally, experimental investigational approach method should be used, but it consumes time and resources.

This paper reveals computational methodology adopted to address the design, development and validation of hanger rods with different weld length boundary condition in the initial stage of hanger rod selection.

2.Hanger Rods

Exhaust hangers are required to provide the excellent vibration isolation of the vehicle body, from engine vibration in the wide range of frequency, 20 to 30Hz for idling vibration up to 500Hz in the interior noise[5].

Generally failure occurs in the hanger to base material region due to improper weld. In this paper deals with the four different critical weld length and its durability comparison through simulation and validation. The engine vibration is transferred through the hanger rod through rubber hanger. In Automotive exhaust system rubber hanger mobility should be greater than the structural mobility. Proper isolator should not allow the more than 10% of vibration energy to be transferred to the chassis or body of the system. The structural borne noise of the exhaust system is depends upon the static stiffness of the isolator. If the stiffness is higher than the target value can induce the structural borne noise and all values lower than this target value indicate sufficient isolation of energy between the exhaust and the hanger attached to the body.[3]Both, the system and the body/chassis mounting location should have high stiffness while the isolator should have low stiffness for proper isolation. Isolation will not occur when the structure mobility is equal to the isolator mobility.

The analysis reveals that vertical stiffness of the flex decoupler is the key parameter for the hanger force response[2].The vertical and lateral bending frequency are very crucial in the vibration transmission which will be balanced by the vertical and lateral stiffness of the bellow.

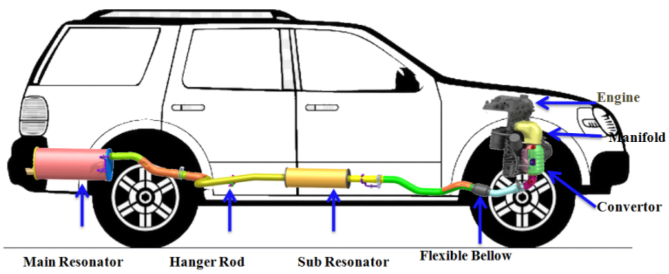

Figure 1: Represent the exhaust system in vehicle

3.Limitations

The automobile exhaust system consists of manifold, converter, flexible bellow, sub resonator, main resonator hanger rod and tailpipe. The main restraint is that all natural frequencies of the hangers must depend on vehicle applications. The excitation sources are assumed to vibrate the exhaust system up to frequency range from 100-250Hz for passenger car vehicles. The vendors demand includes a safety margin of 150-250 Hz, which should be able to withstand the loads such as mechanical loads, thermal loads and corrosion characteristics.

Design parameters are influenced by mass and geometry. The materials used in all case studies are stainless steel grades (SS409.S10C). Stiffness depends on material mechanical properties, geometrical design and connections between hanger and the exhaust system, i.e. weld. The geometrical limitation of hanger rod, i.e. it should be able to fit the standard rubber isolators and should also meet the packaging conditions of the system. As a secondary solution, influencing the damping ratio of the isolator in the structure is possible to decrease the effects of natural frequencies that cannot be increased above the desired level. So, damping effects of rubber isolator is not be discussed in this paper**.**

4.Hanger Location Prediction

First, a modal analysis of the exhaust system is conducted in the frequency range of interest. Since noise and vibration are very important, booming factor is considered to determine the hanger location. In the analysis, one end of the exhaust system is fixed since 'it is considered to be clamped to the engine. The interested natural frequency is in the range of 25Hz to 200Hz.

