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Structure Design and Development of Engine Crankshaft Damper

Ajay D Pingale[#1], Chetan M. Patil[*2], Dr. Sachin U Belgamwar[#3]
[#1]*Research Scholar, BITS Pilani, Rajasthan India*
[*2]*Research Scholar, Dr. D. Y. Patil School of Engineering, Pune, India*
[#3]*Assistant Professor, BITS Pilani, Rajasthan India*

Abstract

Engine crankshaft damper is mainly used to reduce the axial vibration of combustion engines. Vibrations generated in engine assembly are very large in amount. To reduce their impact, and axial vibration damper is installed between the crankshaft and casing. Its technical state directly influences the lifetime as well as the performance of the engine. In this project, diagnosing, designing, and testing axial vibration dampers used in engines will be discussed. To minimize the impact of axial vibration, a damper is installed between the crankshaft and casing. A float of the crankshaft will cause damage to the casing. Hence a soft damper is used to maintain a soft cushioning between casing and crankshaft.

Keywords - *Crankshaft, Damper, FEA, Static Structural Analysis, UTM Testing etc.*

I. INTRODUCTION

An engine crankshaft damper is an element that reduces torsional vibration. The crankshaft deflects under this torque, which sets up vibrations when the torque is released. At particular engine speeds, the cylinders' torques are in sync with the vibrations in the crankshaft, which results in a phenomenon called resonance.

The damper is a combination of a mass & energy-dissipating element. The mass resists the acceleration of the vibration, and the energy dissipating element absorbs the vibrations. The present study's objective is to deal with a damper's development for the crankshaft system of a transporting machine using reverse engineering. According to models and commercially produced products, a tester for performance evaluation is also developed to validate a torsional vibration, viscosity dampers. The several models made up of the damping and the mass variation of an inertia ring were manufactured and tested using an engine simulator.

Due to the clearance gaps between the contacting body surfaces, e.g., in slider bearings, a crank train's corresponding components move relative to each other. To reduce these relative motions, oil is pumped into the gap between the contacting bodies. This oil and the introduced hydrodynamic lubrication reduce friction and wear of the contacting components and structure-borne noise. Different approaches can be used for representing these contacts. Periodically changeable gas and inertia forces which occur during the operation engine generate transverse, axial and torsional vibrations of crankshafts of combustion engines. Vibrations produced in crankshafts of the combustion engine are very large in amount. To minimize their impact, and axial vibration damper is installed between the crankshaft and casing. It's a state that directly affects the lifetime and reliability of the engine. In this project, diagnosing, designing, and testing axial vibration dampers used in engines will be discussed.

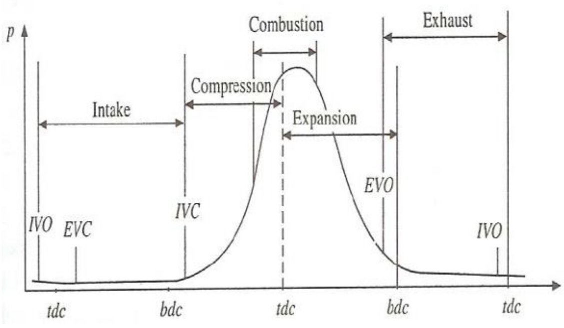

Fig 1: Pressure vs. Angle

Rubber damper - A rubber damper on the hinged support provides a cushioning effect for side impacts to absorb axial vibration

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Fig. 2 Rubber Damper

Engine Crankshaft Damper - To minimize the impact of axial vibration damper is installed between crankshafts and casing. A float of the crankshaft will be 0.2 mm to 1.39 mm, which will cause damage to the casing. The damper is used to maintain a soft cushioning effect between the casing & crankshaft.

Fig. 3 Engine crankshaft Damper

II. LITERATURE REVIEW

A viscosity damper is developed to substitute import products. An engine simulator for performance evaluation has been produced to enable the control of engine speed using a PID controller and evaluate several models' performance by reverse engineering [1].

