STM JOURNALS

Trends in Machine Design
ISSN: 2455-3352 (Online)
Volume 5, Issue 1
www.stmjournals.com

Automotive Valve-Train Components Durability Analysis Using Finite Element Method Approach: A Review

Anuradha J Thakare*, Ashok J Keche
Department of Mechanical Engineering, Maharashtra Institute of Technology, Aurangabad, Maharashtra, India

Abstract
An internal combustion (IC) engine valves is poppet valves used to control the flow of air/fuel mixture in the engine and escape of exhaust combustible gases from the engine using intake and exhaust valves, respectively. Inside an engine the combustion process majorly depends on timing of Air/Fuel mixture induction and release of gases. Both Intake and Exhaust valve also form a seal between the working space inside the cylinder against the manifolds by continually opening and closing of valve according to valve timing diagram. During the combustion process, the pressure pushes the valve against the insert, sealing the chamber and preventing the leaks that are loaded by spring forces and subjected to thermal loading due to high temperature and pressure which affect the durability of the engine. In this paper, general mechanism of valve-train and its working principle are reviewed and discussed. Valve-train component exposed to various mechanical and thermal failure modes due to high temperature, thus it is important to evaluate engine valve durability using engineering analysis technique which gives a complete assessment of valve-train components. Finite Element Analysis (FEM) analysis is a technique fully capable and various modeling and simulation software such as Ansys, ABAQUS CAE, CATIA are also discussed in this paper.

Keywords: *Valve-train Components, Finite element method, Durability, Integrated CAD/CAE system*

****Author for Correspondence*** E-mail: anuradhathakare293@gmail.com

INTRODUCTION

The arrangement of different components which controls the intake and exhaust process totally depends on valve mechanism. Exhaust and intake valves are major components of an IC engine used to control the flow of air/fuel mixture in the engine and escape of exhaust combustible gases in and out of engine cylinders. In four stroke engine during suction stroke intake valve remains in open condition which allows the flow of fresh air inside the combustion chamber and exhaust valve is kept closed. In power stroke both valves remain closed. At the end of the power stroke exhaust valve gets opened to remove burnt gases from the combustion chamber. During operation, thermal and mechanical stresses, load on intake and exhaust valve due to high temperature and pressure inside the cylinder against the manifolds. Mostly the intake valve is larger in diameter than exhaust valves, because the velocity of the incoming air-fuel mixture is less in velocity than exhaust flue gases which live under pressure. There are different types of valves such as poppet valves, slide valves, rotary valves and sleeve valve.

Stress concentration, the deposition of carbon at the valve neck at high temperature and the repeated cyclic loading fails the valve and make the design complicated. Mostly the neck and tip part of the valve affected during working condition.

During engine operation a closed valve is loaded by spring force and pressure inside the cylinder, which varies periodically and reaches a peak value of 15 Mpa. Thus, due to high pressures inside the cylinder cause bending of the valve neck, which results in a sliding motion and improper contact between the valve face and insert which leads to wear failure. Automotive engine valves operate from 600 to 1200°C temperature range.

MECHANISM OF VALVE-TRAIN

In piston engines mostly poppet valves are used to open and close the intake and exhaust ports in the engine cylinder head, it is a directional control valve which is typically characterized as being a high flow, fast acting, design due to the large flow paths through the main body of the valve. The poppet valve usually opened quickly in compare to any other valve. The main components of the valve trains are valves, rocker arm, valve spring, push rod, cam and camshaft. The air-fuel mixture is released in the engine port by the intake valve and the combustible gases are monitor through the exhaust valve. The cam moves on the rotating cam shaft which pushes the cam follower and rod upwards, transmitting the cam action of rocker arm. When the rocker arm from one end is pushed up by the push rod, the other end moves downwards which pushes down the valve stem; causing the valve to move down opening the cylinder port. When the cam follower moves along the cam, the rocker arm pushes the valve which released and returns to its insert and closes by the valve spring.

During the exhaust process, the exhaust valve comes in direct contact with the combustible gases. Additionally the exhaust valves are exposed to very higher thermal overstress more than the intake valves because the incoming air-fuel mixture at atmospheric temperature cools the intake valves.

Commonly viewed situations that leads to valve failure are valve seat and face being too narrow, worn valve guide or valve stem, weak valve spring, sticking valve stem, incorrect tappet clearance, loose valve seat insert, valve guide being becoming loose in the block, valve head and stem breakage, valve head burning, deposits on the valve, etc.

FACTORS AFFECTING THE LIFE OF VALVES

Effects of Temperature

In an internal combustion engine, pressure and temperature affecting the valves varies with fuel type and the combustion characteristics which will directly effect on the life of valves. The most forced engine elements are valves working under different loads and temperatures. This is because they are stressed with rapid variations of temperature and load, and different accelerations, which vary suddenly and periodically during engine operation. In combustion chamber, valves are constantly exposed to different pressure and temperature.

According to the temperature range the behavior of material properties changes. Thermo-mechanical fatigue due to a combination of mechanical and thermal fatigue, corrosion fatigue due to cyclic loads applied on corroded materials, fretting fatigue due to cyclic stresses together with the oscillation motion and frictional sliding between surfaces, etc. Fatigue failure occurs at stresses that are well below the yield point of the material [7].

Due to valve train dynamics, internal combustion engine valves are subjected to repeated cyclic loading. Repeated cyclic loading results in material failure below the yield strength. When the material is subjected to fatigue, one or more tiny cracks usually start developing in the material, and these grow until complete failure occurs.

For the life prediction of the valve fatigue can be assessed by using many approaches such as SN method, crack growth and ∈N. Because fatigue testing is time and energy consuming, predictive methods are often used [4]. In many industries, the number of stress cycles for lifetime services are above 10^7 Cycles, The fatigue fracture are basically observed under low cycle fatigue, normally less than 10^5Cycles. The fatigue life varies usually from 10^5 Cycles to 10^7Cycles [6].

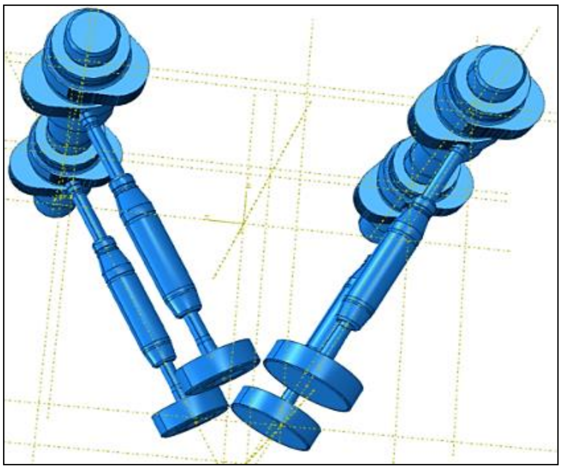

Fig. 1: *Finite Element Model of Valve-train*

Effects of Loading and Inserting

According to various literature reviewed, the exhaust valve wear occurs mainly due to two different ways. As the valve closes the valve get impact on the insert which is the first way and the another way is caused by the elastic deformation at the valve insert interface as the valve head is compressed into its insert by the high combustion pressure that is commonly known as microsliding. Wear can occur in many phases such as adhesive, abrasive, fretting, erosion, cavitations, and contact rolling fatigue [13]. Various experimental works performed also show that combustion load, valve misalignment and the valve closing velocity have a significant effect on valve face recession [9], shown in Figure 2.