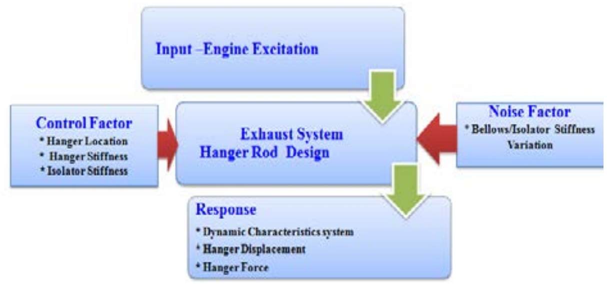

Figure 2 : P-Diagram of exhaust system design

To decide the position of hanger, each mode that does not have deflection at nodal point is rearranged. In this case, only the vertical direction will be considered since lateral direction gives a small effect. At least two or more different frequencies, with no deflection at nodal points are selected for initial hanger position. Engine excitation input is applied to the system in the form of force or enforced motion. This is typically a force/displacement/acceleration vs. frequency in idle or wide open throttle conditions. RMS value of amplitude is calculated for each point across the frequency range and all the values are plotted against the corresponding point numbers. The points with the lowest RMS values are identified as potential hanger locations while the points with the highest amplitudes are identified as locations to avoid. To determine the best locations for hanger placement in order that would minimize the dynamic force transmitted to the body side. In the development of hangers ,it is practically impossible to achieve the dynamic characteristics for the entire frequency range from 20 to 500Hz. All the natural frequencies of the hangers must be above 500Hz. The vibration sources are assumed to excite the exhaust system up to frequency 250Hz. The hanger must also be able to withstand temporary mechanical loads, thermal loads and corrosion. Stiffness along the loading direction

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shall be optimized to meet static weight requirement but shall be as low as possible. i.e. 20-30 N/mm.

Figure 3: Represent the hanger location predation boundary condition (Inlet flange bolt holes are constraint in all degrees of freedom)

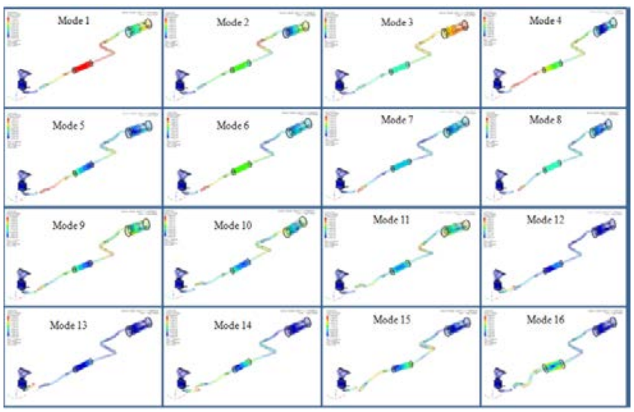

Figure 4: Mode shape behavior of the system

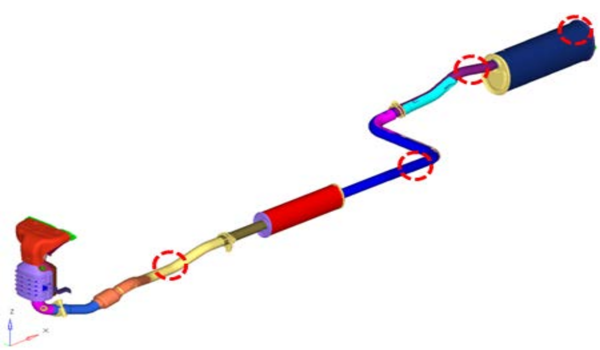

Figure 5: Primary hanger location prediction of the system

5.Isolator selection

The isolator section should follow the mobility transfer function. The implementation of the mobility approach to reduce structure-borne noise in exhaust system simulations, starts with the definition of the static isolator's stiffness. The stiffness defines the desired response target for the exhaust system hanger brackets and body side brackets.

Proper isolator usage should not allow more than 10% of the vibration energy to be transferred to the body/chassis system. This defines the target mobility using target static stiffness value to be achieved. In other words, all values greater than this target value can induce structure-borne noise and all values lower than this target value indicate sufficient isolation of energy between the exhaust and the hanger attached to the body. Both, the system and the body/chassis mounting location should have high stiffness while the isolator should have low stiffness for proper isolation. Isolation will not occur when the structure mobility is equal to the isolator mobility. Consequently, a frequent requirement in exhaust hanger development is to have the first resonant frequency or 1st mode in the range from 250 Hz to 400 Hz. This value of the first mode can be varied with power train and platform definitions.

