Identifying and Studying Various Approaches for Analysis of Crankcase

A state-of-the-art Review

Gouthami S. Tulasi*(Author)*
PG Student, Department of Mechanical Engineering
JSPM's Rajarshi Shahu College of Engineering
Tathawade, Pune, Maharashtra, INDIA
gouthamitulasi18@gmail.com

S. M. Jadhao*(Author)*
Assistant Professor, Department of Mechanical Engineering
JSPM's Rajarshi Shahu College of Engineering
Tathawade, Pune, Maharashtra, INDIA
smjadhao@gmail.com

Ramesh Dandage *(Co-Author)*
Student, Department of Mechanical Engineering
Walchand College of Engineering
Sangli, Maharashtra, INDIA
rameshdandage@gmail.com

Abstract—The main objective of this paper is to critically review various papers related to analysis of crankcase and study the different approaches. The paper critically examines 7 different papers related to analysis of crankcase. The study is aimed at identifying the methodology of crankcase analysis. This feat has never been attempted, owing to unavailability of adequate research material.The review of various papers revealed the techniques adopted in modelling and analyzing the crankcase under static, dynamic, fatigue and material conditions. This research is just the comparison of different model used for analysis. The paper provides an insight for active researchers in the field of engine design. Crankcase being the most critical component for the engine, its failure at any moment is unacceptable and needs to be detected and attended at an early stage. The review will thus help to devise the design process cycle.

Keywords*-crankcase; FEM; static analysis; dynamic analysis; experimentation; material*

*****

I. INTRODUCTION

In an internal combustion engine of the reciprocating type, the crankcase is the housing for the crankshaft. It can be moulded as a part of the block, or bolted on separately. The enclosure forms the largest cavity in the engine and is located below the cylinder(s), which in a multi cylinder engine are usually integrated into one or several cylinder blocks. A crankcase often has an opening in the bottom to which an oil pan is attached with a gasket bolted joint. Crankcase designs fully surround the crank's main bearing journals. Crankcases have often been discrete parts, but more often they are integral with the cylinder bank(s), forming an engine block. Nevertheless, the area around the crankshaft is still usually called the crankcase. Crankcases and other basic engine structural components (e.g., cylinders, cylinder blocks, cylinder heads, and integrated combinations thereof) are typically made of cast iron or cast aluminium via sand casting. Studying crankcase is critical from point of engine design. Any scope for weight reduction in an engine can be achieved through crankcase material optimization. But at the same time this component's failure is highly unacceptable. This review is about identifying the methods used for crankcase analysis. The research is unique, as so far analysis from crankshaft perspective has been carried out extensively but what happens to the crankcase has been ignored. Crankcase can be considered to be sturdy as most engine failures are due to crankshaft fracture. But the fatigue life of crankcase needs to be evaluated as its failure would render the complete engine out of service.

II. CRITICAL AND SYSTEMATIC REVIEW OF METHODS

Alexandre Schalch Mendes, Emre Kanpolat and Ralf Rauschen[1]preforms durability analysis considering conventional methodologies of dynamic simulations for the crankshaft and quasi-static simulations for the crankcase at the main bearings regions. These tests resulted in cracks at flywheel side in a fillet area close to the main bearing cap which were due to the bending vibrations of the crankshaft. As an adaptive solution a steel plate ladder was introduced at the bottom of the crankcase to increase the stiffness of the main bearings, thus reducing the stress amplitudes at the fillet area. This study considered a simulated in-line 6 cylinder engine of 180 bar peak cylinder pressure and a hybrid simulation was performed. The research deals with crankcase analysis in two conditions with and without steel plate ladder at the bottom. Elastic Multi body simulated model is developed for finding the response of the system to excitation caused by combustion and inertial forces of rotating and reciprocating masses. The methodology for hybrid simulation is shown in figure 1.

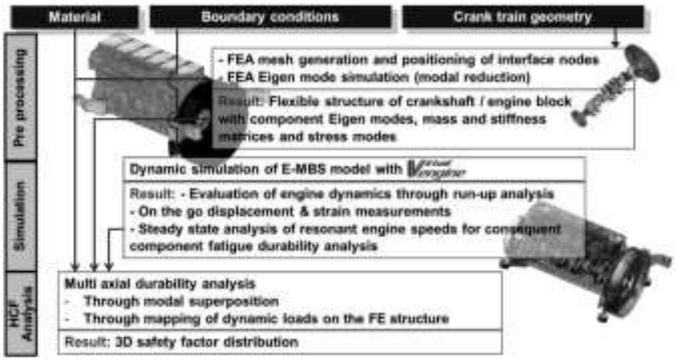

Figure 1: Methodology for hybrid simulation

At Peak Cylinder pressure the dynamic response of the crankshaft is known to introduce higher forces on the main bearings affecting the fatigue strength of the crankcase. The durability study is performed on FEMFAT for a modelled material at engine critical speed of 2200 rpm. The material is created based on the experimentally determined bending fatigue strength and material classification utilizing the FEMFAT material generator with FKM principles. From analysis the most critical location is identified to be crank pin fillet at flywheel side. For crankcase structural analysis, the dynamic loads which were computed during steady state E-MBS simulations at the main bearing shells are considered. These loads are then transferred to the second FE model where the stresses at predefined time steps are evaluated and considered for the subsequent fatigue analysis. For model without ladder frame two load cases representing the minimum and maximum peaks of the engine cycle were studied and stress was calculated from quasi-static simulation which gives only tensile stress in the fillet area.

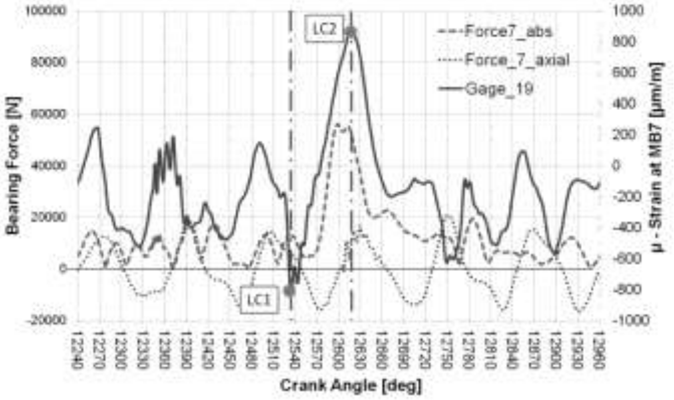

Figure 2: Strain variation at critical area of the crankcase for MB7 at 1500rpm (without ladder frame)

When a 430 hour engine test was performed at full load, condition the crankcase showed failure in the test bed which coincided with the theoretical durability analysis. This is the part of full dynamic study for an engine without ladder frame.