Effects of Valve Materials

The materials used in manufacturing the valves are mostly different as they are exposed to various operating conditions in heavy duty engines. In case of intake valves, the valve head is cool due to the flow of air-fuel mixture over it and a low heat is transferred to valve inset due to this the material used for these valves are commonly EN-52 steel alloy various, composite materials. Actually the material used for exhaust valve should have high resistance to corrosion at the elevated operating temperatures, sufficient strength and hardness to resist tensile forces and wear, adequate fatigue and creep-strength. So the material of the exhaust valve should be chosen with precaution by considering various factors as the engine works under heavy loads, they become very hot due to high temperature and thus it is should be of high heat resistant. To avoid excessive thermal stresses coefficient of thermal expansion should be low and should have a high thermal conductivity for proper heat dissipation [9]. Exhaust valves are in general made up of austenitic steel alloys such as 21-2 N, 21-4 N and 23-8 N, Inconel-751, Pyromet 31 and Nimonic 80A for heavy duty engine operation. And in gas engines to increase hardness the exhaust valves have high levels of cobalt, nickel, iron, chromium, titanium and other elements.

Effects of Combustion Deposits

The combustion or ash deposits on the sealing faces of valves and inserts play an important role in the guttering process consisting of sulphates, phosphates and oxides of inorganic fuel and oil constituents. About 70–85% of the heat absorbed by exhaust valves during closing as the valve and valve insert came in contact with each other [9]. Therefore valves can be coated by excessive temperature and damage.

The erosion-corrosion of exhaust valves (valve guttering) is an important cause of failure of internal combustion engine valves [4]. Leakage causes valve distortion, face peening and degradation of face deposits. The accumulation of combustion deposits on valve surfaces interferes with proper inserting of the valve and leads to leakage.

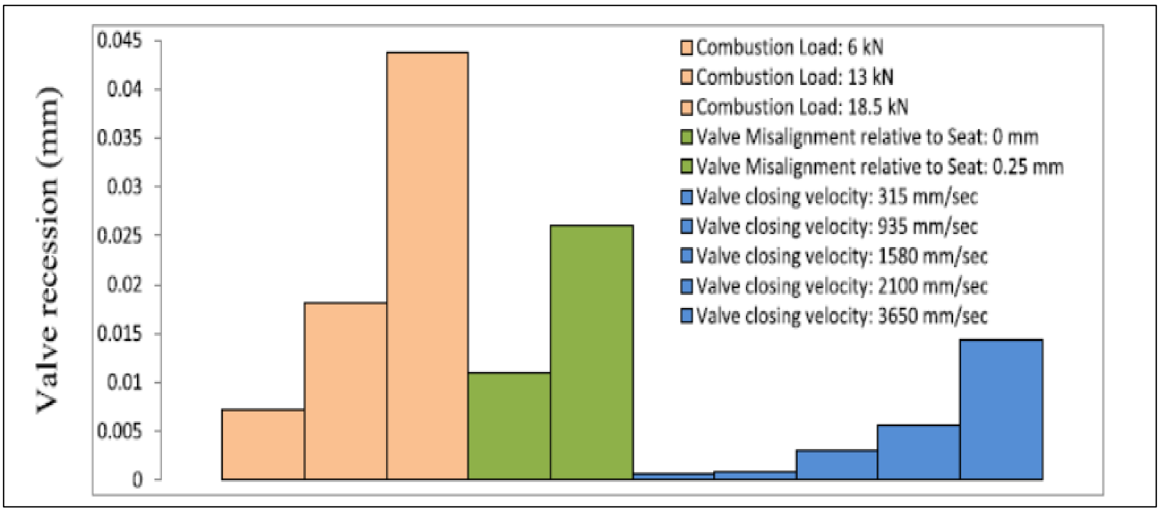

Fig. 2: *Relation of Valve Recession [9].*

Effects of Lubricant

In gas engine, methane is used as a fuel which has higher specific heat content than liquid fuels like gasoline or diesel. As methane is a natural gas, it does not cool the intake air like fuel does. This significantly affects the intake and exhaust valves due to no lubricant which requires for cooling the valves. As a result, gas engines depend on the lubricant ash to provide a lubricant between the hot valve face and its mating insert. After complete burning of the oil; the ash as the lubricant is left behind as a deposit. It is whitish-gray and comes from the metallic detergents i.e., calcium and barium and zinc additives [9].

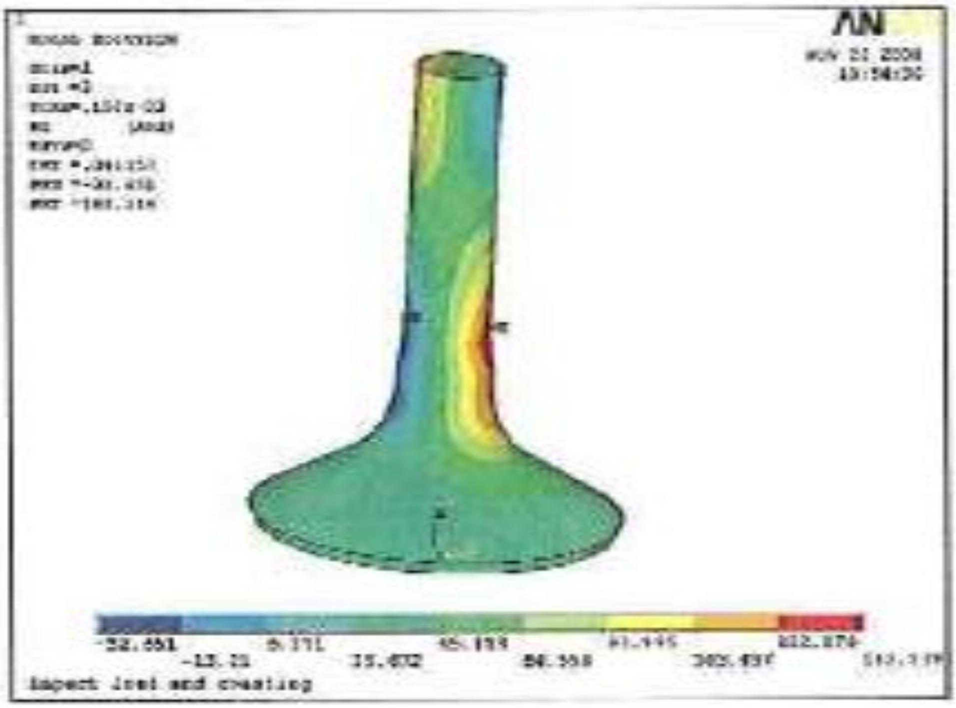

Fig. 3: *FEA Stress Analysis of the Exhaust Valve under Hot Temperature 1400*°F.