The excitation potential increases as a result of the higher performance density in the vicinity of the clutch assembly, the development of more efficient drive trains causes increased sensitivity to alternative torques, and customer expectations become higher with every new generation of vehicle models [2]

Torsional crankshaft oscillations in the diesel engine of an automobile are studied experimentally. Their relation to the cylinder block vibration is considered. It is established that the vibrations appearing not only at the resonant harmonic but at higher frequencies are due to torsional crankshaft oscillations, which produce impacts in the crankshaft's slip bearings [3].

A sleeve spring damper is one such measure to reduce the torsional vibration. In this study, the closed-form equations to predict the spring constant of a sleeve spring and the dynamic characteristics of the torsional vibration damper are proposed to calculate the damper's stiffness and verified their availability through the finite element analysis [4].

The model-based strength and safety factors were derived for crankshafts at Audi. Combining simulation and test results, highly accurate results were achieved and made it possible to develop a good interpretation of the strength behavior. This article examines various disciplines used in the crankshaft calculations. A deeper understanding of the dynamic load situation was achieved [5].

The algebraic constraints originate from the reference conditions and the normalization equation for the quaternions. For the time integration of this system, two aspects have to be taken into account: firstly, for efficiency exploiting the system's structure and using parallelization. Secondly, consistent initial values also concerning a related index-3 system have to be computed to compute missing initial velocities and to reduce transient phenomena [6]

The simulation results are compared with a lumped mass model and a detailed model using the system matrix method. Results of nonlinear torsional vibration analysis indicate that the additional excitation torque created by non-constant inertia activates the 2nd order rolling vibration, and the additional damping torque resulting from the non-constant inertia is the main nonlinear factor. The increased torsion angular displacement evoked by the high order excitation torque relates to the non-constant inertia [8].

A method is proposed for damping the torsional vibrations of an automobile transmission. In this method, the damper's rigidity is reduced to a value at which vibration is impossible [9].

The crank train offers essential potential for increasing modern combustion engines' efficiency by reducing moving masses and friction. The engine power increase by higher combustion pressures and higher speeds leads to increased principal Mechanical load parameters, gas and mass forces, in the crank train [10].

In the AVL engine development process. Crank train and crankshaft analysis consist of two phases: the concept phase at the beginning of the development process and the subsequent layout phase. The concept phase's major purpose is to define the main dimensions, a basic investigation of the strength and an assessment of the bearings, and the dynamic behavior of the most important components [11].

III. PROBLEM STATEMENT AND OBJECTIVE

Mostly all elements in their physical existence are vibrating at some frequencies due to which they fail before their designed life by imposing various ill-effects on its surrounding. For a frequency of excitation equal to their natural frequency, the element/ body is subjected to reach a very high amplitude due to resonance. One technique is to introduce damper in between the vibration so that energy can be absorbed by free mass known as damper between them. Dampers can be constructed in tiny size and can work for a wide range of applications and very small mass replacement to conventional viscous damping system.

This project's primary objective is to effectively conduct design, Structural Analysis, and experimental engine with crankshaft damper. The study focuses on the procedure to calculate damper compression and damping in the system. A 3D finite element model of the system is developed in ANSYS to determine the required results. This study is intended to provide tools that ensure better designing options for Vibrating Systems with Damper.

[1] Identification of failure and cause of damper.
[2] Modeling of Engine crankcase, crankshaft and Damper
[3] Existing damper FEA and result correlation.

[4] Crankcase modification for better compression of damper around 360deg.
[5] Modified damper FEA with new stack-up of crankshaft and crankcase.
[6] Analysis of different frequencies.
[7] Correlation of FEA with actual experiment for compression percentage of damper under specific stacks up along with to check for No damage to have happened for Engine Endurance test.

IV. THEORETICAL ANALYSIS

Stack-Up of Engine Parts for Damper Size:

The table below shows the tolerance variation of parts of which will decide damper compression. An available fixed space between the crankshaft and crankcase will be a constraint for the damper dimension. The only variation in shape of damper button can be done to achieve the compression percentage within 8 – 45% above or below which is unaccepted as either damper will be loosen while in Work or will become hard due to high compression lose its characteristics.

