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INVESTIGATION OF SEIZURE FAILURE OF HEAVY DUTY ENGINE PISTON

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ABSTRACT

In Internal Combustion engines piston failure is a common phenomenon and it is very serious problem which still exist. It is only the component of Internal Combustion engine that encountered failure from different region like stress of thermo-mechanical, wear, fatigue, extreme temperatures etc.

In the present work the intricate problem of seizure failure of piston has been investigate experimentally with metallurgical investigation in terms of chemical composition test, scanning electron microscope (SEM) test and hardness test were carried out for heavy duty engine piston. The problem of piston seizure failure of a four stroke diesel engine we observed one seized engine piston of four stroke heavy duty diesel engine at different parameters.

After observing and studying of different parameters like chemical composition test, Hardness and SEM test result it is believe that there is some theoretical gap and conceptual difference which still need improvement to predict the mechanism of seizure failure in internal combustion engine. It is also believe that there should also be improved in manufacturing technology and improved heat treatment process.

KEYWORDS: Heavy Duty Piston, IC Engine, Seizure physics, FEM analysis etc

INTRODUCTION

Piston is a disc or short cylinder fitted closely within a cylindrical tube in which it moves up and down against a flue gases used in an internal combustion engine to deliver motion. The piston is at the heart of an engine creates motion. Larger piston increases displacement due to which engine generates more power due to burning of more fuel. Internal combustion Engine pistons are one of the most important and intricate components among all kind of automobiles & automotives component. The engine can be called the heart of the vehicles and the piston may be considered the most important part of an engine. Lot of research works has been done and also going on for engine pistons & its technology with a continuous improvement over the last many years. [1]

The Present work is concerned only with the failure analysis of pistons due to seizure. A piston from heavy duty diesel engine has been analyzed. For this one piston sample from seized engine has been taken to study the reason for seizure failure. The Damages theory indicates that failure may be identified at any part of the piston it may either initiated at the crown part, at ring grooves, or piston skirt. An analysis of both thermal fatigue and mechanical fatigue damages is presented and analyzed.

Internal combustion engine piston materials and design have been develop over the years and still continue to doing something else which can makes the internal combustion engines superseded. The main reason of this continuous effort of evolution is based on the fact that the piston may be considered the heart of an engine. The piston is one of the main stressed components of an entire vehicle pressure at the combustion chamber might be reached about 180–200 bar And Speed about 25 m/s and the temperatures at the piston crown may reach about 400 o C . The piston should be design such that it can sustain the maximum heat and pressure of combustion. It should also light enough to stay inertial loads on connected parts at minimum load. It should also be help in sealing the cylinder liner to prevent the leakages of combustion gases and also transmit generated heat to the cooling medium and some of the heat through the piston rings to the cylinder wall. [2]

As piston is one of the main components of the Internal Combustion engine its stronger, lighter, and reliable. The basic function of the piston is to move from top dead center (TDC) to bottom dead center (BDC) in the cylinder liner. The power is generated in combustion chamber and transmits forces through the wrist pin and connecting rod to the crankshaft.

Now day's engine runs cleaner work harder and run hotter than ever before. Despite of this technological development there are still the problems of piston failure exist. Piston failure may be occurs at different regions due to various causes like mechanical and thermal stresses, uneven temperature distribution, corrosion mechanism etc. [3]

In this work only mechanical damage like seizure damages has been investigated. Conventionally the piston failures are attributed to wear and lack of lubrication sources. The major cause of seizure failure is recognized scuffing or lubrication methods may have be the root cause of seizure failure.

In spite of continuous evolution and research on internal combustion engine pistons its failure is a common experience. It is the only component of the Internal combustion engine that come upon failure from different causes like thermo mechanical stresses, extreme temperatures, wear, fatigue etc. and engine operating conditions like lean carburetor mixing, advanced ignition time, present of foreign materials inside, improper clearance between piston and cylinder liners, low octane fuel, loss of lubrication, high compression ratio, and so on. [4]. With increasing demands for faster, cleaner, and powerful engines failure of engines and its subsystems like piston has been also increased proportionately. Many significant developments have been achieved in abridging and understanding the mechanisms of failures. Notwithstanding with the advanced developments, there still exists significant challenges that needs to be addressed, specifically related to the seizure failure of the pistons. This work represents the problem of seizure failure of a four stroke engine piston.