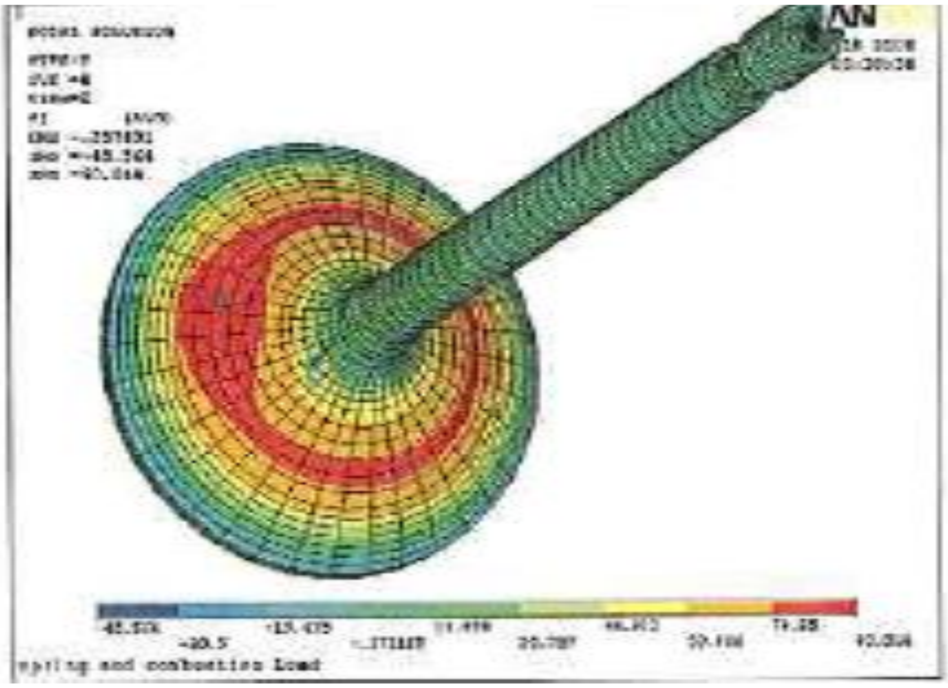

Fig. 4: *Stress Analysis on Valve Neck under Spring Load [1].*

LITERATURE REVIEW

In past limited academic and industrial research work found, conclusive one in SAE paper which focuses on engineering analysis using FEA for Regular Steel Valves. Finite element analysis method for engineering analysis and its visualization in tems of thermal and structural behaviour using CAE package considered robust procedure both in Academic way and Industrial way designed to simplifying stress analysis using engineering calculations under “maximum static loads. it is important to have analytically defined understanding of valve stresses behavior on proposed reference boundary conditions before having a balanced design based on Heat transfer and Stress Strain FEA for manufacturing feasibility.

Pang et al. proposed a stress analysis on automotive engine exhaust valve subjected to various loads. For stress analysis, EMS 222 high strength austenitic stainless steel valve material is used. In this paper, FEM were used to study the valve stress behavior under various loads from product durability cycles. The 3D nonlinear thermal, mechanical model was constructed, implicit time integration was employed in transient dynamics under an impact velocity [1].

From the results of valve stress under spring and combustion pressure load, the valve remains elastic stress state and no local plastic deformation exists at the impact point. It also finds that from FEM simulation the energy transfer during valve closing operation is mainly conservative and a linear relation exists between valve closing and maximum steam, stress.

Kanna et al. in this paper had used finite element technique to equate the material behavior of the Al-Si composites along with valve guide to correlate the relation between the valve and valve guide and the main aim is to increase the engine performance which gets reduced by the effects of heat transfer and wear rate leads to delay in valve opening and closing timing. Al-Si composite coating can be used by varying the percentage of silicon from 0 to 75% of the surface of mating zone of engine valve. The coating of 0.2 mm has been done using a vapor deposition method over the entire surface [2]. The result which has come during analysis were then investigated to optimize the best coating for IC engine valves to improve its life and resistance to wear, corrosion. And the optimization done by the author shows that the alloy of aluminum and silicon proved to have better hardness, crushing strength, higher wear resistance.

From the result from various combination shows that the percentage of silicon modified between 10 and 30% compared to the other percentage of silicon alloy. Table 1 shows the output obtained from the analysis of the engine valve proved that the Al-Si composites coating over the engine valve have the enough potential as a better material for the engine valve and engine guides.

Rao et al. in this paper structural analysis and thermal analysis is done on a four wheeler diesel engine, when the poppet exhaust valve is closed. Different ceramic composite materials are used when the steady condition is attained at 5000 cycles using finite element analysis. The various composite materials used for poppet valve are SUH 1 Steel, Alumina/Alumina composite, carbon/carbon composite, carbon/silicon carbide composite [3]. From the results, it was observed that under structural analysis the least deformation and strain are in C/SiC poppet valve and least strains are recorded in C/C composite and under thermal analysis it shows that there is no much variation in the temperature but maximum heat fluxes are recorded in C/SiC composite followed by carbon-carbon composite. Optimization shows that carbon-carbon composite is the best material for a poppet valve with minimum deformations and thermal fluxes and less stress when compared with the other materials.

Raghuwanshi et al. give a review on different failures modes by which the valves get failed by due to fatigue at high temperature, high temperature effects on mechanical properties of materials, like hardness and yield strength, due to impact loading and the wear rate that depends on load and time in internal combustion engine. And according to author this paper may help the researchers to improve the valve materials with a prolonged life through the study of fatigue life by using a combined S-N curve prepared for the fatigue failure of different materials which get compared at different high temperatures. The reason is given behind valve failure that due to repeated cyclic loading at high temperature there is decrease in hardness and tensile strength of valve material and also causes corrosion of exhaust valves [4].