Component Material:
Head Cover, Head, Block, Cases, Case covers, Tensioner =Aluminum
Valve Seat, Valve guide, Bolts & Mounting bolts washers = Steel
Liner, Main bearing inserts = Cast Iron
Damper = Rubber (FKN4)

TABLE I
Dimensions of damper stack

Damper Design	Unit	Basic Dimensions	Min	Max	Mean
Crankcase LH	mm	39.2	39.1	39.2	39.15
Crankcase RH	mm	44.8	44.8	44.9	44.85
Gasket	mm	0.4	0.36	0.44	0.4
C'Case RH + Gasket + C'Case LH			84.26	84.54	84.4
Damper	mm	3.4	3.2	3.6	3.4
	mm		3.2	3.6	3.4
Crankshaft RH	mm	18.8	18.75	18.8	18.78
	mm	18	17.95	18.05	18
	mm		0.7	0.85	0.77
RH Side Bearing	mm	16	15.85	16	15.93
Crankshaft Assembly	mm		65.05	65.3	65.18
Crankshaft Assembly	mm		81.6	82.15	81.88
Damper Compression			0.26	1.49	0.88
Damper Compression %			8%	41%	26%

Properties:

1. Material properties of Steel, Aluminum and Cast iron

TABLE II
Material Properties for Steel

E	2.1×10^{5} Mpa
µ	0.3
ρ	7.85×10^{-9} tonn/mm^3

TABLE III
Material Properties for Aluminium

E	0.675×10^{5} Mpa
µ	0.34
ρ	2.7×10^{-9} tonn/mm^3

TABLE IV
Material Properties for Cast iron

E	1.2×10^{5} Mpa
µ	0.28
ρ	7.2×10^{-9} tonn/mm^3

A. Bolt Pretension load calculation from torque for Assembly analysis.

TABLE IV
PRELOAD CALCULATIONS

Type M	**Dkm (mm)**	**Torque (Kg.m)**	**Axial Force (N)**	**Description**
M6X1	18	1.2	3700	Head Cover Bolt(4)
M6X1	8	1.2	11503	Tensioner Bolt(2)
M6X1	8	1.2	10544	All Flange Bolt(6)
M10X1.25	14	6.2	37303	Mounting Bolt(4)

V. DESIGN AND ANALYSIS

Static structural analysis of engine crankshaft damper is performed by ANSYS 18.0 software to determine the existing structure's contact pressure and deformation values.

A. Solid modeling of engine crankshaft damper assembly

A solid model of the gate is created by Creo 3.0 software, which makes modeling so easy and user friendly.

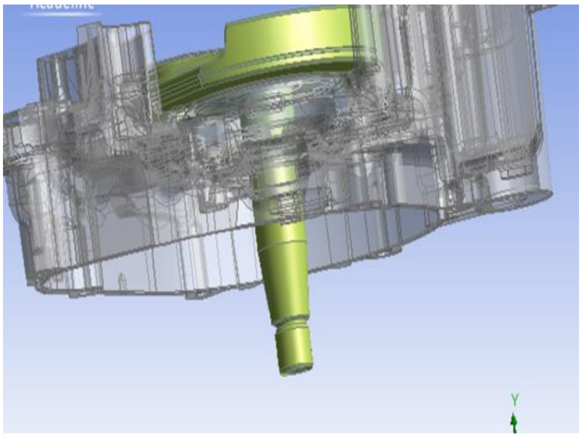


Fig. 4 Solid modeling of the engine crankshaft assembly

Structural Analysis:

Structural analysis is solved with the Bolt Tightening effect by applying preload to all bolts in the crankcase. Contact pressure and contour are observed for the damper for distribution of tightening load on the damper.