In the present work a seized piston as a sample has been taken from heavy duty diesel engine. To understanding of the seizure failure mechanism there are different analytical tools, such as theoretical investigation, experimental investigation including metallurgical analysis may be used wherever they are required for a clear understanding of the seizure failure mechanism.

INTRODUCTION TO INTERNAL COMBUSTION ENGINES (ICE)

In conventional IC engines, the reciprocating motion of piston inside the cylinder imparts rotary motion to the output shaft of the engine. An exception to this kind of engine is the rotary IC engine developed by Wankel in 1957 (Heywood, 1988). However, rotary engines are not widely used because of their complicated design, and higher cost of manufacture and maintenance compared to reciprocating engines. The motion of the piston is transmitted to the output shaft using a connecting rod and crankshaft assembly as shown in Figure 1.1 The crankshaft take rotary motion that impart reciprocating motion to the piston. The piston has two extreme positions during its motion inside the cylinder called the Top Dead Centre (TDC) and the Bottom Dead Centre (BDC) (Thomas, 2008).

The cylinder block keeps the cylinder in position with the top of the cylinder block covered by cylinder head and at the bottom the crankcase where lubricating oil is filled. The combustion chamber volume is designated as the instantaneous volume occupied between the top of the piston and upper portion of the cylinder during combustion (Mathur and Sharma, 2003). In case of gasoline engines an electric spark ignites the highly compressed air fuel mixture above the piston at the TDC position. The resulting explosion imparts a downward force to the piston which results in transmission of motion to the rotary output shaft.

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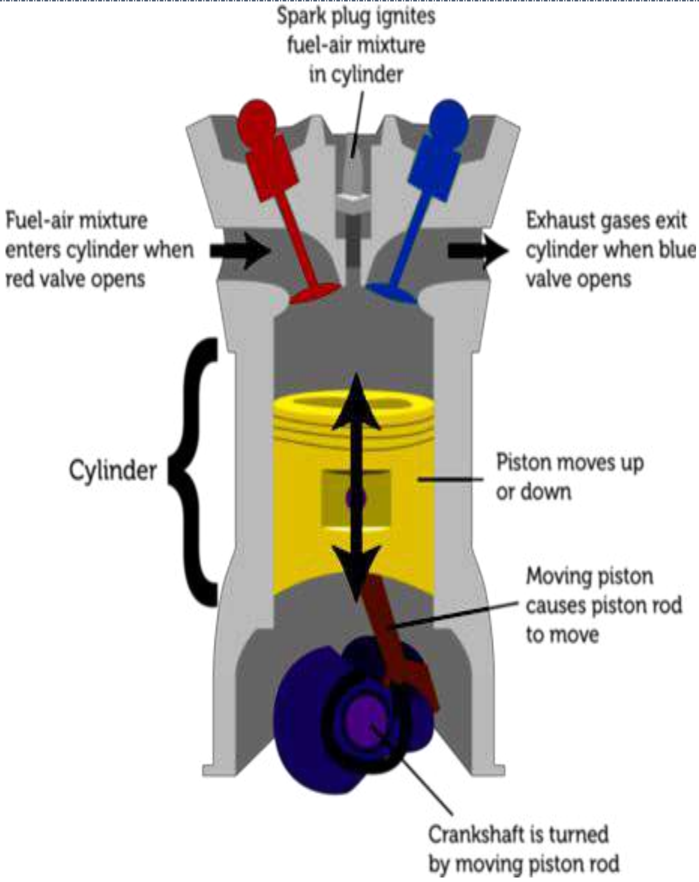

Figure 1.1: Geometry of Internal Combustion Engine

CONVENTIONAL INTERNAL COMBUSTION ENGINES (ICE):

Figure 1.2 shows working principle of the four stroke diesel engine. In the first stroke piston travel from top dead center TDC to bottom dead center BDC suction stroke take place during the downward movement of piston a vacuum create inside the combustion chamber and in this stroke only fresh air sucked inside the engine cylinder through inlet valve till closing of the inlet valve and first stroke is complete.

