Analysis of Piston Failure-A Review

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Abstract- The most important part in IC engine is piston. It is reciprocating member inside the engine through which chemical energy is converted into mechanical energy. A piston undergoes stress, temperature, pressure changes frequently and thermal and mechanical fatigue occurs. Hence analysis has been done on piston to detect the failures, different types of failures. In this paper, causes of piston failure in different machines as well as statistical survey by observing failed engines due to piston failure are studied.

Keywords – piston, thermal, mechanical, fatigue, causes, machines, survey

I. Introduction

The piston is a continuously reciprocating member inside an IC engine, compressors etc. Whenever there is need to convert energy into force we use piston inside of machine.
Piston can fail due to many reasons and even there are many types of failures as well.
Generally a piston which hasn't failed should look like this-

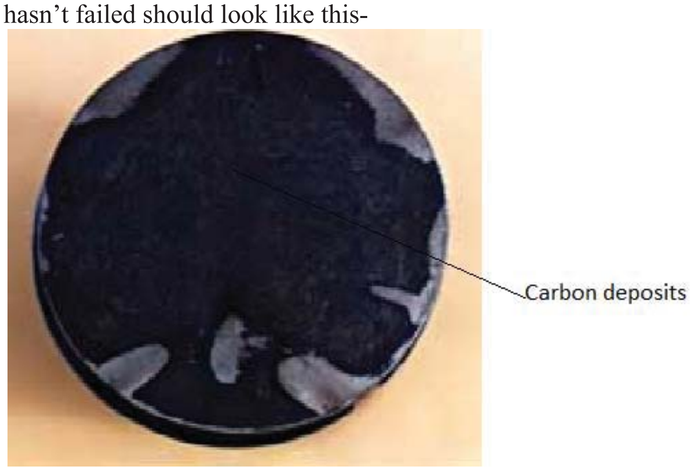

Fig.1 Normal used piston without failure

When piston fails it shows some of these symptoms-

1. Ash

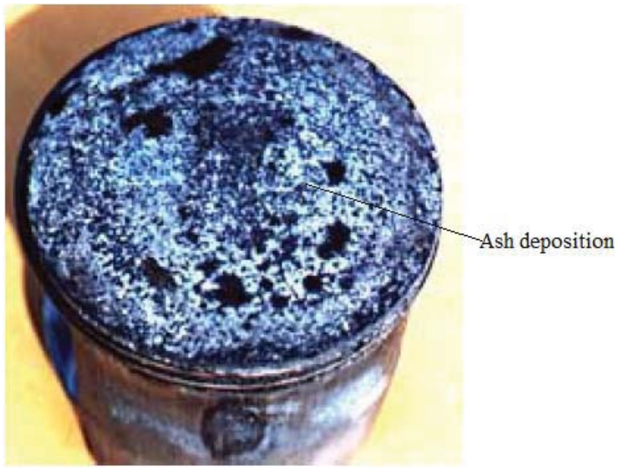

Fig.2 The piston crown shows grey ash color

When engine under operation is very high, that time it becomes too hot and the metal in contact with high temperature i.e. melts and forms tiny flakes.

2. Debris marks

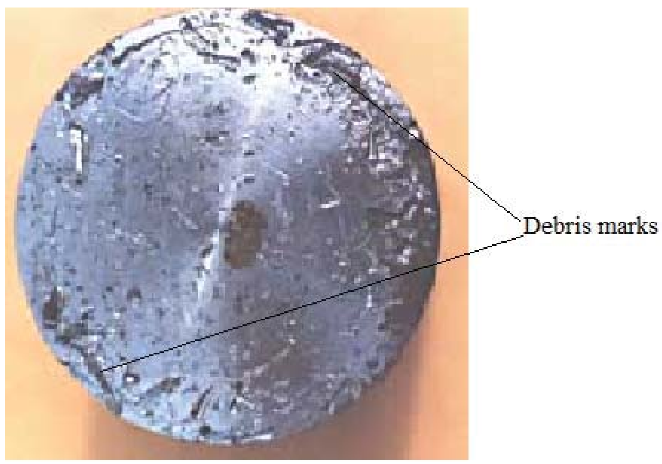

Fig.3 Piston head and piston crown shows damage to surface

When some material is crushed between piston and combustion chamber wall, it damages the piston crown and head. Cause can be broken bearings, broken rings etc.