Torres et al. shot peening method which is used to improve fatigue strength of materials. In this paper, four shot peening conditions are used to gain in fatigue life, the behavior of Compressive residual stress field (CRSF), crack source and local stress and crack initiation points of fatigue specimens of AISI 4340 steel were studied. Residual stress is valued for 10^5Cycles at 0.0027 A, 0.0063 A, 0.0083 A and 0.0141 a shot peening conditions are carried out. An increase in shot peening intensity resulted in an increase in maximum compressive residual stress and the width of the CRSF. However, the surface residual stress was nearly independent of the peening conditions [5]. An increase in the shot peening intensity results in increase the original CRSF size and it does not necessarily increase the fatigue life of AISI 4340 steel with 53HRC hardness. The CRSF enables a better fatigue life for AISI 4340 steel. It is very complex to determine the best shot peening condition to increase the fatigue strength because it depends on many factors.

Singh et al. in this research paper carried out the finite-element simulation of material behavior of intake and exhaust valves in internal combustion engine. Design and analysis of poppet valve using four composite materials has been done. Thermal and structural analysis was done on the poppet valve when the valve was kept closed using finite element method. From the results it is observed that Carbon/SiC is the best material for the intake valve and SUH 1 STEEL for exhaust valve [6].

Khan et al. this study presents failure analysis of the exhaust valve from a heavy duty natural gas engine. In a heavy duty natural gas engine where the valves were manufactured from the precipitation hardened Inconel-751 belonged to a failure analysis of the exhaust valve. In this several factors affecting the life of exhaust valves were discussed like temperature, valve material, loading, lubricant and various failure modes [7]. Several techniques are there to identify the root cause of failure with comparing results of a new valve. It has been found that from results obtained that there was some mechanical lapse in proper inserting of the valve which had been responsible for overheating especially at thinner sections.

Table 1: *Comparison of Properties of Cast Iron and Al-Si Engine Valves.[2]*

Valve Material	Al + Si (10 %)	Al + Si (15 %)	Al + Si (20 %)	Al + Si (25 %)	Al + Si (30 %)	Cast iron
Rockwell Hardness (HRC)	46.25	46.18	51.52	51.14	53.56	35
Radial crushing Load (KN)	19	20	23	28	32	17
Wear rate mm3/ minute	0.2497	0.1421	0.0876	0.1362	0.1218	0.1945

Table 2: *Deformation and Stress Values for Inlet Valve.*

	Suh1 Steel	Alumina/Alumina	Carbon/Carbon	Carbon/Sic
Deformation (Mm)	0.8888	0.0020	0.0068	0.0024
Stress (Mpa)	46.60	48.04	47.62	39.56

Table 3: *Deformation and Stress Values for Exhaust Valve.*

	Suh1 Steel	Alumina/Alumina	Carbon/Carbon	Carbon/Sic
Deformation (Mm)	0.0173	0.0164	0.0545	0.4444
Stress (Mpa)	199.55	206.83	205.46	201.84

Table 4: *Results based on Material (Fillet radius 12.0 mm).*

Material	Elastic Strain, mm/mm	Von Mises Stress, MPa	Allowable Stress, MPa
Carbon Steel-70	0.00027782	55.563	57.5
21-2N	0.00037999	75.998	73.33
AISI 1541	0.012128	57.955	66.67

Study of Voorwald et al. revealed that overheating had been responsible for a creep-rupture failure accentuated by precipitation of undesirable constituents at grain boundaries. Mainly the fatigue cracks initiated at the microcracks and propagated through the chrome layer, causing some small plate delamination and nucleating several cracks on the specimens reducing fatigue life. The tensile strength has also been affected by the chromium deposition and also by nitriding [8].

Mamta and Zade in this paper discussed the stresses induced in a valve due to high pressure inside the combustion chamber, spring force and the cam force for the optimization of fillet radius of inlet valves. The results obtained through static structural analysis suggest that the optimized value of fillet radius is 14 mm shows safe results and is selected for further work that is for material optimization which shows good improvement compare to allowable stresses. Material AISI 1541 shows less stress (23.74 %) compare to 21-2N with higher allowable stress and hence finally suggested for valve improvement. Overall reduction in stress is 40.78% [9].

Sanoj et al. show that thermal and structural analysis has been done on two different exhaust valve materials Nimonic 80A and Nimonic 105A. This is related to the stress induced in the valve due to high thermal and pressure inside the combustion chamber. It has been concluded from results that the displacement value for Nimonic105A is very less than the values of other material for the same thermal and structural loads [10].

Yu and Xu, in this three diesel engine valves used in a truck which failed during the service. This causes failure at the plates of the exhaust valves. Usually the plate material is made from 5Cr21Mn9Ni4N steel. This fracture surfaces were then investigated by SEM and visual observation. This paper describes a detailed metallurgical investigation and fractographic analysis on the failed exhaust valves [11]. The results shows that the cracks initiated from the off the tapered plane and the transition region of the plate and propagated toward the bottom of the valve for two failed exhaust valves.

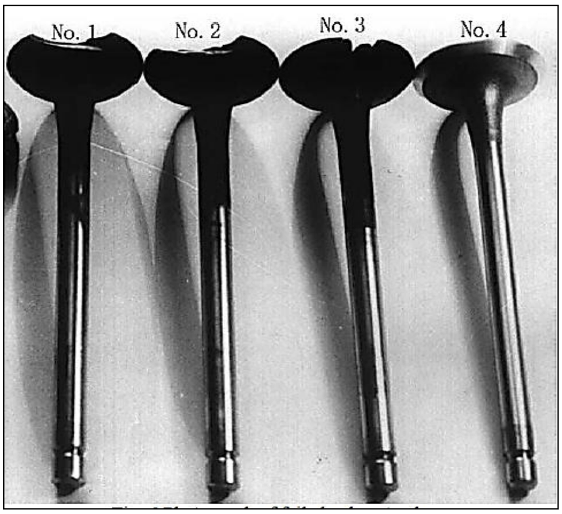

Fig. 5: *Specimens of the Failed Valves no. (1,2,3) and New Valve (4).*

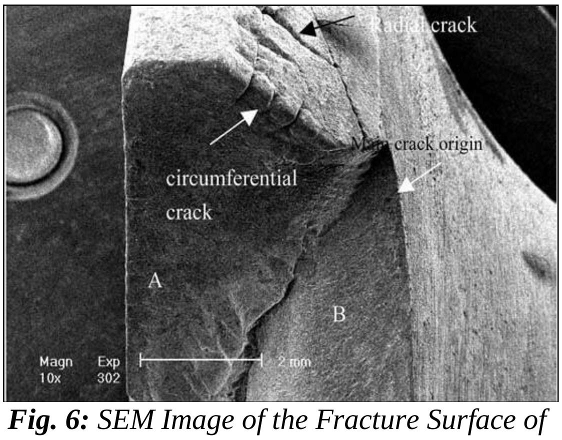

Fig. 6: *SEM Image of the Fracture Surface of Valve no. 1.*

Scott et al. in this review involve (a) the effect of lubricant additives on the formation of exhaust valve deposits and (b) the effect of valve deposit morphology and composition on the erosion-corrosion of valve seat surfaces. In order to study the potential effects of oil ash chemistry, experimental, all-calcium and all-magnesium formulations were explored. Testing with calcium-containing engine oil resulted in the formation of deposits rich in calcium sulfate (CaSO), and catastrophic failure of several exhaust valves [12]. Calcium sulfate was the primary constituent in deposits removed from valves run on oil containing an all-calcium detergent. Magnesium zinc phosphate was the primary constituent in deposits removed from valves run using all-magnesium-detergent oil.