In the second stroke this sucked air is compressed due to traveling of piston from BDC to TDC. In compression stroke both valves are closed and piston travel from bottom dead center to Top dead center and compression stroke complete. In the compression stroke the temperature of fresh air is increased from 550 oC to 650 oC. It is only a theoretical concept but in actual practice as the temperature of air reached up the desired temperature before reaching the piston on top dead center diesel oil is injected in to the combustion chamber this will happened before piston reaching on TDC.

After completion of compression stroke power stroke began in this stroke diesel oil is injected in the combustion chamber in the atomize form. As the atomize diesel fine particles contact with high temperature air burning is take place of atomized fuel and huge amount of head produce and sudden explosion create large amount of pressure which apply on piston head and combustion chamber , this high pressure flue gasses try to push back or push down the piston head and power stroke is complete. As it is cleared from the concept of working principle of internal combustion engine, piston is only the moving component inside the cylinder so it will try to move in downward direction.

After the power stroke expansion or exhaust stroke is take place in the final or expansion stroke flue gasses have to exhaust from the combustion chamber so that fresh air would enter inside the combustion chamber for next power stroke. As the power stroke over expansion process of burn gases start at that time piston move from top dead center to bottom dead center and at certain point the exhaust valve is open and all burn gases get away from the combustion chamber. As we know that theoretically valve is open and closed only at either top dead center or

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bottom dead center but in actual practice there is a slightly some angle variation of valve opening and closing, it is also seen that there is a dancing position of both valve have been observed where both valve open at same time this is due to movement of valve mechanism in the internal combustion chamber. The inlet valves open 10° to 22° before TDC in exhaust stroke and exhaust valve open 56° before BDC.

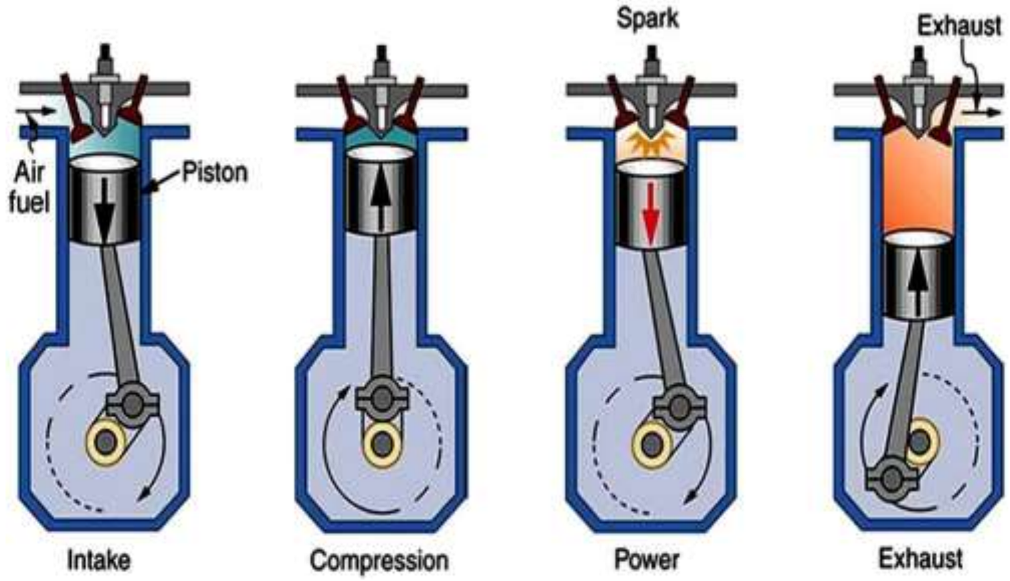

Figure 1.2: four stroke diesel engine.

AIR STANDARD DIESEL CYCLE

Air standard diesel cycle and processes are shown on P-v and T-s diagrams.