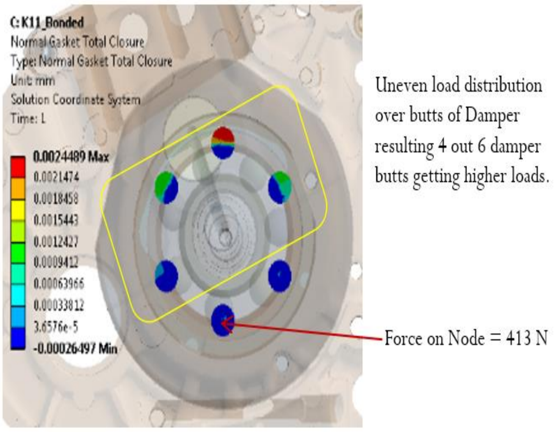


Fig. 5 Total Deformation plot of the old damper when uneven load distribution

Fig. 6 Old damper at uneven load distribution

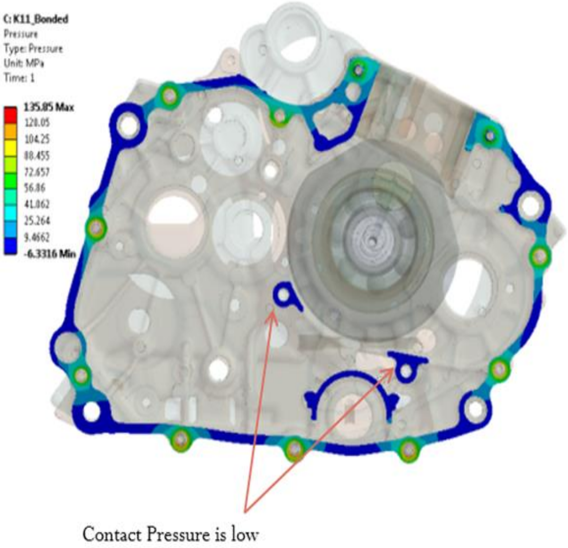


Fig. 7 Pressure plot of crankcase when uneven load distribution

The above image shows damper buttons of the existing damper are non-uniformly loaded. This will lead to uneven loading to the damper, and high wear will result. FEA simulates actual wear from the field. After modification in cases: Below image shows damper buttons of the existing damper is uniformly loaded after the addition of 2 bolts to the crankcase.

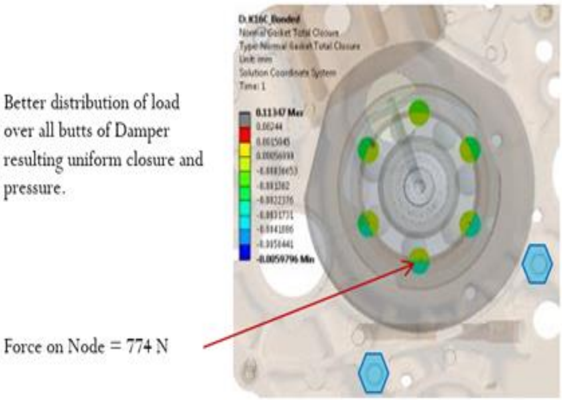
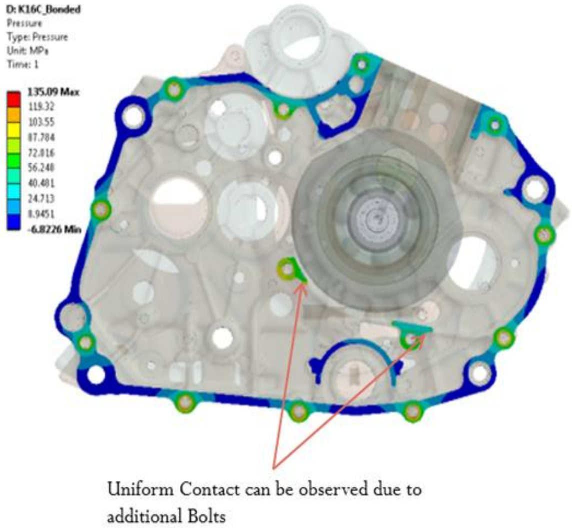


Fig. 8 Total Deformation plot of the old damper when uniform load distribution

Fig. 9 Old damper at uniform load distribution



Uniform Contact can be observed due to additional Bolts

Fig. 10 Pressure plot of crankcase when uneven load distribution

This lead to even loading for the damper. But even with betterment in damper loading, high compression was observed, and cut marks were observed in the actual engine endurance test for 2 engines. Hence we go for a new damper design.