3. Chipped piston

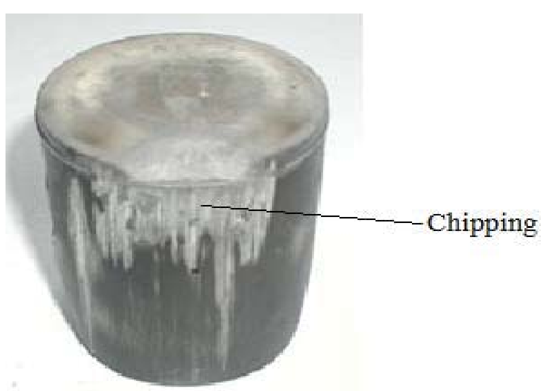

Fig. 4 The piston crown is chipped along the top ring groove.

When head gasket leaks the coolant is drawn into the combustion chamber, this leads to sudden cooling of piston crown surface and results in brittle piston crown.

4. Shattered skirt

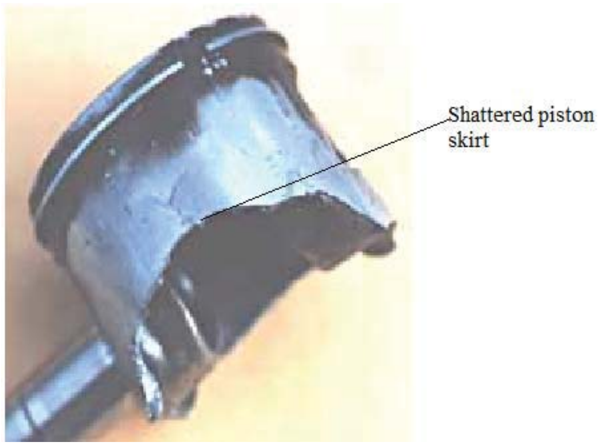

Fig.5 Piston skirt is shattered

This happens when the clearance between piston and cylinder is too large, due to this piston rattles inside the cylinder and develops stress fractures and cracks after certain time.

5. Multi point seizure

Fig.6 Piston shows multiple vertical marks on its circumference.

If the piston and cylinder is mismatched or if piston was heated suddenly, it expands quickly even before the cylinder becomes hot, this seizures occur at multiple points.

6. Deposit on piston skirts

Fig.7 Piston skirt shows deposits

If the rings are worn more than maximum specification, the gases in combustion chamber escapes and some carbon content get deposited on the piston skirt.

This is most common causes we see.
Causes of Piston failures

1. Thermal fatigue
2. Mechanical fatigue

1. Thermal fatigue
When there is large temperature gradient over piston body it undergoes thermal fatigue stresses. The piston body expands non-homogenously and hence crack formation takes place.

2. Mechanical fatigue
This is also a cause for failure of wide variety of engine pistons.
Due to reciprocating motion of piston various stresses also acts on the piston which tends to deform the piston shape. If the piston material is improper the crack initiation takes place and hence stress concentrates at the cracks and after some cycles the piston failes.

Also piston is a part of engine system and also gets affected by improper functioning of othe system inside the engine or defects in other parts of engine as well.

II. Literature Survey

Jan Monieta [1] researched on the engines type 6RLB66 which was manufactured by Sulzer in 1984 and 1985 respectively. These engines used in bulk carrier type B-542.
When he examined engines, he found that piston failure would have been found by temperature rising in outlet cooling water, leak of cooling water, rise in peak firing pressure and compression pressure also. Sometime knocking is also found in engines.