Figure 3: Crack at main bearing (flywheel side)

With resonant engine speed being changed from 1500 rpm (without frame) to 1550 rpm and 2200rpm (with frame) new dynamic simulation was carried out with minimum and maximum strains at critical areas for main bearings under 4 load cases, 2 for each rpm.

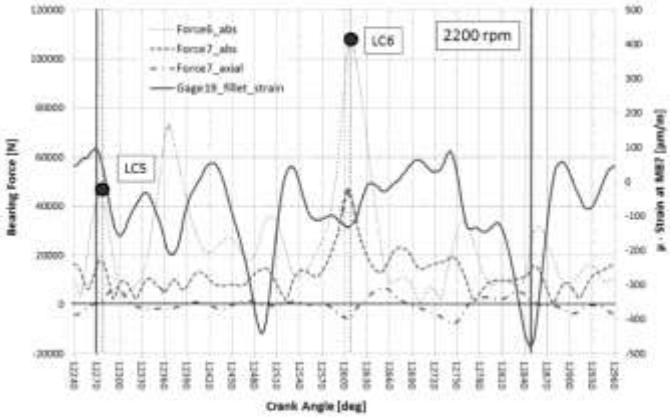

Figure 4: Strain variation at critical areas of the crankcase for MB6 at 2200rpm (with ladder frame)

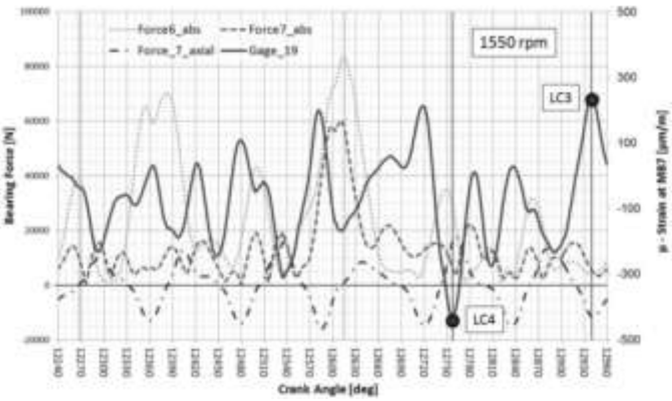

Figure 5: Strain variation at critical areas of the crankcase for MB7 at 1550 rpm (with ladder frame)

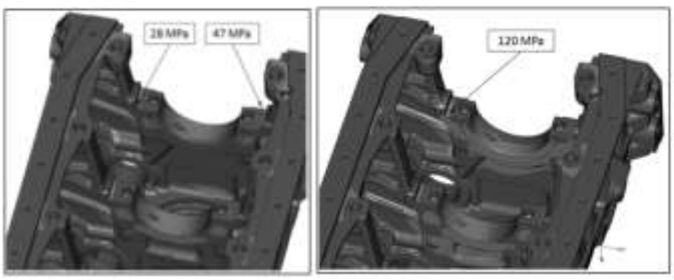

Figure 6: Maximum principle stress at main bearing for load case 3 and 4 respectively

When the same full dynamic study was performed on a crankcase with ladder frame the fatigue design margin was seen to be elevated by 96%.

Thus the study showed an effective usage of hybrid dynamic simulation to detect the fatigue crack issues and solve a crankcase-crankshaft coupled model with high accuracy.

Abhijit Londhe and Aparajita Sen [2] in their paper - A Systematic Approach for design of engine crankcase through stress optimization, discussed procedure adapted to design a low weight crankcase without comprising the strength and durability. The process is carried out in two phases first being optimized concept design and next prediction of FOS for the conceptual model. The author has explored the crankcase for the purpose of study and divided into regions specific to each discipline. The fields of study are thermal management, NVH and durability.

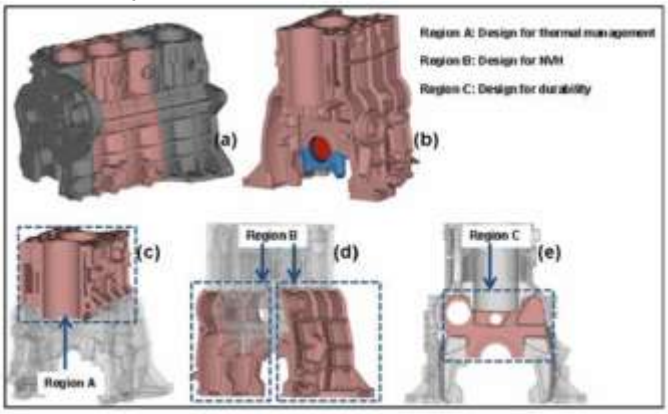

Figure 7: Crankcase design divided as per different disciplines

Region A that houses the cylinder block has mechanical load exerted due to bolt load and block assembly and is subjected to increase in temperature during operation. Region B is the skirt of the engine crankcase, the source of noise. Region C is the main bearing wall of the crankcase, a region susceptible to fatigue failure during durability tests. Since the influence of change on regions A and B will affect region C negligibly, hence the author has considered only region C for testing. The existing design process is based on experience but the author intents to change the process to first time right design. For the procedure a 4 cylinder 4 stroke diesel engine has been selected. The load distribution is considered to be asymmetric. A stress based optimization is carried out for designing the region C that has the required dynamic strength and the required fatigue factor of safety considering the gas load acting on the engine. For the purpose of analysis the model has been divided into design volume and non-design volume.

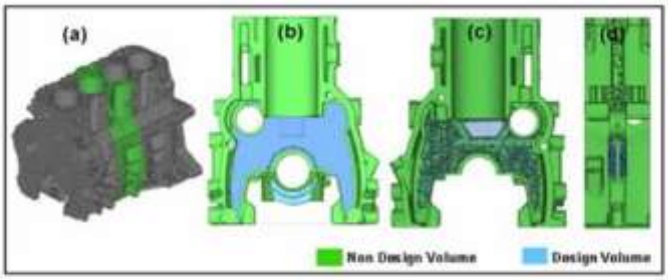

Figure 8: Division of model into design volume and non-design volume

The non-design volume has been specified as journal bearing area, bolt bosses, crankcase wall, and cylinder block region and oil galleries. The assembly is constrained at the top deck in all degrees of freedom and symmetric boundary conditions were applied along the cutting plane. Gas load applied was sinusoidal. The worst loading conditions were taken care by considering reaction loads at the mounting locations and reaction forces at the cam shaft for iteration 2 along with gas load.