A. Solid modeling of engine crankshaft damper

A solid model of the damper is created by Creo 3.0 software, which makes modeling so easy and user friendly.

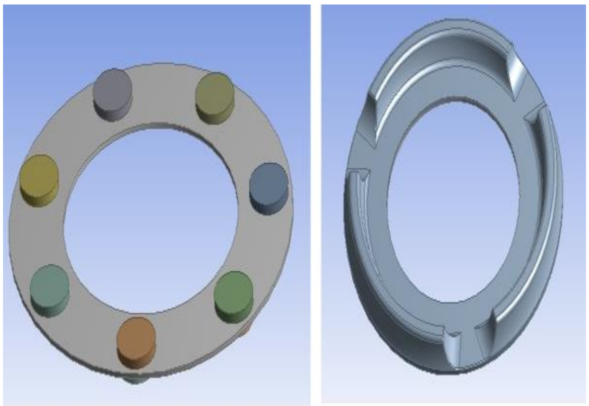


Fig.11 Old and Modified Solid model of damper

B. Structural Analysis

A solid model of the gate is created by Creo 3.0 software, and then this model is saving in IGES format and export into the FEA software ANSYS 18.0. The existing and modified structure is analyzed in FEA software. Following steps are used to find analysis results,

1) Material properties
2) Connections
3) Meshing.
4) Loads and boundary conditions.
5) Results

C. Mesh generation

The meshing of existing and modified damper followers was done in ANSYS 18.0 (Workbench) software. Fig.12 and 13 show the meshing of the modified gate structure.

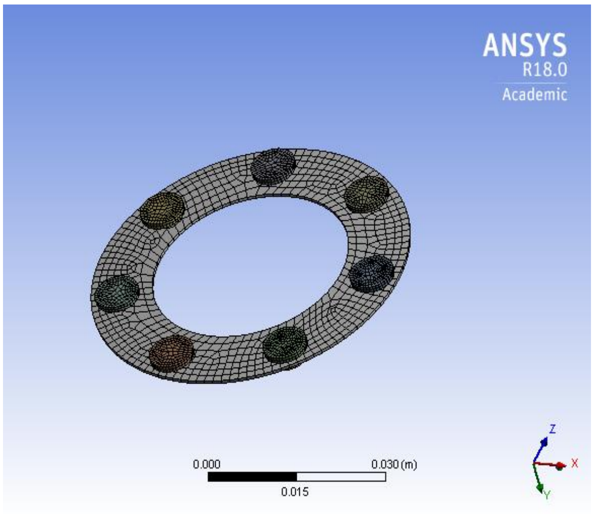


Fig. 12 meshing of an old damper

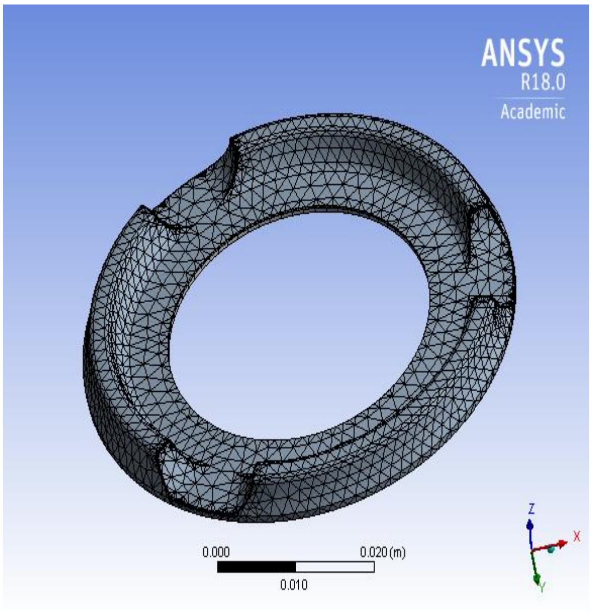


Fig. 13 meshing of the modified damper

D. Loads and Boundary Conditions

Static structural analysis was performed to determine the total deformation of existing and modified Damper by ANSYS software. For this above, boundary conditions are used: Fixed support and displacement. The existing and modified damper is fixed, as shown in fig.14 and fig.15. The maximum displacement is 1.3mm. So, 1.3 mm displacement was applied in the vertical direction of the structure in a downward direction.