The results are shown in figure below for compression pressure and maximum combustion pressure.

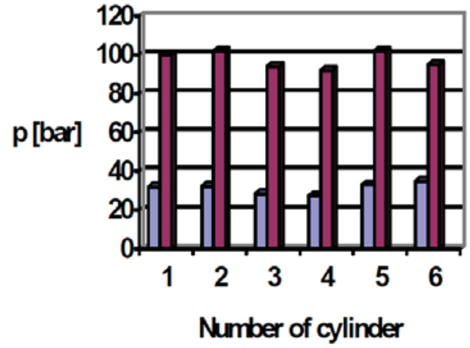

Fig.8 Value of compression pressure and maximum combustion pressure

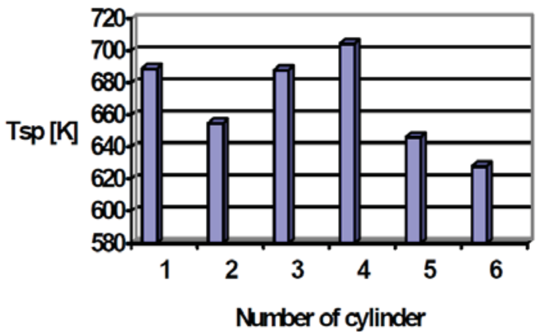

Fig.9 RLB66 at engine speed 188rpm and load 76%

Results for time interval for pistons to fail are shown as below.

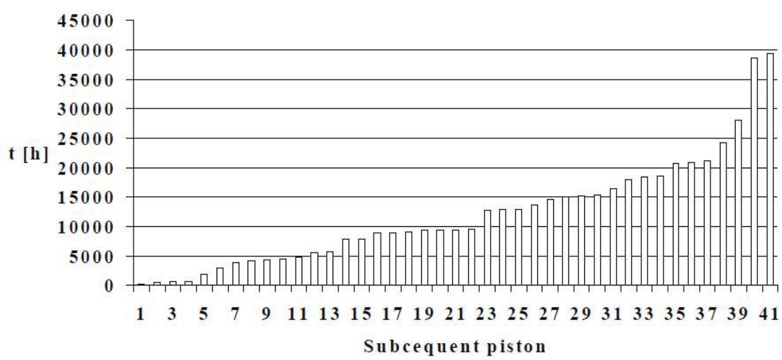

Fig.10 Well ordered realization of time to failure of examined piston engines, type 6RLB66

Most pistons found to have long cracks on piston skirts or crown.
During examination of failed pistons Jan Moneto[1] also studied changes in dimension of piston along longitudinal and perpendicular axis.

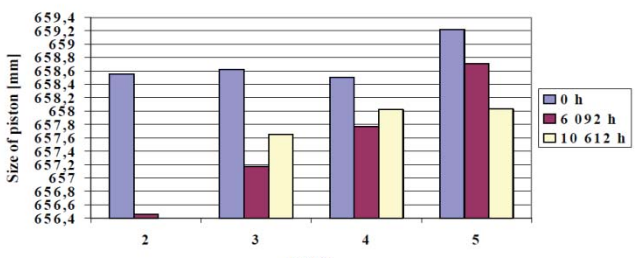

Fig.11 Changes of piston dimensions in direction along the axis of engine for different times of work

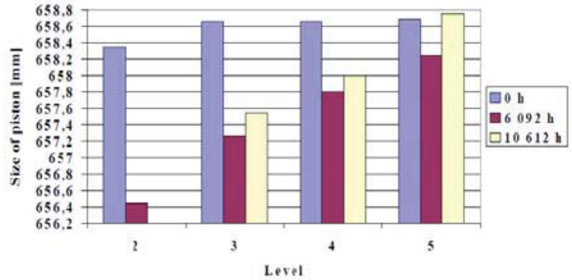

Fig.12 Changes of piston dimensions in direction perpendicular to engine axis for different working times

He calculated failure flux parameter of piston engine of type 6RLB66 and result is shown below