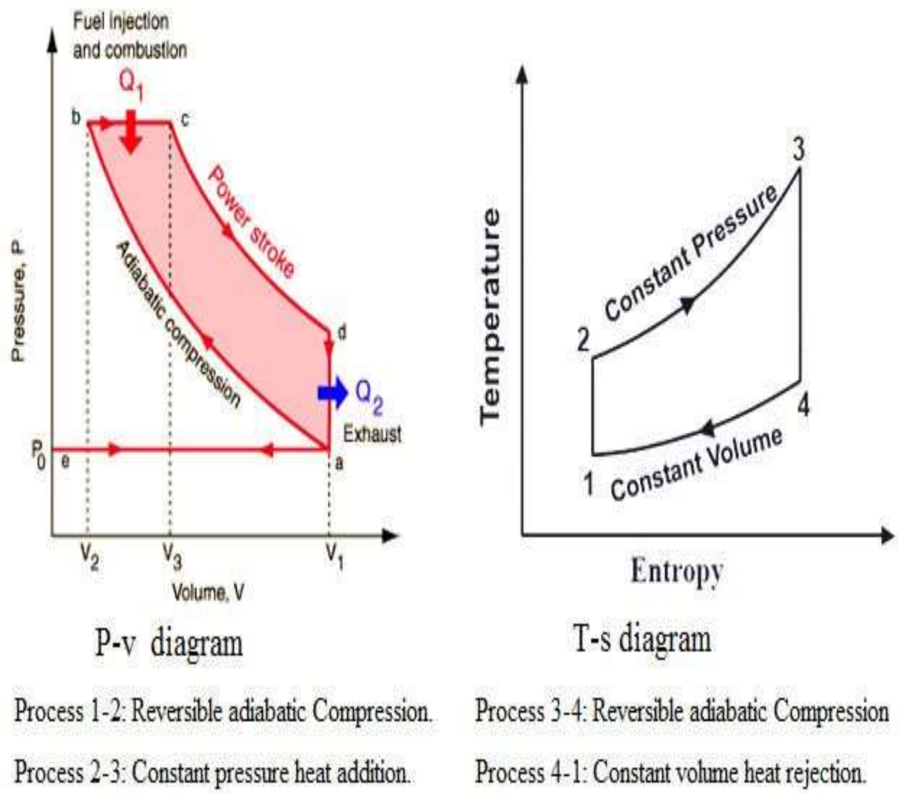

Figure 1.3: P-v and T-s diagrams.

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CAUSES OF THE ENGINE PISTON FAILURES:

a. **Seizure due to Overheat:** this type of piston failure occurs due to the engine overheating. In this case engine loss power and cannot be turned to start. To prevent the engine of this problem we must check and connect cooling system.

b. **Rings Lands fracture:** Due to excessive combustion chamber pressure the fracture progressively increased and thus resulting rings land section broken from top to the bottom. Due to piston ring land facture compression ratio increased and the pre-ignition and detonation type problem arising. The symptoms of ring land facture are the engine loss power, Oil consumption increased smoking and the engine creates unwanted noise.

c. **One Side Skirt Seizure:** Due to one side thrust produce during the movement of piston seizure or scuffing occurs. The causes are the insufficient oil or dry assembly. The engine makes noise and some power loss. In this case we have to check oil pump, oil pressure valve, oil level in sump and cylinder bore. If problem is more serious then change the piston.

d. **Misalignment:** if there is any error during engine assembly these types of failure occurs which damage end bushes and extra thrust produce on crankshaft. The only symptoms are increased oil consumption. The remedies for this problem is to check and correct connecting rod, small bush end alignment and crank end-float.

e. **Abrasive Wear:** Abrasive wear occurs when a hard rough surface slides across a softer surface. Scratching or scuffing on the piston skirt may be appearing due to relative movement of piston in cylinder liner. The remedies to this problem are that ensure air and oil filters are clean and fitted with correct filter elements. If the engine went for overhaul must clean all engine components and oil ways.

f. **Insufficient Clearance:** if wrong size component or oversize components assembled together this types of problems occurs. In this case seizure marks may appear on skirt. During the engine running engine does not develop normal power and the engine may overheat. The remedies are to check cylinder bore sizes, re-bore or hone to the correct diameter.

g. **Circlip Ejection:** due to overheating some material get melt and piston skirt get erosion adjacent to the gudjeon pin. Another cause may be some foreign material assembled with piston or may be circlips are fitted incorrect. The symptoms are oil consumption increased, engine creates unwanted noise and some power losses.