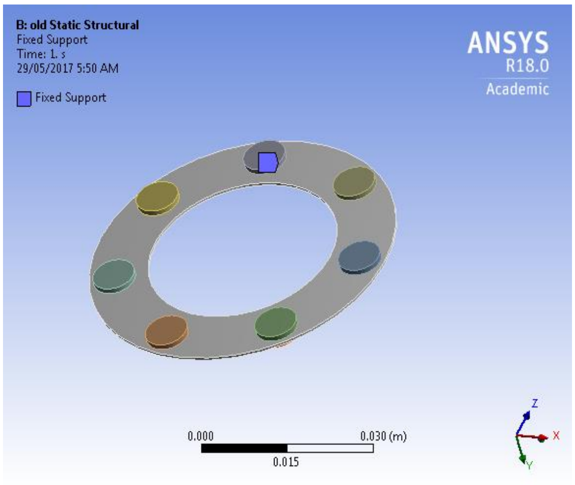


Fig. 14 Fixed supports for old damper model

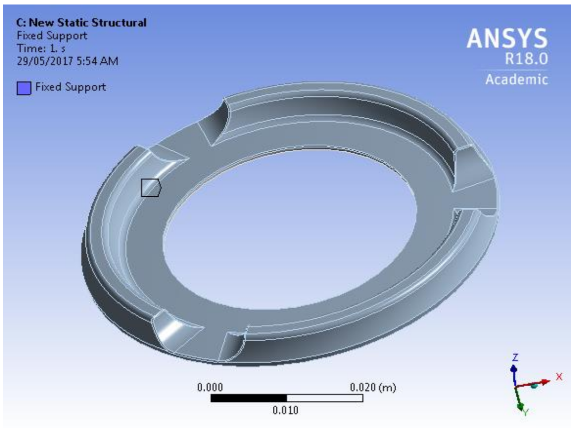


Fig. 15 Fixed supports for modified damper model

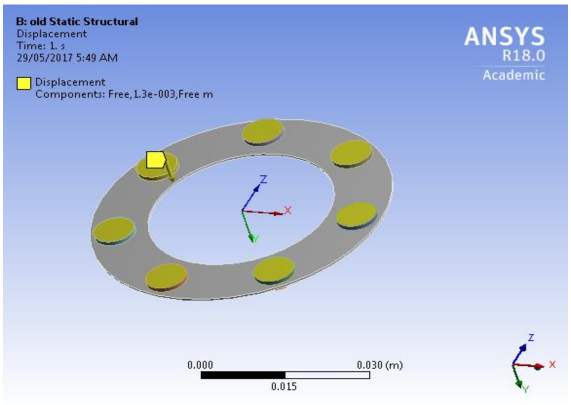


Fig. 16 loading on old damper model

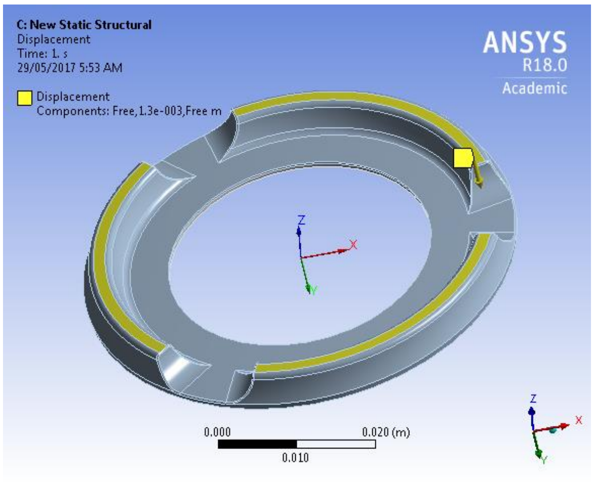


Fig. 17 loading on the modified damper model

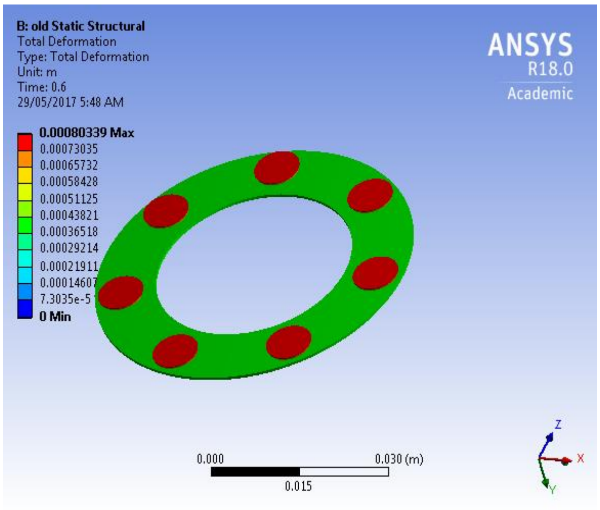


Fig. 18 Total deformation in the old damper model

E. Analysis: total deformation of the old damper model

The fig.11 shows deformation of the modified gate structure is 0.8033 mm.

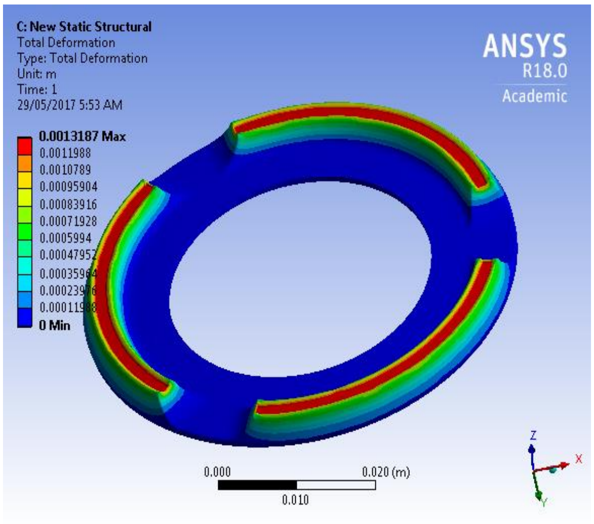


Fig. 19 Total deformation in the modified damper model

F. Analysis: total deformation of new damper model

The fig.19 shows deformation of the modified damper structure is 1.318 mm

VI. EXPERIMENTAL TESTING

To verify the damper experimentally's deflection values, we tested both the damper structure on the universal testing machine in a metallurgical laboratory. The readings from the machine are used to verify with the Finite element analysis results damper structure.