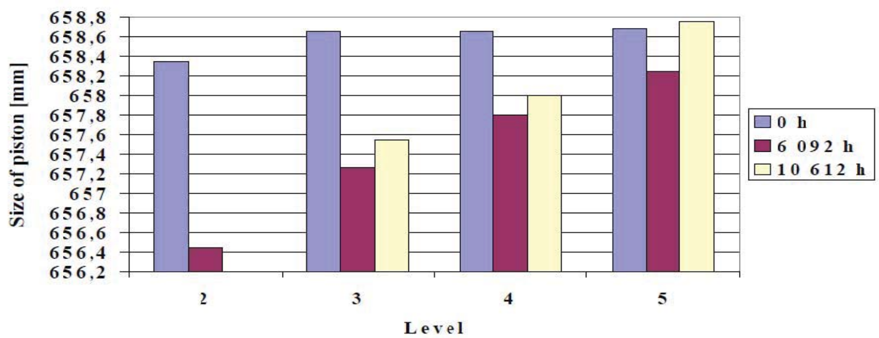

Fig.13 Flux failure parameter of piston engine type 6RLB66

G. Floweday, S. Petrov, R. B. Tait, and J. Press[2] also studied failures occurred during the experimentation done on turbo charged, intercooled, common rail diesel engines to check fuel system component durability for various fuel types initiated by Sasol Technology(Pty) Ltd. In 2006.

The results are as shown

Description of failure types in the testing programme.

Element	Test engine designation	Cycle hours at failure (hours)	Mode of failure
Benchmark endurance tests	Engine A	350	Cracked cylinder head
	Engine A	975	Cracked cylinder head
	Engine B	368	Turbocharger failure
	Engine B	850	Cracked cylinder head
	Engine B	900	Piston ring failure
Fitness-for-purpose endurance tests	Engine D	453	Turbocharger failure
	Engine D	588	Cracked cylinder head
	Engine D	980	#1 Piston failure
	Engine E	342	#3 Piston failure
	Engine E	342	Cracked cylinder head
	Engine E	747	Turbocharger failure
	Engine E	876	Cracked cylinder head
	Engine E	897	Turbocharger failure

They also did Fractography of the pistons.

In optical inspection and stereo microscopy they found that cracked surface get damaged significantly by exposing to the combustion gases and fatigue failure occurs.

Their material analysis shows the chemical composition of the piston as below

Chemical composition of the piston material.

Element	Piston D failed	Piston D	Piston E failed	Piston B	FM-B2
Si	12.96	13.52	13.59	13.62	12.0–14.5
Cu	4.00	4.72	4.48	4.79	3.7–5.2
Mg	0.588	0.605	0.656	0.579	0.5–1.5
Mn	0.119	0.117	0.034	0.097	
Zn	0.073	0.072	0.018	0.059	
Fe	0.501	0.393	0.43	0.413	<0.7
Ni	2.42	2.33	2.31	2.29	1.7–3.2
Cr	0.008	0.007	0.003	0.010	
Ti	0.036	0.032	0.028	0.032	
Sn	0.007	0.007	0.002	0.004	
Al	79.26	78.17	78.4	78.1	

They discussed causes and prevention of piston failure in which major points were covered such as mechanical and thermal over load due to insufficient inter cooling, by over fuelling and preventions methods such as reducing engine coolant temperature set point, various fuel formulation considerations and prevention of future failures.

W. T. Riad, B.S. Hussain, H. M. Shalaby[3] studied aluminium cast piston failures of gas reciprocating compressors. Those compressors were utilized to un an electric motor at of 2500 HP and at 4.16 kV with speed of 865 rpm. They did comparative study of two modified piston failures and compared the results as below

Chemical compositions of the body of the pistons and plugs.