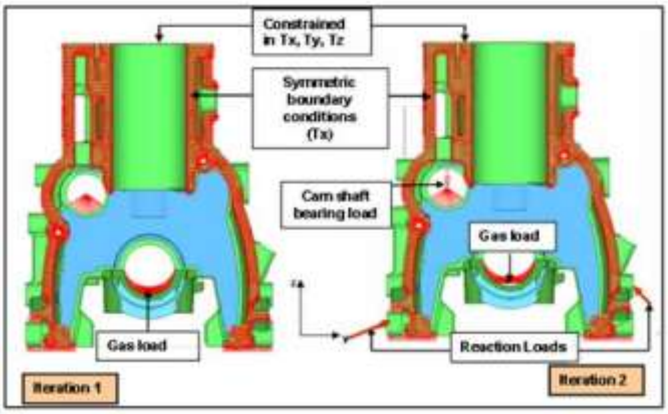

Figure 9: Loads and boundary conditions

Optistruct solver was used to find the optimal material distribution. Maximum material concentration was seen along the load path i.e. the bolt axis. The critical stress region coincided with the maximum material region along the load axis. On comparing the existing and optimized design the researchers found a decrease of 1.2 kg. But the durability needs to be analyzed hence the fatigue strength of both the models were evaluated. For the procedure, the main tool used was Abaqus. Contact between interfaces was established simulating load transfer between components like bolt head-bearing cap, bearing shells-bearing cap, bearing shells-crankcase, crankshaft-bearing shells and bearing cap-crankcase. The loading conditions include bolt load, shell interface along with gas load while the boundary conditions remain similar to previous iterations. The stress amplitude and the fatigue factor of safety are both governed by the fluctuating gas load. Comparison of the existing and modified model show significant reduction in stress due to gas load.

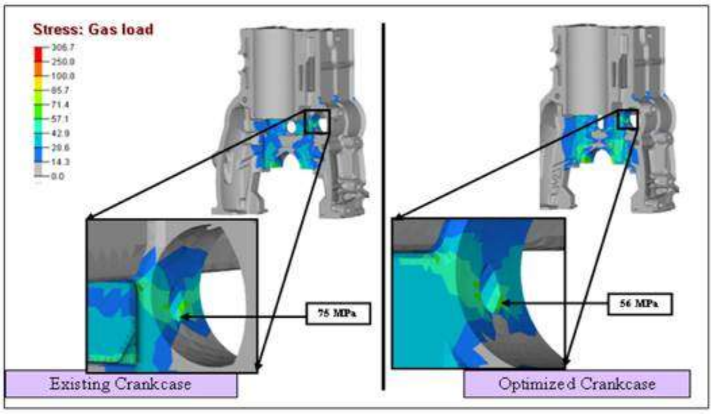

Figure 10: Stresses predicted by standard analysis procedure using Abaqus.

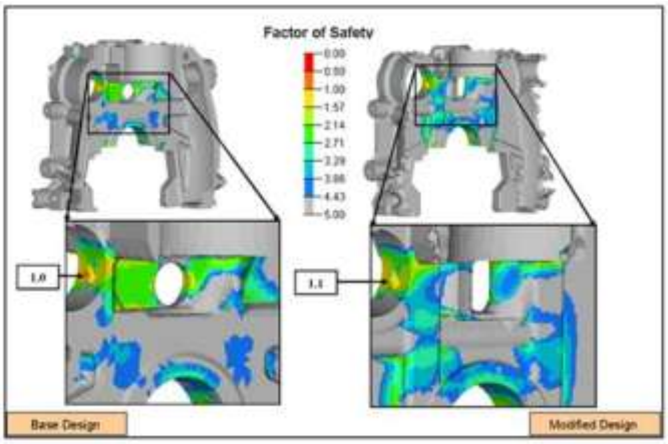

Figure 11: Comparison for fatigue factor of safety for crankcase.

The durability cycles calculated by considering the worst service conditions have been multiplied to the load case.

The author here shows that the result from durability analysis gives higher factor of safety for the new model, thus eliminating the need for design iterations and proving the theory of first-time right result.

A crankcase failure incident was observed in an on-road endurance test of scooter engine by **K. Sriram, R. Govindarajan, K. Nagaraja, Ravi Kharul and N. Jayaram[3]** of TVS motor company ltd. The author says to have been motivated to take up the research after examination of a component subjected to endurance test which revealed crack formation as shown in figure.

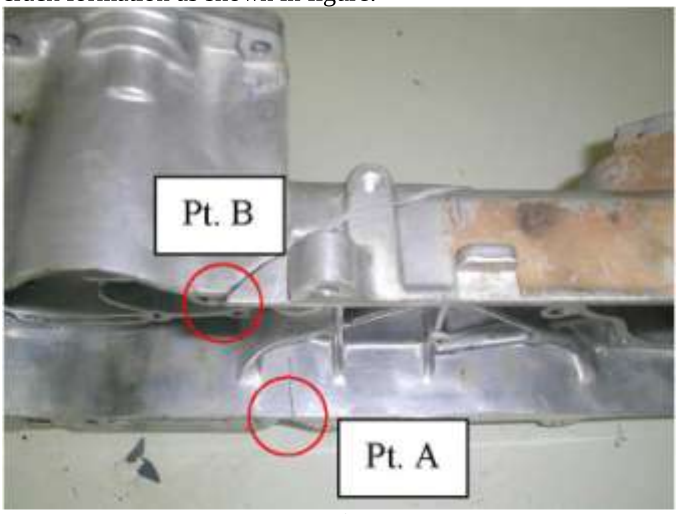

Figure 12: A typical crack formation in the crankcase

To address the issue FEM techniques were applied to investigate the stress fields in the region of crack formation. The authors here considered unit static load acting in the stress fields due to unavailability of direct methods to evaluate actual dynamic load value. They created a solid Pro-E model meshed with tetrahedral elements and analyzed in ANSYS.