Chun et al. stated the average Rmax of the exhaust valve seating face and insert seating surface and the tendency of the wear mechanism according to the cycle. Numbers (mileage) and hertz (rpm). This study was performed to improve the performance of the valve and insert by examining the relationship between the causes of wear, average Rmax and wear mechanism [13]. The cycle numbers for tests were 2×10^6, 4×10^6, (350◦C), $6\times10^6$and 8×10^6, and the test speeds were 10 and 25 Hz. All other parameters here such as temperature, fuel (LPG) and load (1960 N) were kept fixed. In this an optical laser scanner was used to measure the Rmax of the valve seating face and seat insert seating face. Figure 6 shows that as the number of cycle increases; the average Rmax of the valve and insert seating faces increase linearly. The Hz (RPM) had greater influence on the increase in the average Rmax than the cycle number.

Kumar and Mamilla illustrate the study of different failure modes of internal combustion engine valves which caused due to fatigue, high temperature effects, and failures due to impact load that depends on load and time [14]. For overcoming these effects coupled field static analysis and steady-state thermal analysis is to be done on valve with the seat and fin segments on two different materials at 5000 cycles in working condition. There are many variables that make valve fail which causes thermal and mechanical overstresses, longitudinal cyclic stress, and crop conditions, forging defects, etc. leads to many troubles include valve breakage, valve face wear.

Fatigue analysis is done on valve, valve with a seat and fin segments by varying two materials. As per the analytical results valve with mag alloy fin is the right choice for maximum life.

Gurunathan et al. during engine operating conditions, insert area touches the seat insert which causes reaction force, drift and deformation due to the effect of contact pressure. Since to improve these all parameters; the new models have been implemented in this for better durability and lifetime by using ABAQUS. Flathead valves are mostly used since it provides good scavenging and smooth gas flow, but it lacks the elasticity property which distributes stress all over the valve head [15]. And in case of flex angle valves allows carbon residue to deposit along the valve face, but it provides good elasticity, uniform stress distribution and reduction in weight. A small weight reduction in the valve train system can contribute to significant improvement in performance of the engine. This study proposed structural analysis of valve train components through CAE approach for increased durability. From the results of normal flat head valves and flex angle valves it is clear that the deformation and reaction force parameters are good in the flex angle valves. And another advantage is that it will improve the fatigue life of the material.

Londhe et al. showed that in this experimental analysis of valve and valve insert were in gases (CNG) fuelled engine is carried out. Engine runs for 100 h for four different configurations of durability test. To find the problem of valve and valve seat wear durability is one of the ways in any R&D department. Wear mainly depends on the properties of valve and valve insert materials and the angle between them. The most possible way to come out of this is to have some modification in the valve and valve seat angle changes from 45°to 30°, for better side width so that the seat and the resting area for the valve is increased [16]. And also on selection of material it should be such that it withstands its hot hardness in order to secure wear resistance in the dry environment characteristic of gas fuel. So in this iron base material is replaced to cobalt base material as it has high hot hardness. This result concludes that 30° can sustain the combustion pressure more than that of 45° and prefers satellite material for valve seat and valves (both intake and exhaust) than bi- metal with Stellite 12 coating on seat area.