h. **Trapped Rings:** This problem arise when the piston rings trapped in their grooves a rapid peripheral ring wear occurs. That is happen from high combustion temperature and engine start using oil and loss power. The solution is to ensure ignition setting and spark plugs and Check that induction system should free of air leaks.

i. **Pin Seizure:** That mean the gudgeon pin seizure due to lack of lubrication during assembly and possibly during initial stages of engine use. Or tight small end. Engine going to be noisy followed by loss of power. The right remedies for these symptoms are you need to inspect and correct any damage to the bearing, connecting rod, valves and cylinder head. Fit new pistons ensuring the gudgeon pin is the correct fit in the small end and that the piston and the pin are adequately lubricated. Avoid lengthy periods of slow engine RPM during running-in.

j. **Rough Honing / Oil Consumption:** Immediate smoking or short period of operation before engine starts smoking. This problem is caused by incorrect bore surface finish. No honing or insufficient honing. Scratches or machine marks in bore. And the symptoms are smoking engine loss power and oil consumption. To rectify this problem you need to correct damaged bores by re-honing. Fit new rings to pistons. Note piston to bore clearance. Re-bore to next oversize if necessary.

LITERATURE REVIEW

Piston overheating seizure can only occur when something burns or scrapes away the oil film that exists between the piston and the cylinder wall.

When two moving metallic parts lose lubrication between them, scuffing is likely to occur. Scuffing is the process by which the metals weld themselves together and then break loose. Welding can occur between the piston or piston rings and the cylinder walls when the piston stops at TDC. As the piston starts back down from TDC, this weld breaks. The rough surface that results wears ridges in the cylinder wall and on the piston ring or the piston itself. Scuffing can also be caused by detonation, which causes higher temperatures and pressures in the combustion chambers.

Nautiyal and Schey [09] found that aluminum exchange to a steel surface may happen even within the sight of a considerable measure of ointment. Reddy et al [10] found that in un-greased up Al–Si amalgam/steel contact, the move from extreme wear to scraping was identified with surface temperature, and that rubbing coefficient expanded with burden in serious wear areas. Reddy likewise reported that scraping loads expanded with silicon content and diminished with sliding speed and proposed a scraping measure for this kind of contact, expressing that scraping would happen if the footing power was bigger than the reasonable shear anxiety of the surface material. [11] He. X. indicated the three lines of barrier against scraping for an Al–Si amalgam/steel communication—the oil film, the synthetic film (oxides or substance layer shaped by response between the surface and the ointment) and surface defensive layers and the criteria for disappointment moves as for these layers. Wang et al. [12, 13] assessed the tribological conduct of and similarity between covered cylinder skirts (with either composite polymer coatings (CPCs) or nickel/earthenware composite coatings) and aluminum or cast iron bore counter faces.

Li [14, 15] utilized a three-dimensional limited component model of an aluminum diesel motor cylinder to ascertain working temperatures, warm and mechanical disfigurements because of thermo mechanical burdens. He demonstrated that skirt shapes had vital influence in the lessening of scraping and contact.

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Tahar Abbes et al. [16] exhibited the thermo mechanical conduct of an immediate infusion diesel motor cylinder subjected to the joined warm and mechanical burdens. Liu and Reitz [17,18] built up an axi-symmetric transient warmth conduction model to anticipate the burning chamber divider temperatures.

Moffat et al. [19], researched an eutectic Al–Si cylinder combination containing 12.45 wt% Si, 3.9 wt% Cu and 2.8 wt% Ni, and affirmed that weariness split start happened at essential Si particles as well as at a few bury metallic mixes. The primary bury metallic that seemed to start weariness breaks was Al9FeNi, despite the fact that others, for example, Al7Cu4Ni and Al3 (CuNi)2 were watched nearby split start locales. Besides, little pores (most extreme measurement ~50–75 µ m) were regularly watched connected with the entomb metallic at start locales [20]. Moffat et al. [21] further explored the exhaustion conduct of three other model amalgams with comparative compound substance aside from decreased Si levels of 6.9 wt% (unmodified and Sr adjusted) and 0.67 wt%. For the Sr-adjusted amalgam with 6.9 wt%Si,

It is unmistakably evident from Moffat et al's. work [22] that bringing down Si levels decreases the part of Si particles in weariness split start with entomb metallic particles (especially, the Al9FeNi stage) playing a more overwhelming part. Notwithstanding, the lessening of Si is likewise joined by expanded porosity because of poor castability.CHOI H and SHI Yu-liang [23, 24]. As per this idea, thinks about on aluminum combination rather than steel to be the fundamental material of cylinder skirt have pulled in more research interests, which may advantage vitality preservation and natural security.