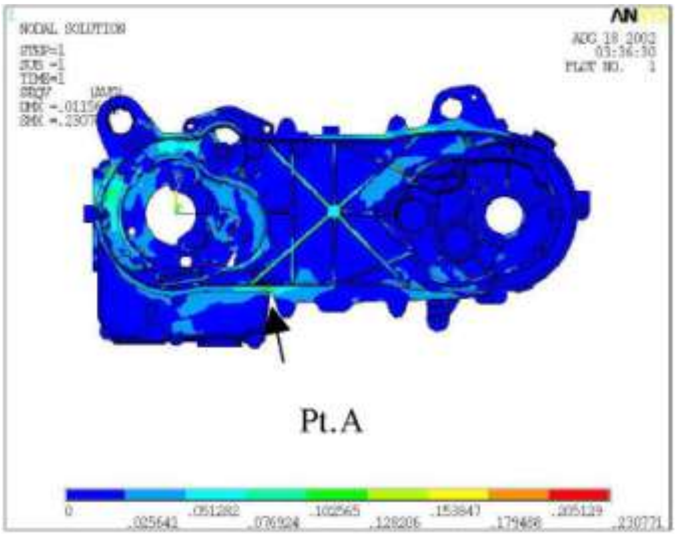

Figure 13: Stress contours in the region surrounding Pt. A in the initial design.

In order to substantiate the FEM results, an experimental set up was developed to subject a sample crankcase to the same type of static loading used in the FEM simulation The experimental set up consists of a fixture fitted to a uniaxial tensile machine to create an insitu condition for the crankcase.

Figure 14: Experimental set up for static load.

The formation of crack in the experimental sample is similar to that of the crankcase that failed in the road endurance test. A new accelerated dynamometer crack test has been developed to simulate the road conditions in the laboratory. In this test, specially designed bumps fixed to the dynamometer drum, apply periodic loads on the rear wheel of the scooter, thereby subjecting the crankcase to fatigue load. The bumps were designed in such a way that they produce loads along all the three co-ordinate axes, in the proportion of their occurrence in field. The crack developed in the crankcase as a result of this test is similar to the crack developed during the endurance test as well as the static test. The design was optimized by adding rib pattern to the crack initiation area which increased cracking resistance four times in comparison to the initial design. The stress in the final design is reduced by around 75% with 8% increase in the mass of the crankcase.

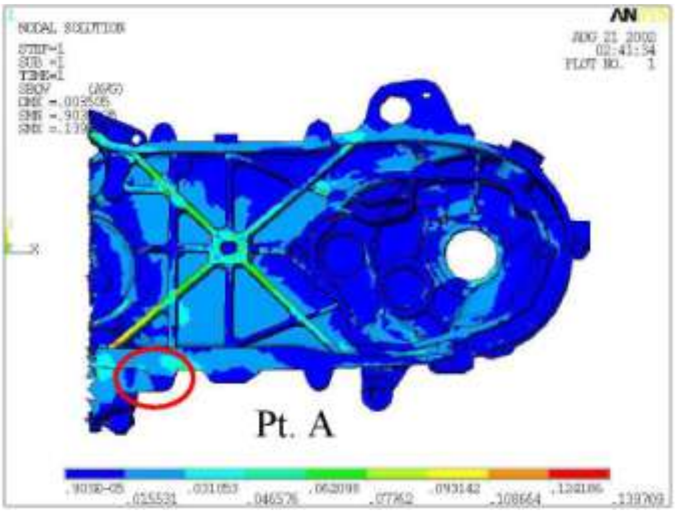

Figure 15: Close-up view of the stress contours near Pt. A in the final model

This was validated using dynamometer dynamic test and static test where in the design was known to survive for 2500 km as opposed to 600 km at which the initial design had cracked.

Here, the analysis of crankcase has been performed on ANSYS and results are evaluated through experimentation. The most significant point here is the reduction in process cycle, the component before manufacturing is being tested virtually and its validity is checked and design modifications if any are done at an early stage without the production process being affected.

Stefano Cassani[4], in his paper on High Performance Motorbike Engine Block Structural Calculation contains an in-depth analysis of the stresses exerted on the crankcase of a Ducati 999 by its engine. The engine used here is twin cylinder V-engine of 999cc. According to the author the crankcase is subjected to a complex system of loads due to static, pseudo static, dynamic actions. Firstly, static stress exists due to the nature of the assembly. Dynamic stress is then exerted by the crank mechanism as a result of the pressure of the mixture and the inertia of the moving parts. There are the pseudo-static loads due to the thermal gradients which occur in the heating of the lubrication oil. As we know, in the internal combustion engine, the combustion of the mixture is the fundamental energy source which imparts motion to the crank mechanism and transmission. During the engine's thermodynamic cycle, the pressure of the mixture in the cylinder varies continuously. An initial study of the kinematic properties of the crank mechanism was conducted in order to find out piston position, its velocity and acceleration. The inertia force was also determined along with centrifugal and tangential force produced due to the crankshaft motion. To calculate the loads transmitted to the engine block, all the forces were placed in the middle plane of the engine by adding the transfer torque and were evaluated considering a constant engine rotation speed. The results of the analysis were plotted with the help of MS Excel Data Sheet, which showed that during the engine cycle the forces transmitted to the heads and to the main bearings reach their maximum at the moment of the two explosions, while the forces on the cylinders reach a peak when the con-rod and the crank are orthogonal.

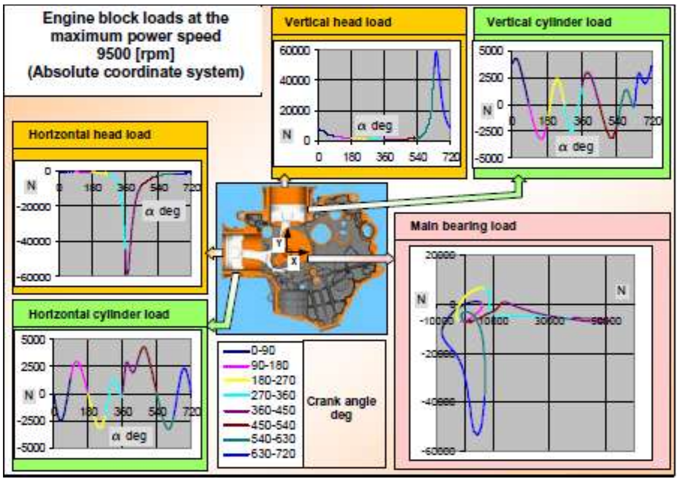

Figure 16: Loads acting on the engine block at the different engine speeds.