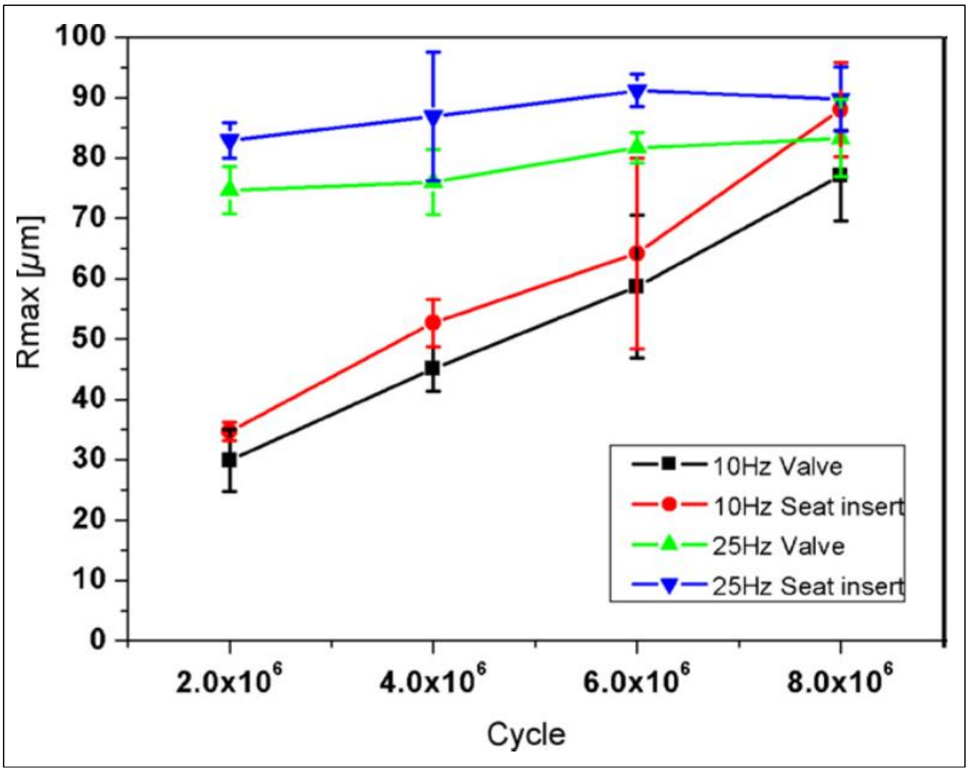

Fig. 6: *Rmax and Rmax Rate of Valve and Seat Insert at 10 and 25 Hz.*

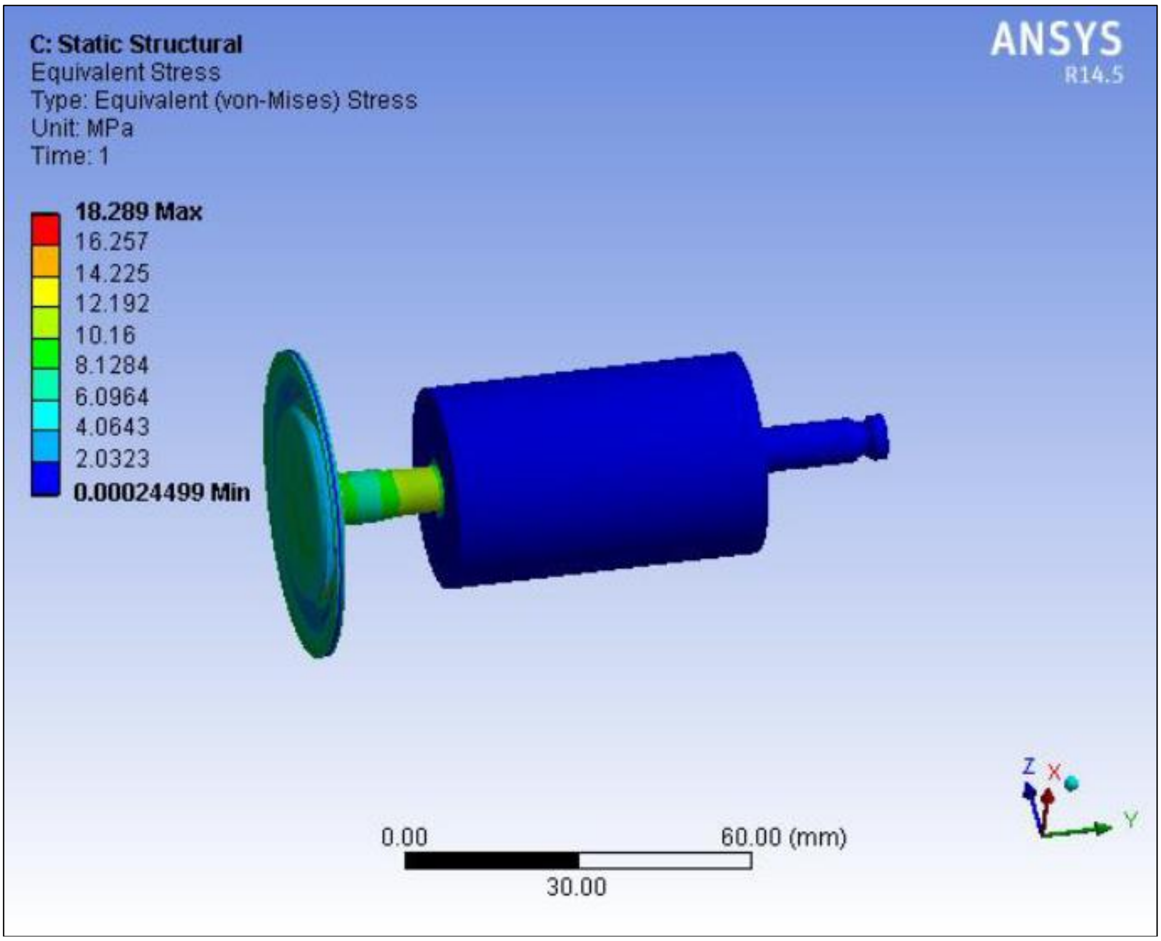

Fig. 7: *Static Structural Analysis of Valve with Seat and Guide.*

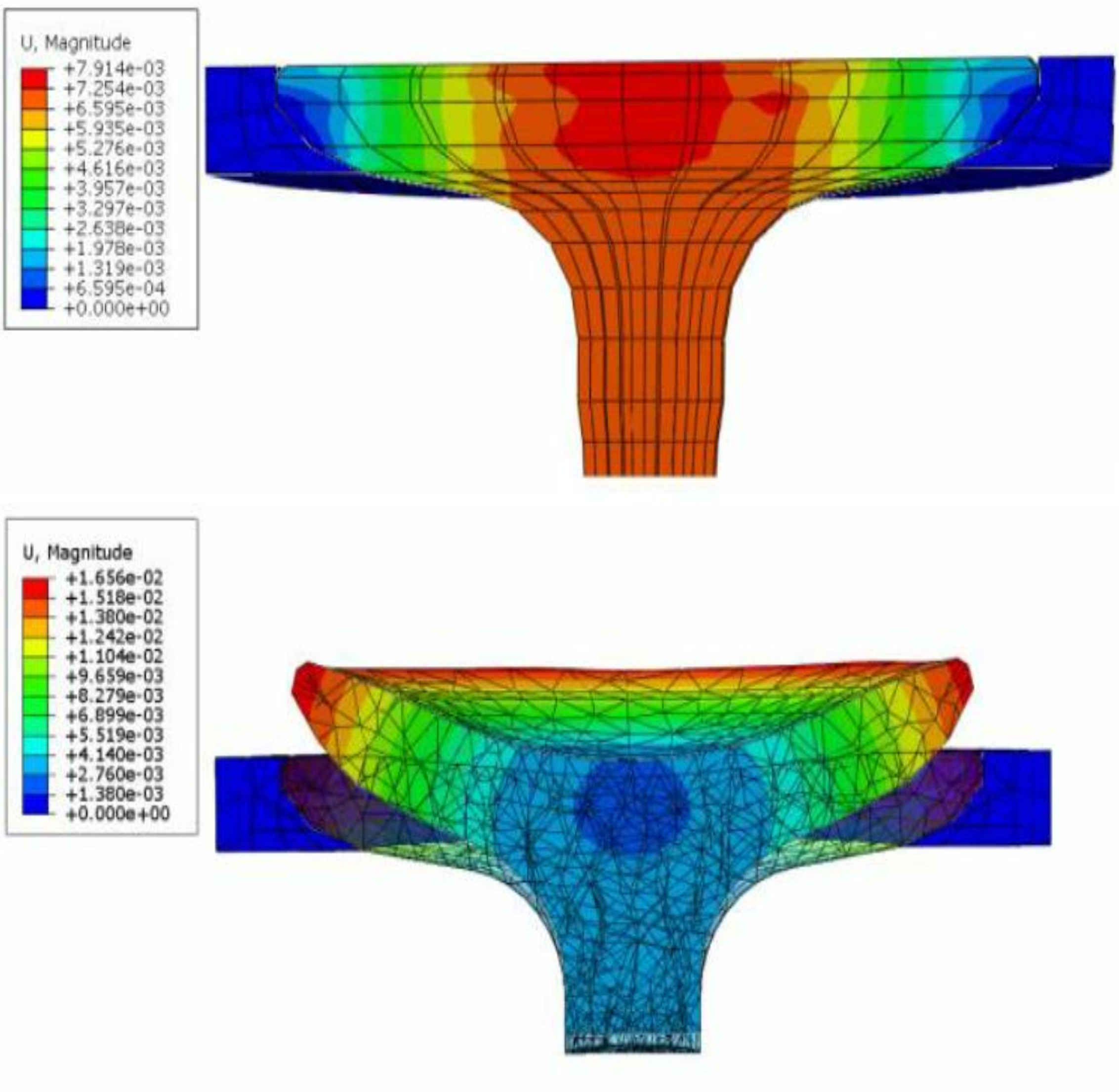

Fig. 8: *Elastic Behavior Comparison.*

Kale et al. in this paper discussed the effect of varied materials mechanical properties of poppet engine valve and geometric parameters such as valve angle, diameter of valve head, thickness of valve disk to improve the performance of valves over fatigue life using Ansys. The analysis is to done on various materials: Inconel 625, Ti-4.5Al-3V-2Fe-2Moz, Ni - Cr - Mo Steel SAE8640_361_QT. The results obtained by transient structural analysis are least equivalent elastic strain for Ni - Cr - Mo Steel SAE8640_361_QT as 0.000010901 and 0.000010895 for 34 mm valve head diameter and 6 mm valve disk thickness and for Inconel 625 as 0.000012526 to 45 degrees which most acceptable. Least equivalent stress is obtained for Ti-4.5Al-3V-2Fe-2Mo as 11.492 Mpa and 10.988 MPa for 22 mm valve head diameter and 42 degree valve angle [17]. Fatigue life remains almost unaffected by change in geometrical parameters but is altered by a change in material. And thus from the above result it was found that Ni - Cr - Mo Steel SAE8640_361_QT has the highest fatigue for all values of geometrical parameters as 1.00E+11 which is most desirous.

Pandey and Mandloi conducted experimental of the investigation of valve failures by observing and analyzing the changes in microstructure of valves as reflected by, images taken through a Scanning Electron Microscope (SEM). For this purpose, a number of specimens were prepared out of engine valves that failed in service and the changes were benchmarked against the new valves. The benchmarking of microstructures of failed valves v/s new valves revealed that the size of grains, grain boundaries, and distribution of carbide particles across the material matrix is affected by high temperature conditions and the effects are more severe for exhaust valves [18]. The microstructure of the valve material shows discernible changes after operating at high temperatures. The grain size of the material also changes in high temperature, thus resulting in a reduction in the hardness of the valve material which, in turn, causes more wear.

The most important factor affecting the performance of a valve is its operating temperature. An investigation of stress and heat transfer by finite element method and thermal analysis selected cylinder heads (converted engine) is conducted in the present work to determine their critical areas and weak points for development and design. Maximum compressive stress is located on valve seats and at the valve bridge, resulting from a constrained thermal expansion of the cylinder head [19]. Cast iron GG-30 in the production process is used instead of cast iron GG25, leads to prevention of fractures in the cylinder head as it makes the assurance factor increase. From the analysis results for both valve materials, it has been concluded that the displacement value is very less than the values of other material for the same thermal and structural loads.