In experimentation, we find out results on the universal testing machine. The load is applied to the damper by using load cells of the universal testing machine. As the load applies to the damper, the universal testing machine's display shows the load vs. deformation graph.

By using this, we can find out the deflection of the damper at the deformation point. Deflection values for the old damper are 0.8 mm, and the new model is 1.3 mm.

Fig. 20 Experimental setup on UTM

The deflection value is taken at peak load, and this value is compared with our FEA, and theoretical results also calculate stiffness for both dampers from load vs. Deformation graph. Using stiffness, we find out the natural frequency of both structure and frequencies of both structure is in the range. The same procedure was applied for both damper structures.

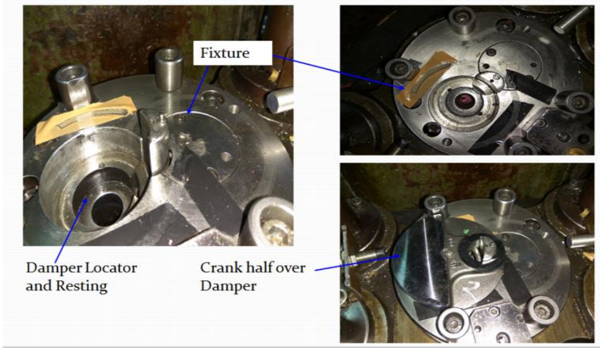


Fig. 21 Experimental setup for Endurance testing

A. *Experimental results*

From experimentation, we obtain a graph of load Vs. Deformation of both gates on that graph also gets the peak load value and stress on that load. So this stress was used to analyze the results.