When experimentally validated the kinematic and dynamic properties and the corresponding forces transmitted to the engine block were known to change by less than 6 percentage points. Starting from the engine block geometry, a plane model was defined which would make it possible to describe its behavior faithfully. The forces exerted by the crank mechanism on the main bearings, on the heads and on the cylinder, mainly stress the sidewalls, which react similarly to drilled plates. Thus the average wall thickness was chosen from the CAD model; this was adopted in a plate with the external profile of the crankcase. The tool used here was PRO-E and then the component was imported to ANSYS. After producing the model, several numerical simulations were conducted by applying the load conditions at various crank mechanism configurations. The plane model was subjected to two critical conditions corresponding to the combustion in the two cylinders.

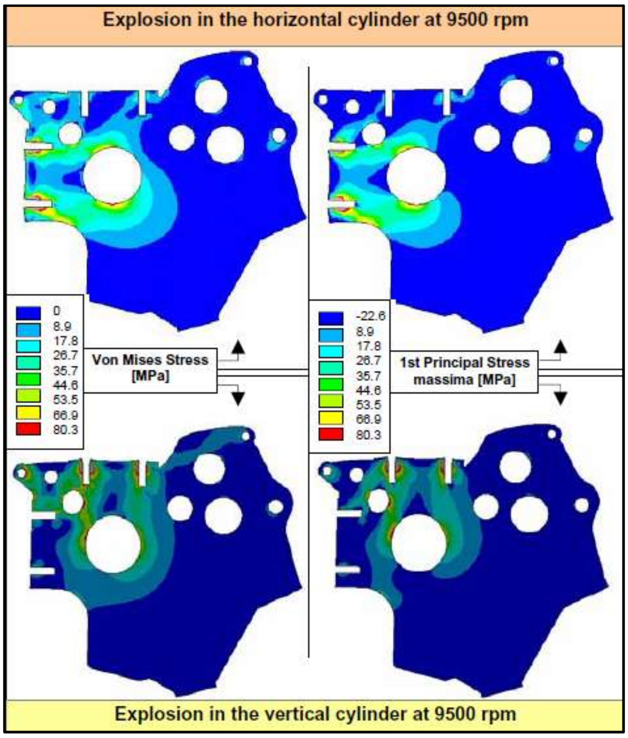

Figure 17: Von Mises stress and 1st principal stress field during the explosion in the horizontal cylinder (on the left) and the combustion in the vertical cylinder (on the right) at 9500 rpm

The stress concentration factor at the inner edge of the two holes where the maximum stress occurs was obtained by calculating the reference stress by means of a crankcase model without holes. Fracture mechanics of the plane model was studied by importing it into FRANC2D where the boundary conditions were defined from the previous simulations. FRANC2D predicts the direction in which the crack will propagate: the direction of the maximum hoop stress around the crack tip was used; it was found to be very close to the direction of the maximum strain energy rate and to the direction of the minimum strain energy density. The author has also built a three-dimensional FEM model using the tetrahedral finite element SOLID 95. The forces deriving from the behavior of the crank mechanism and from torque transmission to the gearbox were distributed over the nodes of the crankpin external surface, with constant axial and sinusoidal distribution in a circumferential direction.

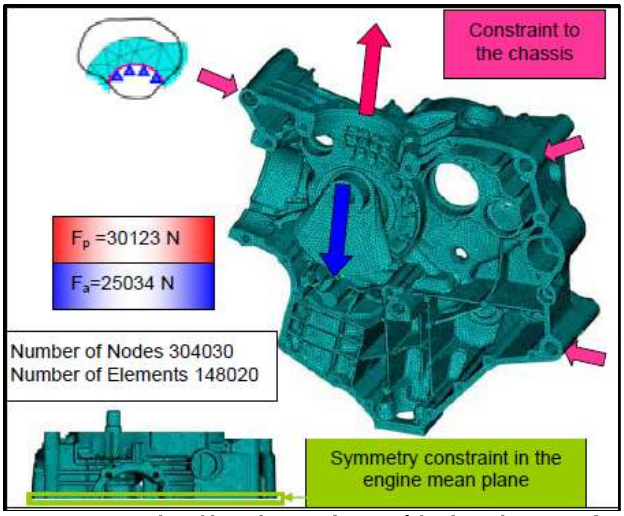

Figure 18: Mesh and boundary conditions of the three-dimensional FEM model

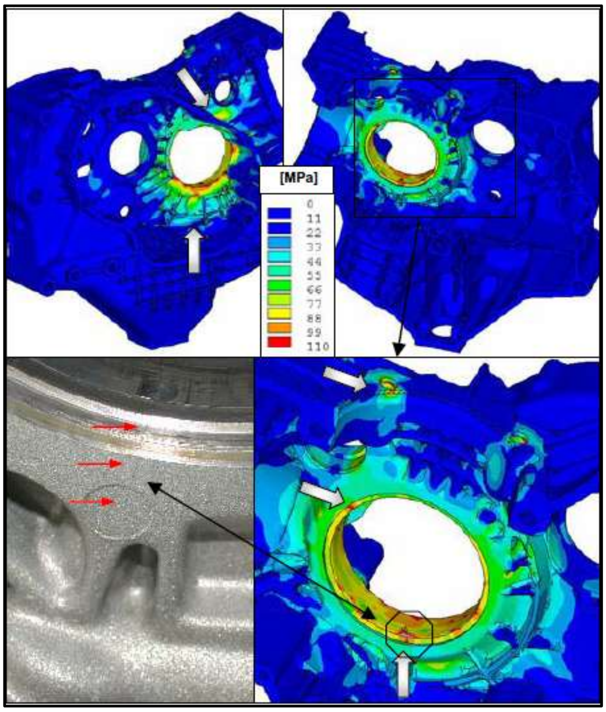

Figure 19: Von Mises stress field of the clutch half crankcase during the combustion inside the vertical cylinder at 9500 rpm (on the right) and the bench test failure (on the left)

The numerical analysis gave a line of force flow very similar to that of the plane model: the maximum stresses occur in the clutch sidewalls, in the stud connecting regions and near the main bearing. A small bench was built to reproduce the critical condition, by simulating the explosion in the combustion chamber by means of an oleodynamic system.