PROBLEM IDENTIFICATION

from [5-08] piston failure due to scuffing occurs on the different region, there are various causes by which scuffing and scoring have been identified end explained by many authors. From [09-13] material composition review have been explained. From [14-18] piston failure occurs due to thermal property changed have been explained by many authors. Thermal failure occurs due to overheating and overload on the engines, lubrication is also a cause for thermal failure. From [19-22] various fatigue failure has been identified in the internal combustion engine. from [23-24] failure of high speed engine piston have been explained by many authors.

OBJECTIVES

In this advanced and modern technology age internal combustion engine technology have been evolved drastically but in engine technology we are still using same old and backward technology, whatever the growth of human civilization and comfort life internal combustion engine power going increased and robust design. In spite of advanced development there is still exist engine failure problem which have to be solved on this same context the present work has some following objectives.

The main objectives of this present work are:

1. To understand the mechanism of IC engine failure.
2. To study the various possibility which may causes of piston failure.
3. To investigate of pistons seizure in heavy duty Compression Ignition engines.
4. To predict the various causes of seizure failure by visual inspection in theoretical investigation.
5. After the theoretical investigation experimental investigation has to be done on the sample to fail piston.
6. Experimental investigation help to predict various hardness points on the piston sample during Rockwell hardness test.
7. By the chemical composition test it is possible to predict various element ratios which composed the piston material.
8. By the scanning electron microscope test it is possible to see various images of inter metallic and wear surface.
9. Find the optimum solution to minimize such types of problems in heavy duty engines.

METHODOLOGY

METHODOLOGY

The systematic theoretical and experimental studies have been explained in this chapter and the whole methodology process is simply explained by a flow chart.

The present work has been completed in two stages.

1. Theoretical investigation

2. Experimental investigation

THEORETICAL INVESTIGATIONS

Theoretical investigation is categories in two parts first one is visual inspection and second one is theoretical investigation which is based on some theories on which piston material functioning and its failure studies and design theories have been compared with visual inspection.

First stage is visual inspection in which all points that are causes for piston failure will be analyzed one by one. For the visual inspection a deep analysis of sample images have been studies, various images have been taken from the piston sample and mark each possible failure regions and try to understand visually its causes.
In the theoretical investigation all the concluded result from the visual inspection have been applied on some basic failure theory which are taken from standards manual and then theoretically applied for the fail piston sample.

EXPERIMENTAL INVESTIGATIONS

Experimental investigations are based on some laboratory test which is carried out on the piston sample. The entire laboratory test has been performed in CSIR-Advanced Materials and Processes Research Institute (AMPRI), Bhopal. The following lab test has been carried out on heavy duty engine piston:

1. Chemical composition test
2. Hardness Test and
3. Scanning Electron Microscopy (SEM) Test

The detail explanations are discussed in chapter-6.

CHEMICAL COMPOSITION TEST

Chemical composition test is a process in where a piston sample material is to be a analyzed for its chemical composition. Chemical composition test can be qualitative (determining which types of element present) as well as quantitative (determining how much quantity is present). This type of elemental analysis comes within the dominion of analytical chemistry.

In the present work Chemical composition test is performed for material identification purpose Chemical analysis of piston material is performed to determine the quantity and composition of various elements such as cu, si, Fe, Ni, Zn, Mg, Ni, Pb, Ti & Sn are presents in particular selected sample.

HARDNESS TEST

The metal handbooks define hardness as the resistance of metal to plastic deformation usually by indentations. In other words we can say that the ability of material to cut another materials. We also said that about its property of metals which gives the ability to resist permanent deformation when the load is applied on the material. Greater hardness show greater resistance against deformation.

Figure 4.1: Hardness Tester Machine

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In the metallurgical science the hardness is define as the material ability to resist plastic deformation. In the present work Rockwell hardness testing is performed. Before going to performed hardness test we have to understand that what is Rockwell hardness?