Location	Al (%)	Si (%)	Cu (%)	Fe (%)	Mn (%)
Piston No. 1 (Body)	95.65	3.92	0.30	–	–
Piston No. 1 (Plug)	98.44	–	1.00	0.21	0.17
Piston No. 2 (Body)	94.81	4.75	0.30	–	–
Piston No. 2 (Plug)	99.74	–	–	0.10	–

Mechanical properties of the body of the pistons.

Part	Tensile strength (MPa)	Elongation at break (%)	Hardness (HRA)
Piston 1	225.12	6.74	33.3
Piston 2	224.67	5.27	41.5

The piston no. 2 found to have much lower failure frequency than the piston no. 1.

Similarly, Jan Filipczyk and Zbigniew Stanik also worked to detect early indications of engine piston failures. They examined total 58 engines and recorded some observations as below

Tab. 1. Mileage of examined engines

	Mileage of engine, km				Total number of engines
	< 1000	50 000 – – 100 000	100 000 – – 150 000	> 150 000	
Faulty engines (working)	2	58	100	296	456
Completely breakdown engines	1	12	17	28	58

Piston damages were shown by following chart

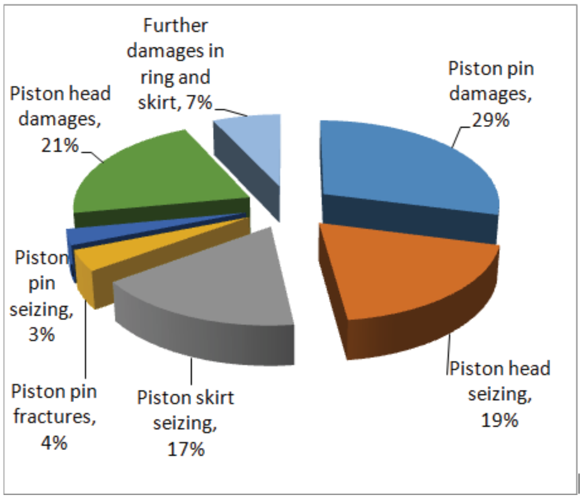

Fig.14 Structure of piston damages

Causes of piston damages were shown by following chart

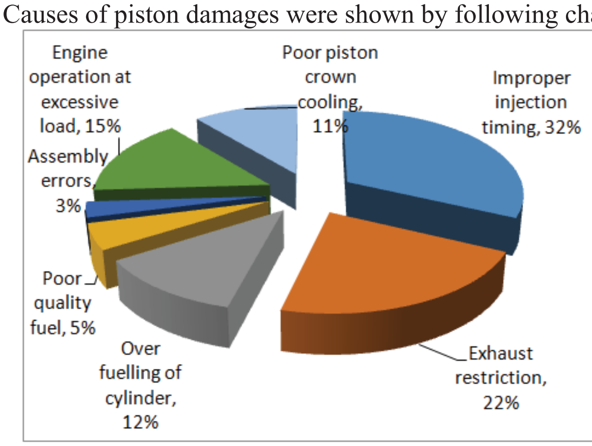

Fig.15 Structure of cause of piston failure

III. DISCUSSION

A piston can fail due to many causes like normal wear during operation, improper maintenance, damage in lubrication system, imbalanced fuel injection timing, defects produces while manufacturing etc. And in most of the cases piston failures can be detected by early diagnosis such as raise in temperature of outlet water, loss of cooling water, change in peak firing pressure, knocking tendency in cylinders etc.

The faults in electronic control system, timing of ignition, can lead to complete destruction of the engine.

The micro-structural analysis has also shown that if there are any faults in piston manufacturing, even the minute ones, they can lead to crack initiation and thereafter to failure of piston.

Piston surface always undergo numerous changes in thermal stress frequently, so if the surface is not properly designed it contributes as a major factor in failing the piston.

IV.CONCLUSION

In almost all the cases, the piston shows early indication of failure, and by checking the engine properly we can detect these signs of failure. Hence the proper checking of engine and piston for failure is necessary. Therefore as a countermeasure the detected faulty parts of engine can be repaired or replaced before failure to increase the durability of vehicle.

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