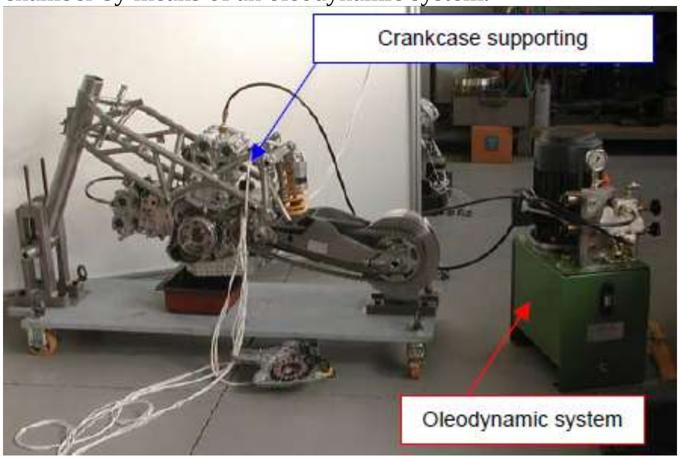

Figure 20: Experimental setup

Final verification of the numerical calculation was achieved in the bench test at the Ducati Engine Testing Service, which measured the crankcase strains in the engine running at 3,500 to 10,500 rpm.

The approach of using MS Excel Data sheet for engine parameter calculation and data plotting to find the engine performance characteristics is unique. The author can be highly appreciated for developing such detailed methodology of exploring stresses acting on engine through dynamic analysis and fracture mechanics.

Stefano Cassani, Simone Di Piazza [5] in their paper on Ducati 999 Crankcase Strength Increase by Changing the Main Bearing Type suggests strengthening of engine block sidewalls in order to improve the reliability of the component. The history of the motorbike shows that in the quest for higher performance, rolling bearings were preferred to plain bearings: the rolling friction causes lower resistant forces in the coupling of the different components. Moreover compared with rolling bearings, sliding bearings need both a greater amount of lubricant and more work for oil delivery: the oil pump causes a further power loss. But the oil pumps are now known to be much more efficient and only contribute towards minimal engine power losses. So the scope for using sliding bearings is revived. The purpose of this study is the FEM calculation of the stress field in the rolling bearing crankcase and in that with plain bearings during critical working conditions in order to verify if the reduction in hole-size offers increased strength in the sidewalls, which are currently the critical areas for the component. The geometry of the rolling bearing crankcase was obtained in Ansys 8.0, directly importing the original one from Pro Engineer R2002i2.

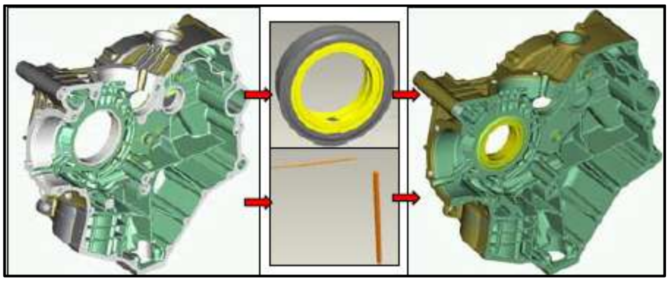

Figure 21: Definition of the sliding bearing crankcase numeric model starting from the rolling bearing crankcase one.

The three-dimensional model of the sliding bearing crankcase has the same features as the rolling bearing one except for the addition of some final operations to obtain a different structure in the main bearing housing. The second step is the numeric study that investigates the effects of the main engine loads which are the static loads developing in the assembly of the plain bearings, the rolling bearings andthe bearing holder bushes and the dynamic actions due to the crank inertia and the combustion of the air/fuel mixture. Applying the same load system of 38000 N and 30000 N(the first being applied on the crankshaft and the second is distributed on the nodes of the upper surface of the chamber respectively) in both the simulations is equivalent to assuming the same pressure cycles in the two types of crankcase while changing the engine speed. The final step is the in-depth analysis of the Von Mises stress, the maximum and minimum principal stress and the maximum shear stress.

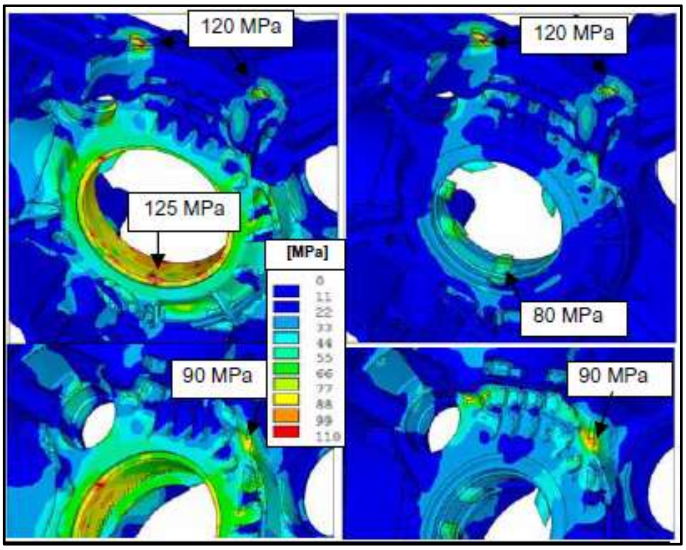

Figure 22: Details of the Von Mises stress field in the rolling bearing crankcase (on the left) and in the plain bearing one (on the right).

The stress fields in the two different configurations are calculated by the finite element method. The results obtained enable a better understanding of the engine block behavior. The sliding bearing solution reduces the stress in the region near the main bearing housing: this holds good only assuming a perfect adhesion between the steel insert and the aluminum casting. On comparing the Von-Mises plots for the rolling and plain bearing, it has been seen that the stress value is more for rolling than plain bearing. In this analysis thermal loads have not been considered, but these are known to play an important role in determining the worthiness of the bearings. Moreover plain bearings produce more energy losses than rolling. Hence the study in this paper leaves an open question for research whether or not plain bearings should be preferred over rolling bearings.