The dynamic stiffness K and the loss angle δ are used to evaluate the vibration isolation performance of exhaust hangers. When an exhaust hanger is subjected to the steady-state harmonic excitation of the angular frequency ω, the excitation displacement X(t) and the transmitted force F(t) across the exhaust hanger can be expressed as

$$X(t) = X_o \sin(\omega t) \qquad (1)$$

$$F(t) = F_o \sin(\omega t + \delta) \qquad (2)$$

Where,

X_o – amplitude of excitation displacement

F_o - amplitude of transmitted force

$$\text{Dynamic stiffness } K = F_o/X_o \qquad (3)$$

6.Different weld Length for Hanger Rods

Even though stringent procedures are followed in exhaust system development, the hanger rod weld length selection is important parameter, Nevertheless the vibration isolation. In this paper deals with different types of weld length and its durability. For achieving durability of the components we consider worst case RLDA data for virtual and testing. The weld length is taken from previous bench marking data

Figure 6: The pipe to hanger rod weld

Basically this hanger rod weld length study consists of four different types of weld length

A. One side full welding
B. Staggered intermittent welding
C. Two side full welding
D. Intermittent double fillet welding

An overview of the process adopted in performing the analysis is shown in Figure.

The RLDA assumes the major role to predict the weld parameter and its equaling cycles. The given RLDA is consider as the vertical directional load in Z direction to the hanger rods. The weld length of the hanger to pipe is taken from the previous benchmarking data. Simulation and testing were performed to validate the hanger rods life through RLDA. The following flow chart is explain the process flow of the work. In the case of simulation we used Msc Nastran /Msc fatigue software and testing MTS bi axial test machine.

Exhaust system geometry (CAD data)
↓
Design inputs for analysis
↓
FE Model building
↓
Modal Analysis (Sol 103) Stiffness and Mode
↓
Dynamic transient (Sol 109) analysis
↓
Fatigue analysis
↓
Fatigue test under MTS machine
↓
Correlation

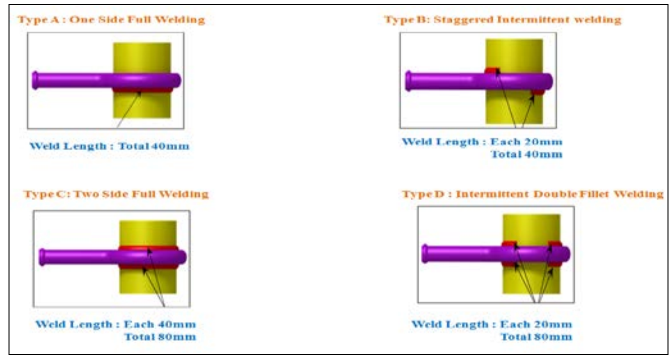

Figure 7: Different weld length for hanger rod to pipe

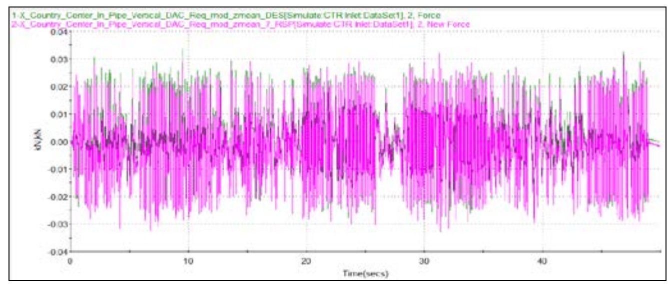

Figure 8: Vertical RLDA in the hanger rod

From the observed RLDA input we predict the approximate life of the components using virtual lab and test lab.