Lavhale et al. in this failure trend of inlet and exhaust valve that takes place in different manners due to fatigue, thermal loading, wear, corrosion and erosion which leads to loss of mechanical properties of material and engine performance were discussed [20]. And briefly explains the various tools and techniques for the fracture analysis. Carbon deposition on the valve neck leads to poor sealing which creates a hot spot on the valve sealing face which in turn results in channeling effects. From the results it concludes that the exhaust valves fail more than the intake valve.

Gawale et al. in this research paper the exhaust valve is designed for diesel engine by selecting suitable fillet radius (10.35 and 14 mm) to reduce the stress concentration further finite element analysis is to be done to optimize best alternative material in order to increase the working life of the exhaust valve [21]. Result showed that the percentage of vol-misses stress and weight of material super alloy 21-2N steel is lower compared to AISI 1541 carbon steel and austenitic steel 23-8N materials and thus it can be used as an alternative to existing material of the exhaust valve.

Nayudu et al. in this paper showed that the finite element method is used for modeling the thermal analysis of an exhaust valve. Blended fuels are biofuels blended in different percentages vary from 0, 5, 10 and 20% [22]. Here the effect diesel blended fuels on the valve is studied by mathematical correlations applying thermal loads produced during combustion. Detailed analysis is carried out to estimate the boundary condition of an ICE. From the comparison result, silichrome steel have minimum thermal gradient and thermal flux with 0% blended fuels as compared to silichrome steel and nimonica 942 with 5, 10 and 20% blended fuels. The variations in minimum temperature are very low in all cases that suggest that we can use bio-diesel blends with regular diesel engines without any effect on engine material, lifetime and heat dissipation. Thus, as per result observed silichrome steel can be used with blended fuels up to 20%.

Rao et al. has done the theoretical calculation on design of an exhaust valve for a four wheeler petrol engine by using three-d model transient thermal analysis to determine the mode shapes of the valve for the number of modes when it is closed and open at 5000 cycles [23]. Here material optimization is to be done on both materials EN 52 and EN15 while analysis. From the results we observed that materials saving, grinding cost saving i.e., total savings per annum will be rupees 20 lakhs lead time reduced by 2 days.

Muzakkir et al. proposed the three conceptualizations of an innovative valve train aiming at lesser number of components, reduction in friction and wear, proper sealing, and trimming down pumping losses were discussed in this paper. Various geometric designs of valve trains have been detailed and compared. Finally convolution based poppet valve mechanism, which is free from many mechanical elements like the camshaft, cam, push rod, rocker arm and bearing has been recommended [24]. Finite element analysis of convoluted spring has been used to ascertain safe limits in terms of stress and achieving desirable valve lift. Magneto rheological fluid and electromagnet are used to vary the valve lift. This innovative valve train provides 11 mm as valve lift with six convolutions on spring however, for adaptation of this concept a detail a fatigue analysis an experimental study is required (Figure 9).

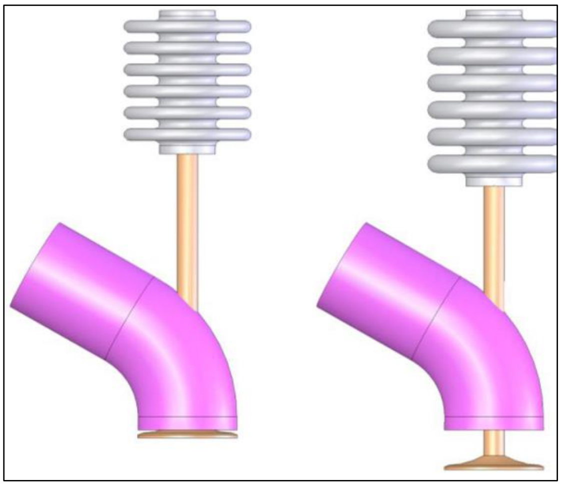

Fig. 9: *Closed and Open Positions of Valve Actuated using Six Convolution Spring.*

More et al. presented the analysis of valve mechanism. In that they perform a kinematic and a dynamic analysis [26].