This paper is about finding an alternative for rolling bearings, in order to reduce the bearing hole-size for increasing the crankcase wall strength. So far in the research only static analysis has been conducted on rolling bearing and plain bearing crankcase and the results have been compared. Crankcase showed significant strength improvement in case of plain bearings. The effectives of plain bearings need to be evaluated from thermal perspective as well.

Hiroshi Kuribara, Junya Saito, Hidei Saito, Daisuke Sekiya[6] developed a technology that uses FEM analysis to theoretically evaluate the fatigue strength of the entire crankcase, including the internal thread portions of the main bolts. A characteristic issue with aluminum crankcases is fatigue fracture in the engine starting from the roots of the internal threads of the fastening areas of bolts subject to high axial force, such as the cylinder head stud bolts and the crankshaft main bearing fastening bolts.

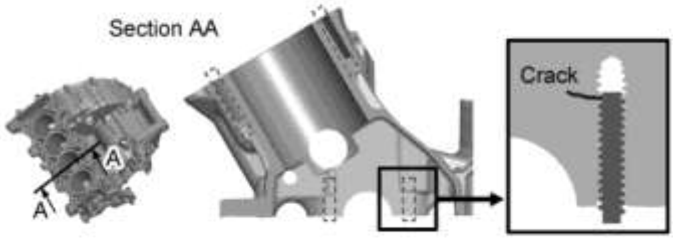

Figure 23: Location of starting point of fatigue fracture at internal thread

Three processes were used to develop the technology, an FEM model for stress analysis of the bolt fastening area, an FEM model for entire crankcase stress analysis, and a method for calculating the fatigue safety factor. To establish FEM stress analysis model for bolt fastening area initially direct measurement of strain was performed and then stress analysis of the root was conducted. When the results were compared, it was seen that high tensile strain is generated at the roots of the internal thread where thebolt external thread is engaged. Again the same procedure was repeated for external thread strain measurement and concluded that strain increases from the start to the end of bolt engagement, but strain temporarily dropswhen external thread engagement ends, and the strain reachesa maximum value where the bolt is not engaged.

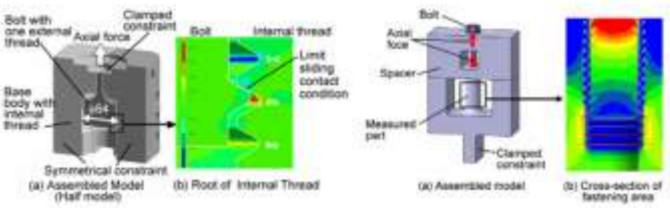

Figure 24: FEM model for strain analysis at root of internal and external thread respectively

Later a FEM stress analysis model was whole crankcase was generated.

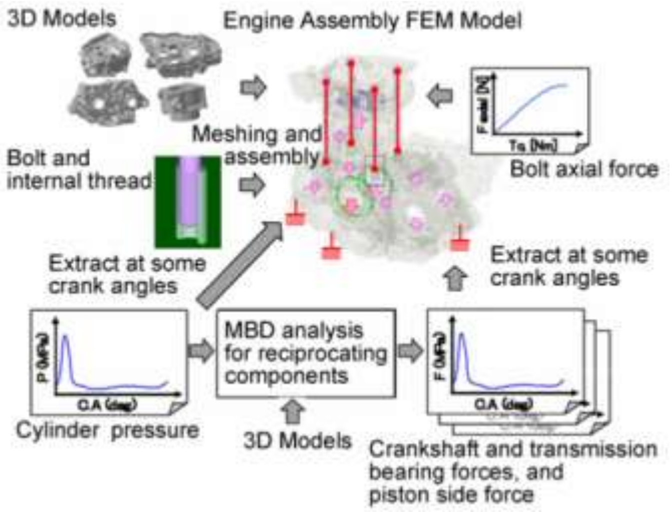

Figure 25: Stress analysis model for entire crankcase

Strain generated in the engine assembly process and due to internal force excited by cylinder pressure and bearing loads are considered in particular as they affect the internal thread root stress distribution.

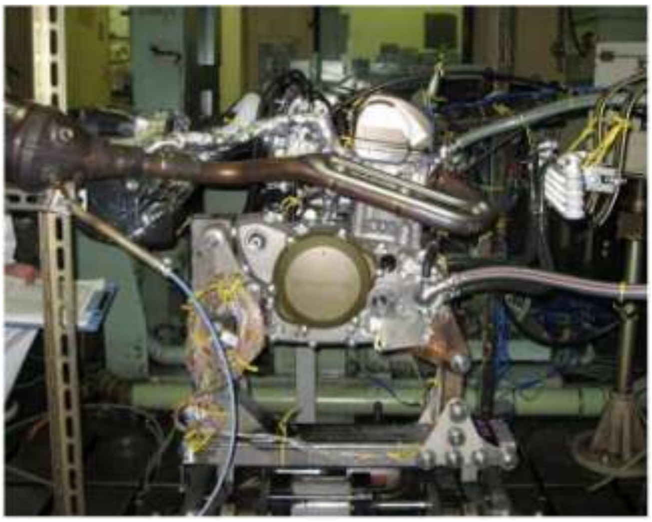

Figure 26: Engine used to measure strain when assembled and under operating conditions

Verification of stress analysis was performed parallel subjecting to the same test conditions and strain was measured experimentally by attaching strain gauges at six critical locations for which the results were found to be practical in terms of both calculation accuracy and accuracy time.

This paper is a technological development to predict the fatigue strength in roots of the thread for crankcase, by evaluating the stresses through an entire crankcase FEM based model and verifying them through experimentation using strain gauges.

G.A.Bhosale, Dr. V.V.Kulkarni [7] in their paper on failure analysis of crankcase for single cylinder, have performed the failure investigation from perspective of material chemical composition. Visual inspection with naked eyes and microscopy showed that the main cracks propagated axially along the flywheel location surface and its opposite surface.

Figure 27: Crankcase visual inspection

It is found that, the cracks occur near crankcase hole where the crankshaft is supported with the help of bearings. The chemical composition of the material from failed crankcase of single cylinder four stroke high speed diesel engine, by using a spectroscopic metal analyzer is reported. A microstructure analysis was carried out which required determination of morphology, crystal structure and elemental composition. Hardness test was performed using Vickers and Brinell hardness machine. The results showed that Carbon and Silicon content of the crankcase material is on higher side than that of the technical specification. It causes material to become more brittle. Also the type of graphite distribution increases the brittleness adding to the undesirable feature of the material of crankcase.