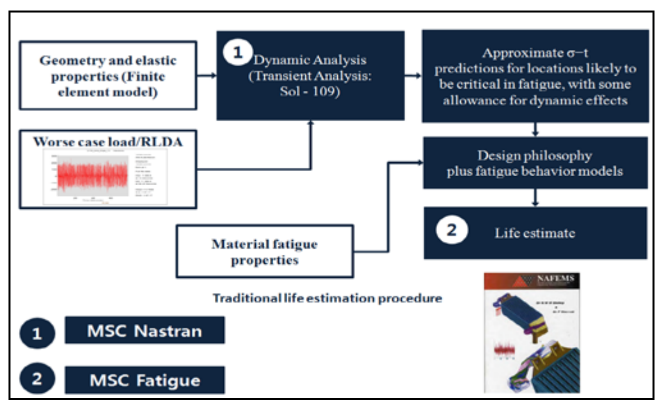

Figure 9: Life prediction process

Predictive analyses using FEA helps in understanding the performance of the product when it is exposed to service conditions. Performance of the design when using different materials for manufacture can also be studied. The performance of the current product can be benchmarked and criterion for new product development can be established.

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A Stiffness requirement for a hanger rod is the first and one of the most important information that a designer needs to design a part. The shape and size of the part can be projected based on the stiffness requirements and a geometrical envelope of the component can be created. FEA is used to predict the load-deflection characteristics and judge whether the stiffness is as per the requirements.

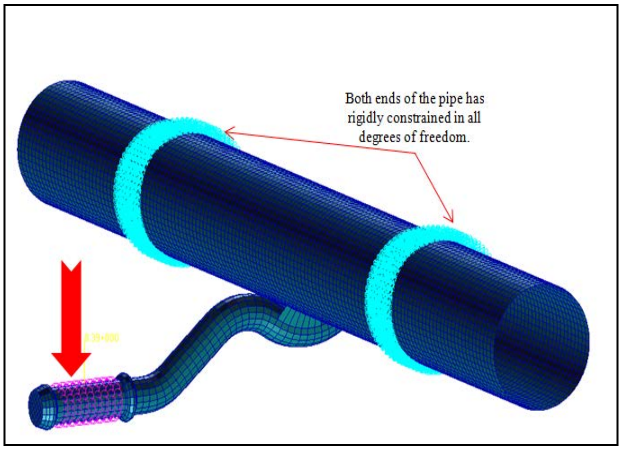

Figure 10: Loading condition of hanger rod

Table1 : Linear materials properties

Component	Material Name	Young's modulus (N/mm^2)	Poisson's ratio	Density (ton/mm^3)	Yield strength (MPa)	Ultimate tensile strength (MPa)
Pipe	SUS409L	2.2 E+5	0.3	7.75 E-9	175 min	360 min
Hanger Rod	S10C	2.0 E+5	0.3	7.87 E-9	350 min	650 min

7.Virtual Analysis Results

In this hanger rod simulation consists of two type of analysis, the first one is dynamic transient (Sol 109) analysis & second one is fatigue analysis using SN method.