CONCLUSIONS

Following are the conclusions drawn from the present study:

(1) This paper describes that a limited literature on design feasibility and its verification available up to date. From the literature review it can be seen that researchers had done work on developing various methodologies for designing the valves, but thermal (heat transfers) has not been considered in Finite element analysis and the interest of production of low-weight, has strongly been intensified due to economical and ecological aspects of engine operation.
(2) The valve design and the valve timing indirectly affects the engine performance the use of finite element analysis or simulation is more effective way for the optimization of the design.
(3) The paper also describes the different causes of failure of valve that can be analyzed in the design stage to increase the life of the tool and prevent early failure.

The information obtained from this literature study would be helpful in further research.

REFERENCES

1. M.L. Pang, S.P. Smith, R. Herman and B. Buuck, Stress Analysis of an Automotive Engine Valve by Finite Element Methods,Eaton Corporation, *SAE International*. 2006 ,paper offer no.06P–78.
2. Rajesh Kanna SK, Ragu R, Rajeswaran PS, *et al.* Performance evaluation using FEA on AL-SI Coated engine valve; *Int J Curr Res Acad Rev*. August 2015; 3(8): 67–72p.
3. Yalla M Surya Chandra Rao, VV, Ramakrishna, Mohan Krishna S. Structural and Thermal Analysis of Poppet Valve made of different composite materials, *Int J Mech Eng Technol*. 2(9): Dec 2015, 939-944p.
4. Naresh Kr. Raghuwanshi, Ajay Pandey, Mandloi RK. Failure Analysis of Internal Combustion Engine Valves: Review; *Int J Innovative Res Sci Eng Tech.* 1(2): 2012, 173-181p.
5. Torres MAS, Voorwald HJC. An evaluation of shot peening, residual stress and stress relaxation on the fatigue life of AISI 4340 steel, *Int J Fatigue.* 2002; 24: 877–886p.
6. Awanish Kumar Singh, Karthick P. Design and Analysis of Poppet Valve using Composite Materials; *Int J Emerg Trends Sci Technol IC Valve.* 4(5): May 2017, 5194- 5199p.
7. Muhammad Imran Khan, Muhammad Arsalan Khan, Abdul Shakoor, A Failure analysis of the exhaust valve from a heavy duty natural gas engine, *Eng Fail Anal.* 2018; 85: 77–88p.

8. Voorwald HJC, Coisse RC, Cioffi MOH. Fatigue Strength of X45CrSi93 stainless steel applied as internal combustion engine valves, *Procedia Engineering* 2011; 10: 1256–1261p.
9. Mamta. R. Zade, Optimization of inlet valve of IC Engine using Finite Element Analysis; *Int Res J Eng Tech (IRJET).* 3(10): Oct-2016, 451-454p.
10. Sanoj. T, Balamurugan S. Thermo Mechanical Analysis of Engine Valve; *Int J Sci Res*. 3(5): May 2014, 1834- 1838p
11. Yu ZW, Xu XL.“Failure analysis and metallurgical investigation of diesel engine exhaust valves, *Eng Fail Anal.* 2006; 13: 673–682p.
12. Scott CG, Riga AT, Hong H. The erosion-corrosion of nickel-base diesel engine exhaust valves, *Elsevier Wear.* 1995; 181–183: 485–494p.
13. Keyoung Jin Chun, Jae Hak Kim, Jae SooHong, A Study of the exhaust valve and seat insert wear depending on cycle numbers, *Elsevier Wear.* 2007; 263: 1147–1157p.
14. Goli Udaya Kumar, Venkata Ramesh Mamilla, Failure Analysis of internal combustion engine valves by using Ansys, *Am Int J Res Sci Tech Eng Math.* 2014,169- 173p.
15. Gurunathan R, Jitendra Sharma, Velshankar M. Structural Analysis of Valve Train Components through CAE approach for increased Durability, *SAE International.* 2017.
16. Rohit T. Londhe, Kshirsagar JM. Experimental Analysis of Valve and valve seats wear in gases (CNG) fuelled engine; *IQSR Journal of Mechanical and Civil Eng*. Jul-Aug 2014; 11(04): 56–62p.
17. Vidyadhar. C. Kale, Sagar S. Deshpande, Design and Analysis of Poppet Engine Valve for Enhanced Mechanical Properties with Varied Geometric Parameters and Materials; *Int J Eng Sci Tech.* (Kale, 3(11): November, 2014, 176- 187p).
18. Ajay Pandey, Mandloi RK. Effects of High Temperature on the Microstructure of Automotive Engine Valves, *Int J Res Appl.* ISSN: 2248-9622, Vol.4, March 2014, 122–126p.
19. Arul Murugan P, Ranganathan S. New Thermo Mechanical Analysis of Engine Valve using a multi-field approach; *IJEDR*, 3(2): 2015, 958-961p.
20. Yuvraj K Lavhale, Jeevan Salunke, Overview of failure trend of inlet & exhaust valve; (*IJMET) Int J Mech Eng Sci Tech.* March 2014; 5(3): 104–113p.
21. Snehal S. Gawale, Shelke SN. Diesel Engine Exhaust Valve Design and Optimization; *IQSR J Mech Civ Eng.* 13(04): Jul-Aug 2016, 85-93p.
22. Raja Nayudu, Kuppili Mohan Krishna, Ramakrishna VV, *et al.* Effect of thermal load on valve by using conventional diesel and blended fuels; *Int J Sci Eng Adv*. 3(11): November 2015, 1093-1100p.
23. Seshagiri Rao B, Gopi Chandu D. Petrol Engine Exhaust Valve Design, Analysis and Manufacturing Processes; *Int J Mech Eng Robot Res.* 3(4): October, 2014, 395-401p
24. Muzakkir SM, Patil MG, Harish Hirani, Design of Innovative Engine Valve; *Int J Sci Eng Tech.* 4(3): March 2015, 212-217p.
25. *Design of automotive systems, Authors of the book*-A. Kolchin and V. Demidov, first edition- *1984*.
26. SAE J 775- Engine Poppet valve Information Report- *SAE International,* Surface Vehicle Information Report, Issued 1961-06, revised 2004-1.1
27. More AS, Deshmukh SP. Analysis of Valve Mechanism- A Review; *IOSR J Mech Civ Eng.* ISSN(e): 2278- 1684, ISSN(p): 2320-334X, 2012, 06–09p.

Cite this Article

Anuradha J Thakare, Ashok J Keche. Automotive Valve-Train Components Durability Analysis Using Finite Element Method Approach: A Review. *Trends in Machine Design*. 2018; 5(1): 54–66p.