The paper hereby studies the material aspects of crankcase and determines the reasons for failure initiation and nature of cracking through chemical analysis and microstructure study respectively.

III. CONCLUSION

The point to be highlighted from review is any simulated dynamic analysis is incomplete without experimentation. Through experimentation the crankcase failure location has been ascertained. In most crankcases the crack seem to be initiated from main bearing side i.e. flywheel mounting end of the crankcase. In two significant cases the crank initiation has been curbed by adding rib to the crankcase body and in one case a ladder frame addition has improved the stress distribution. One of the reasons for crankcase cracking has been detected as the crack initiation and propagation from the threaded joints. The review suggests the need for thorough stress analysis of bolted joints as they are subjected to fluctuating dynamic stresses during combustion. The crankcase has also been evaluated from material perspective. The failure for crankcase needs to be avoided at the earliest possible stage; hence changes are expected to be incorporated during initial step of the process cycle. Thereby the need for prototype manufacturing can be eliminated. This review gives a gist of the methodology that can be developed for manufacturing crankcase right from phase of idea initiation to mass production. By knowing the operational conditions that the crankcase would be subjected to and predicting its behaviour under those conditions, the designer can optimize at initial stage itself. Following is the table giving a summary of the papers.

Paper No./ Type	Key Approaches and Deductions	Select Weaknesses/ Limitations
P1. Crankcase and Crankshaft Coupled Structural Analysis Based on Hybrid Dynamic Simulation	Gives a methodology to evaluate the dynamic responses of Engine referred to as hybrid simulation, which consists of the solution of the dynamics of an E-MBS (Elastic Multi Body System) coupled with consecutive FEA (Finite Element Analysis). This method is implemented against the traditional quasi-static simulation and its merits have been shown through elevated fatigue design margins for the revised model.	Though effective the method requires hands-on training in creating the E-MBS model. The authors here have experimentally created a material and but its validation through fracture mechanics is missing.
P2. A Systematic Approach for Design of Engine Crankcase Through Stress Optimization	This paper aims at outlining a systematic approach for designof crankcase for fatigue which would eliminate designiterations for durability. FE modelling techniques were used for establishing model and then ABAQUS was used to model interfaces where loads were being transferred.	Gas load has been applied on the model under static conditions. Even the optimized model does not consider the effect of dynamic forces acting on the engine.
P3. Simulation of Scooter Crankcase Failure Using FEM and Dynamic Testing in Laboratory	Here PRO/Engineer has been used to create solid model which is then analyzed on ANSYS and the results are validated experimentally. The author intends to develop a methodology free of iterations and save time on field trials.	The forces applied here are unit static load i.e. 1KN. Even the counter measure is aimed at reducing the stresses per unit load, thus considering a linear relation between applied load and stress. The accuracy of the stress values hence plotted needs evaluation.
P4. High Performance Motorbike Engine Block Structural Calculation	Tools used here are MS-EXCEL sheet for engine parameter representation, PRO Engineer for CAD Model and ANSYS. Additionally analysis of fatigue crack growth due to material defects was made by means of FRANC2D. The results were validated through Oleodynamic system which simulated the actual gas conditions	The method is extensive and requires high investment.
P5. Ducati 999 Crankcase Strength Increase by Changing the Main Bearing Type	In order to improve the crankcase reliability, the sidewalls housing the main bearings need to be strengthened. To serve the purpose the DUCATI crankcase has been thoroughly studied through modelling in Pro Engineer and analysis in ANSYS	The study ends without concluding whether plain bearings or rolling bearings are better. Both having their pros and cons are needed to be evaluated for thermal stresses.
P6. Establishment of Prediction Technology of Fatigue Strength in Roots of Internal Thread for Crankcase Assembly and Clarification of Cracking Mechanism in Roots of Internal Thread	Research establishes the method to evaluate fatigue strength of the entire crankcase including the roots of internal threads using a large-scale and nonlinear finite element method (FEM)analysis	Details of dynamic analysis performed are missing. Only static forces are considered for stress analysis to evaluate fatigue strength.
P7. Failure Analysis of Crankcase for SingleCylinder High Speed Diesel Engine	Investigation is carried out through visual inspection, chemical composition analysis, microstructureexamination as well as hardness determination	Crankcase is not evaluated through FEM analysis. The failure is investigated only from material perspective, static and dynamic forces acting on the engine are not considered.

FUNDING STATEMENT OR DECLARATION OF CONFLICTING INTERESTS

THIS RESEARCH RECEIVED NO SPECIFIC GRANT FROM ANY FUNDING AGENCY IN THE PUBLIC, COMMERCIAL, OR NOT-FOR-PROFIT SECTORS.

REFERENCES

[1] Alexandre Schalch Mendes, Emre Kanpolat and Ralf Rauschen, "Crankcase and Crankshaft Coupled Structural Analysis Based on Hybrid Dynamic Simulation" *SAE International Journal Engines* Volume 6, Issue 4, December 2013.

[2] Abhijit Londhe and Aparajita Sen, "A Systematic Approach for design of engine crankcase through stress optimization" Mahindra & Mahindra Ltd, A.S, Nasik, *SAE International Journal,* 4 December 2010.

[3] K. Sriram, R. Govindarajan, K. Nagaraja, Ravi Kharul and N. Jayaram, "Simulation of Scooter Crankcase Failure Using FEM and Dynamic Testing in Laboratory" 2003 SAE/JSAE Small Engine Technology Conference & Exhibition Madison, Wisconsin, USA September 15-18, 2003

[4] Stefano Cassani, "High Performance Motorbike Engine BlockStructural Calculation", University of Bologna, *SAE International,* 11April 2005.

[5] Stefano Cassani, Simone Di Piazza, "Ducati 999 Crankcase Strength Increase by Changing the MainBearing Type", *SAE World Congress Detroit, Michigan*, April 11-14, 2005.

[6] Hiroshi Kuribara, Junya Saito, Hidei Saito, Daisuke Sekiya. Establishment of prediction technology of fatigue strength in roots of internal thread for crankcase assembly and application in product development. Honda R&D Technical Review October 2010 pp.215-221

[7] G.A.Bhosale, Dr. V.V.Kulkarni.Failure analysis of crankcase for single cylinderInternational Journal of Latest Trends in Engineering and Technology (IJLTET) (2015) 248-253.