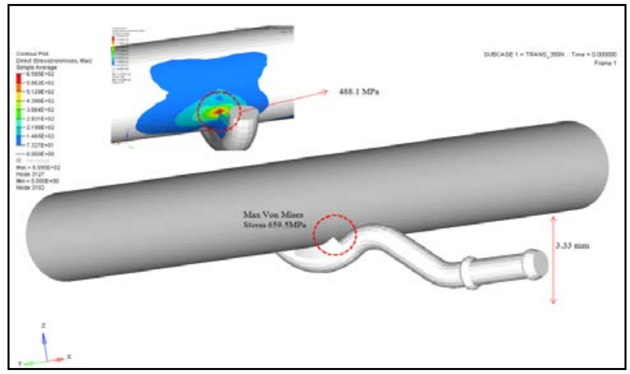

Figure 11: One side full weld (Type A) stress plot

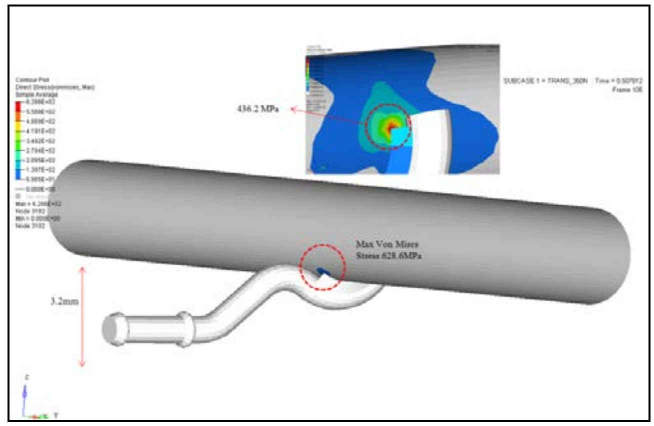

Figure 12: Staggered intermittent weld (Type B) stress plot

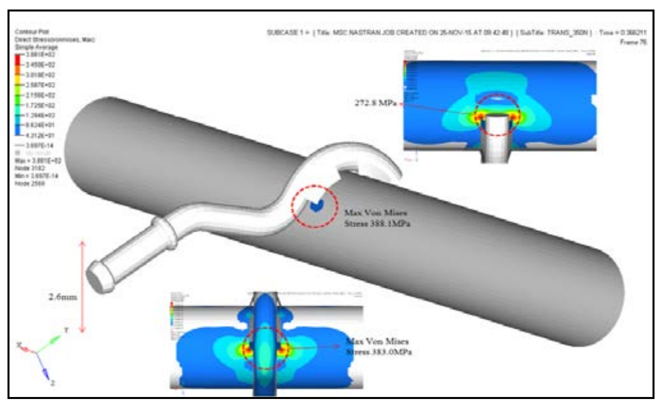

Figure 13: Two side full weld (Type C) stress plot

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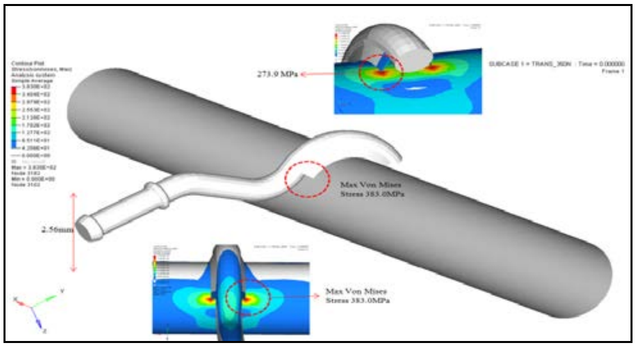