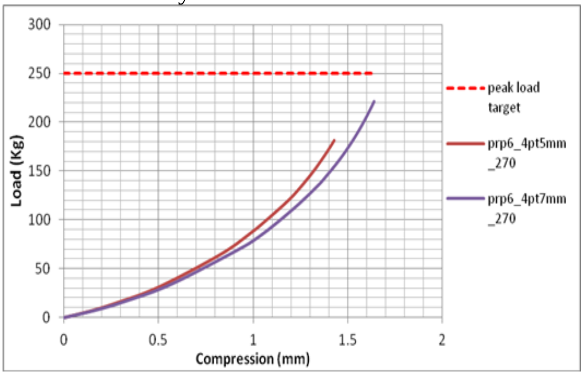


Fig.22 Graph of load Vs. deformation of an old gate

Fig.22 shows the graph of load Vs. Deformation of an old and new gate model is respectively. The X-axis shows the deflection(mm) values, and Y-axis shows the load (Kg) of the damper.

VII. RESULTS AND DISCUSSION

Static analysis of existing and modified damper is carried out by theoretically, experimentally and Finite element method. By theoretical calculation of the new model, the deflection is 0.9 mm. By the Finite element method, the deflection value is 1.3 mm. By the experimental testing, the deflection is 1.2 mm.

Hence according to all methods, the result is matching with all the processes.

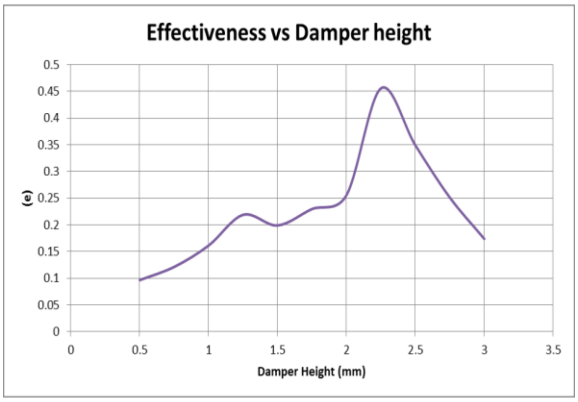


Fig. 23 Effectiveness vs. Damper height plot

From fig. 21, we calculate the damper's effectiveness by calculating acceleration and from that data, we plot a graph of effectiveness vs. damper height. From fig. 23 it shows that the effectiveness of the new damper goes increasing and at the end suddenly decreasing. At the damper height of 2.25 mm, we get maximum effectiveness. Hence the above plot shows damper gives better vibration absorption up to 2.25 mm than the old damper.

TABLE V

Effectiveness calculations

Damper (mm)	Accl. after (m/s^2)	Accl. After (m/s^2)	Effectiveness of Damper
0.5	0.00405125	0.0003911	0.09654797
0.75	0.00405125	0.0004911	0.12123171
1	0.0036597	0.0005903	0.16131524
1.25	0.00315648	0.0006907	0.21884662
1.5	0.00397464	0.0007908	0.19897902
1.75	0.00387534	0.0008901	0.22969847
2	0.00354	0.0009048	0.2556116
2.25	0.0033287	0.0015168	0.45569441
2.5	0.00401564	0.0014018	0.34910343
2.75	0.00400259	0.0010056	0.25124675
3	0.00548645	0.0009541	0.17390461

VIII. CONCLUSION

It is concluded from a survey of the industry, major failure mode of engine crankshaft damper. The following conclusion has been drawn from the theoretical, software work & experimental Work:

We have successfully found the Failure Investigation of Damper in Engine due to uneven load distribution. Uniform Load distribution observed in modified crankcase having additional 2 Bolts in the vicinity of the damper. We have successfully optimized the shape of the crankshaft damper. Damper compression v/s Load carrying capacity for a new proposal is nearly the same. Actual experiment for compression percentage of damper under specific stacks up along with to check for No damage to have happened for Engine Endurance test.

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