The Rockwell hardness test is the amount of hardness based on the total penetration or impression marks which may appears during application of load. The Rockwell hardness number does have any units and generally read in the form of R, L, M, E & K scale. For the harder material hardness number indicates higher value.

For the Rockwell hardness testing the indenter of specific dimension and size is used by the penetration on the working sample. The indenter may be of steel ball of specific dimension or spherical diamonds tip cone of included angle 120^o and radius of 0.2mm. These different types of indenter and different types of loading define the hardness scale listed on the display scale like A, B,C etc.

In the test procedure load of 10 KG is applied for the primary penetration and then hold the indenter for the time till the dial set on the zero. After that the major load is applied on the test specimen. After taking away the major load read the depth of penetration impression on hardness scale directly. At that time minor load of 10 kg is still on.

In the present work for hardness testing the Rockwell hardness testing machine is used for the aluminium alloy which is the sample material taken from heavy duty engine piston. For the same testing the indenter used as the steel ball of 1/16" diameter with primary load of 10kg and the major load of 100 kg and the hardness number is read on B type scale. The technical specification of the present setup are shown in below table 4.1

Table 4.1: Technical Specification

Model	TRB
Test loads (Kgf)	60, 100, 150
Initial loads (Kgf)	10
Maximum test height (mm)	215
Depth of throat (mm)	132
Maximum depth of elevating screw below base (mm)	230
Size of base (mm) (Approx.)	430X180
Machine height (mm)	635

SCANNING ELECTRON MICROSCOPY TEST (SEM)

Scanning electron microscopy SEM may be analyzed the work material surface. In the Scanning electron microscopy measurement and evaluation of surface like pitting failure, dust deposition category, contaminated particles and other application.

SEM is the types of electron microscopy which can produce images of work sample used for this test. In scanning electron microscopy test a focused beam of electrons passes over the work sample to produce different signal that may be identified and explore the information about the topography of work sample surface and its compositions. Electron beam is generally scanned in different scan pattern and position should be combined within the identified signal which produces images as the result. In the SEM test we can get the image resolution superior than 1micron.

In the scanning electron microscopy test the tungsten filament as the electron beam source. A camera used in this test for capturing digital images of the work specimen and can be stored digitally in computers and other storing devices. For the present work the scanning electron microscopy setup is installed in AMPRI Bhopal. The technical specification of the setup or SEM machine is given below table 4.2

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Table 4.2: Technical information of SEM machine

Image resolution	3.5nm
Required probe current	6 – 12 A
Voltage	30kv
Magnification range	Up to 300000x
Specimen area	125mm in dia
Image mode	SEI

PROCESS FLOW CHART

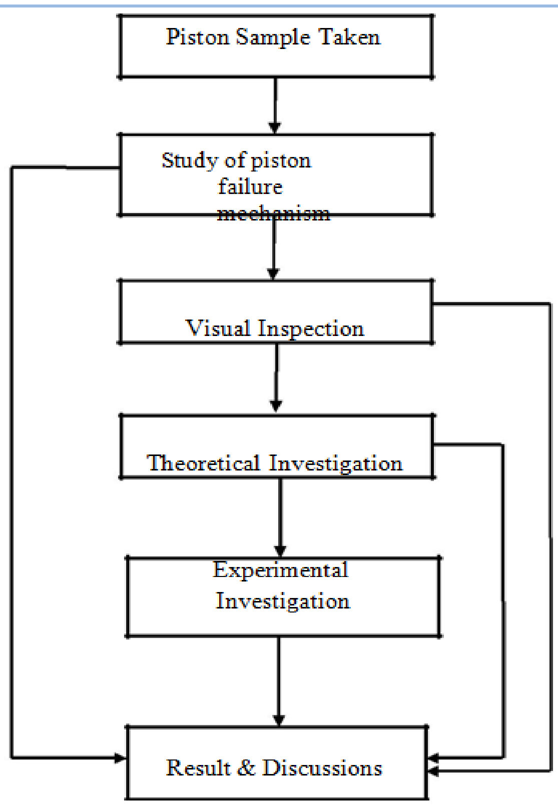

Figure 4.3: Process Flow Chart

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