Figure 14: Intermittent double fillet weld (Type D) stress plot

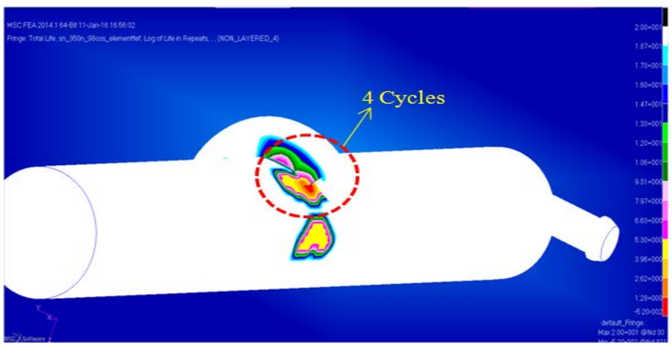

Figure 15: One side full weld (Type A) fatigue life

Figure 16: Staggered intermittent weld (Type B) fatigue life

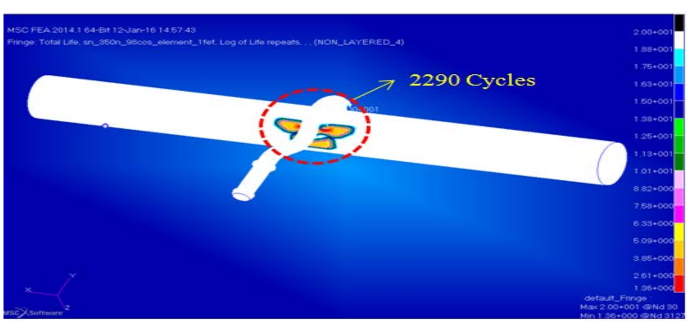

Figure 17: Two side full weld (Type C) fatigue life

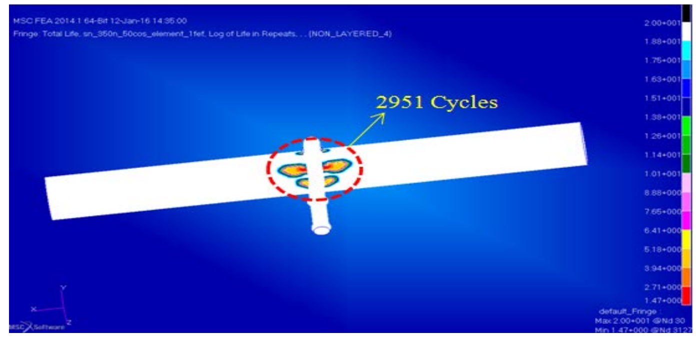

Figure 18: Intermittence double fillet weld (Type D) fatigue life

8.Experimental test

Figure 19: Testing sample

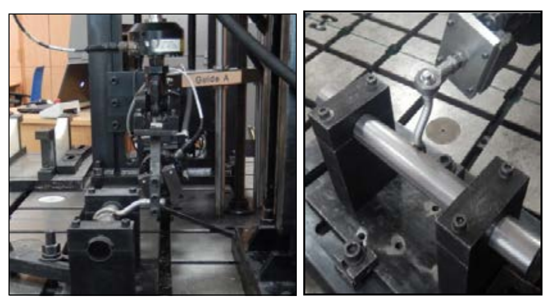

Figure 20: Test ring setup

9.Test Results

The test is conducted with same RLDA data with 10 to 15 samples and the number of failure were recorded.

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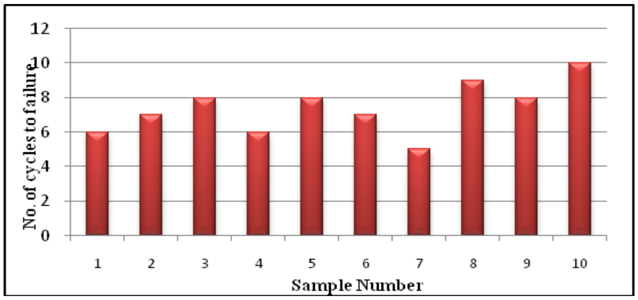

Figure 21: One side full weld (Type A)

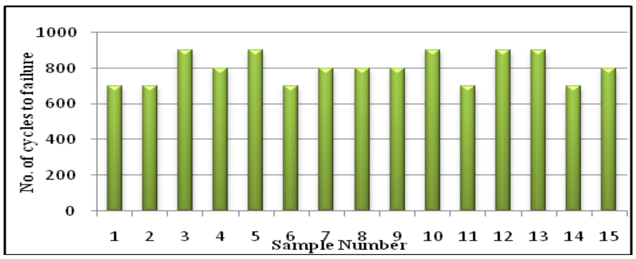

Figure 22: Staggered intermittent weld (Type B)

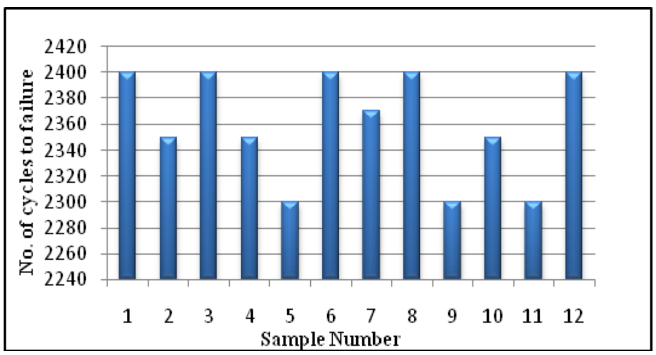

Figure 23: Two side full weld (Type C)

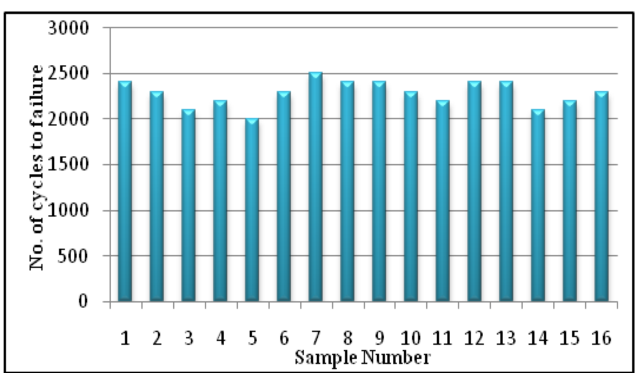

Figure 24: Intermittent double fillet weld (Type D)

10.Virtual Vs Experimental Comparison

Table2 : Result comparison

Weld Type	Load Level	Max.Stress	Damage	Component Life	
				CAE	Experimental Average
Weld Type A	350N	659.5	1.15	4	10
Weld Type B		628.6	0.8	1023	750
Weld Type C		388.1	0.328	2151	2000
Weld Type D		383.0	0.41	2290	2300

11.Conculsion

The development through simulation and testing of a control strategy to assist the drivers during maneuvering in the gradient is discussed in this paper. This methodology supported not only the fine-tuning of the proposed control strategy but also reduced the design cycle time and testing time. From the development study we observed that the maximum life is predicted in the type C & type D hanger rod. Depends upon the our application and demand we move for hanger type C or Type D. Finally, this strategy will be taken to the production level in future.

Acknowledgments

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Dr.S.Rajadurai,Ph.D. born in Mylaudy, Kanyakumari District, Tamil Nadu, India, received his Ph.D. in Chemistry from IIT Chennai in 1979. He has devoted nearly 35 years to scientific innovation, pioneering theory and application through the 20th century, and expanding strides of advancement into the 21st century. By authoring hundreds of published papers and reports and creating several patents, his research on solid oxide solutions, free radicals, catalyst structure sensitivity, and catalytic converter and exhaust system design has revolutionized the field of chemistry and automobile industry.Dr. Rajadurai had various leadership position such has the Director of Research at Cummins Engine Company, Director of Advanced Development at Tenneco Automotive, Director of Emissions at ArvinMeritor, Vice-President of ACS Industries and since 2009 he is the Head of R&D Sharda Motor Industries Ltd. He was a panelist of the Scientists and Technologists of Indian Origin, New Delhi 2004. He is a Fellow of the Society of Automotive Engineers. He was the UNESCO representative of India on low-cost analytical studies (1983-85). He is a Life Member of the North American Catalysis Society, North American Photo Chemical Society, Catalysis Society of India, Instrumental Society of India, Bangladesh Chemical Society and Indian Chemical Society.

Second Author: Kavin R, Assistant Manager - Structural Analysis at Sharda Motor Industries Limited, R&D centre, Chennai, for the past 4 years. Mr. Kavin holds a bachelor degree from Anna University, Tirunelveli.

During his career, Mr. Kavin has been involved in FE model building and assembly, solver input deck preparation and CAE structural analysis such as Modal, Static, and Dynamic & Thermal stress simulations for exhaust system hot end, cold end and full system. Team Lead for Structural analysis team. He published 5 SAE technical papers and also more than international 6 journals. He won 3rd prize in 2013 - Altair technology conference, Pune for paper titled on" Passenger car Exhaust system Muffler Bead Optimization and Comparative study using OptiStruct".

Area of interest includes Engine and power train, Project/product management, Techno-commercial activities, Product design, structural analysis, fatigue /durability analysis, experimental/operational modal analysis. Future plans include develop my experience and expertise in dynamic analysis (modal and transient frequency response), fatigue or durability analysis on Exhaust system and acoustic simulation of muffler. The objective of concentration is to move towards experimental testing such as tensile, compression, component fatigue, Full exhaust system fatigue, experimental modal analysis, NVH analysis and correlation with FEA simulation.