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Failure analysis of six-cylinder diesel engine

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Abstract: Reliability of engines for longer run has been a prime concern for Maharashtra State Road Corporation Transportation (MSRCT).This projects deals with finding the maximum causes of failure in the TATA-CUMMINS six-cylinder diesel engine and giving recommendation for reducing the engine breakdown The maximum failure was observed for cracking of the cylinder bore, which caused complete engine to be scrapped and causing heavy financial loss to State Transport(S.T.) Workshop, Dapodi, Pune. About 100 TATA-CUMMINS 697 engines were inspected for the engine failure and following results were obtained. Remedies for reducing the failure have been suggested at the end of paper.

Keywords: Causes,Engineblock,Failure,Tata-Cummins-697,

I. INTRODUCTION

Around the world, many different types of fuels such as petrol, diesel, CNG, LPG, electricity is used for running of different kinds of engines. Among the given type of fuels, Diesel is most widely used around the world due to low cost and good efficiency. Therefore maintenance of Diesel engine is top priority. This project is about finding the Failure which occurs frequently in Diesel engines leading to Failure of the engines. By early detection of the cause of the Failures in this engines, we can avoid damage to the entire engine by replacing or repairing the worn out parts. This will save lot of time and money, thereby increasing reliability of the engine.

The MSRTC Workshop in which this project is assigned receives failed Diesel engines which are inspected for defects and repaired accordingly. This project aims at finding reasons which causes maximum defects in engines. So that corrective action can be suggested for permanent elimination of problems are deciding the frequency of its service. Failure rate is usually time dependent, and an intuitive corollary is that the rate changes over time versus the expected life cycle of a system. For example, as an automobile grows older, the failure rate in its fifth year of service may be many times greater than its failure rate during its first year of service—one simply does not expect to replace an exhaust pipe, overhaul the brakes, or have major transmission problems in a new vehicle. From this it can be seen that the most common component failure is that of the engine (41%) and that the most common cause of failure is abuse (29%) [1].The engine we are inspecting here is inline six cylinder engine.

II. METHODOLOGY

The main purpose of this paper is to determine the root cause for the failure of the engine. A proper investigation
regarding the disassembled engine will be done along with the failures will be noted down.
The following investigations was done step by step for the failure analysis.
1 Improper maintenance and repair
2 Overloading and other service abuses.

3 Design shortcomings.
4 Material imperfections due to faulty processing or fabrication.
5 Environment-material interactions.

To determine the cause of the failures, the following method was used:
Appearance – an illustration and brief description of a component that has failed due to a specific cause.

- Damaging Action – what actually damaged the component under the conditions which were present?
- Possible Causes – a listing of those factors capable of creating the particular damaging action.
- Corrective Action – the action that should be taken to correct the cause of failure.

III. INVESTIGATION OF FAILURE OF DIFFERENT COMPONENTS OF ENGINE.

ENGINE [13]

- Model CUMMINS 6BT 5.9 TC
- Type Water cooled, Turbo charged diesel engine

• No. of Cylinders	6 inline
• Bore/Stroke	102mm x 120 mm
• Capacity	5883 cc
• Max. Engine Output	93.5 kw (125.3 HP) at 2500 rpm
• Max. Torque	410 Nm (41.8 mkg) at 14001700 rpm
• Compression ratio	17.6 : 1
• Firing Order	1-5-3-6-2-4
• Air Filter	Dry Type remote mounted
• Oil Filter	Spinon full flow paper type
• Fuel Filter	Pre & fine filteration with water separator
• Fuel Injection Pump	MICO “A” Type inline
• Governor	Built in centrifugal type
• Turbo Charger	HOLSET
• Capacity of Cooling system	24 liters (total)
• Coolant Water & Ethylene glycol,	ratio 1:1 premixed
• Crank case oil	Max. 14.3 Litres
• Capacity	Min. 12.3 Litres
• Weight of Engine	413 kg (Dry): With flywheel and alternator but without air compressor and starter
• Radiator frontal area	2887 sq. cm.

3.1 Failure of valve

The working life of the valves is in proportion to the other engine components. The fuel injection, lubricating, cooling and air filter systems, as well as the operation of the equipment (vehicular, agricultural, stationary,
industrial or naval), when done in normal working conditions, lead to the normal wear of the valves. The failures observed are as follows:

- Valve stem scuffing
- Valve seat wear
- Valve fractures and breakages.
- Fracture at the keeper groove region with the stem
- Crack at valve seat region

3.1.1 Causes of failure.

- Incorrect alignment between disc/spring, guide and valve seats: The misalignment results in excessive clearance in certain regions and in others compromises the clearance between the stem/guide, to the point of causing its scuffing

- Incorrect clearance between the stem/guide and the oil/seals: Both the stem clearance with the valve guide, as well as incorrectly applied oil/seals, jeopardize the oil film which exists between the valve stem and the valve guide, resulting in scuffing, followed by material dragging.
- Inadequate engine operation: When the engine works under inadequate overload/ speed for the working conditions, the lubricating oil film, which exists between the valve stem and the guide, can be disrupted
- Incorrect synchronization.: The valves interference in the piston top due to incorrect synchronization, can cause bending of the stem, resulting in inadequate clearance between stem and guide. This problem can also jeopardize the sealing between the valve and the valve seat in the cylinder head
- Combustion residues: Carbon residues ,generated by the combustion of the mixture, when deposited on the lower part of the valve stem, can jeopardize the clearance between the stem/valve guide in this region and start the seizing.

3.1.2 Corrections

- Check the alignment between the components: spring/disc/valve guide/seat.Clearance and correct applications shall be checked;
- Check synchronization and avoid excessive engine speed;
- Follow the engine manufacturer's recommendations, with respect to the engine's regulation of the fuel injection system .


Fig.3.1a wear at seat region


Fig.3.1b scuffing at valve guide


Fig.3.1c breakage of valve

3.2 Failure of engine liner

Liner is a cylindrical sleeve fitted in cylinder block. With working of engine the liner suffers changes in dimensions and properties,this leads to premature failure of engine. Following types of failures were observed:

- Corrosion, scales, cavitation.
- Circlip explusion
- Distortion in shape due to irregular machining of cylinder block

3.2.1 Causes of failure

In engines running with dry cylinder liners, existing irregularities of the engine block housing, due or not due to machining, can cause:

- Irregular contact between the cylinder liner and the housing can impair the thermal exchange between the two and, consequently, can result in scuffing between the piston and the cylinder liner;
- Reduction in sealing effect of the piston rings, with possible increase in lubricating oil consumption or even blow-by (gas leakages) to the carter.
- Chemical corrosion - is the result of an attack to the cylinder liner iron, done by the oxygen present in the water, forming iron oxides or rust. This phenomenon is accelerated by higher oxygen content in the water, due to faulty sealing of the cooling system, which allows air to enter through hoses and connections, defective caps, low water level, among other things.
- Cavitation - During the engine running, the cylinder liners are submitted to pulsations, which are the consequence of the air/fuel combustion in its interior. When the combustion occurs, the cylinder wall expands fractions of a millimeter, due to the pressure of the expanding gases against the inner walls. This cause perforation of the wall.[3]

3.2.2 Corrections

- Keep the dimensions of the cylinder liner seat at the engine block according to recommendations given by the manufacturer/producer.
- Follow the engine manufacturer recommendations when fitting the cylinder liners at the engine block.
- Machine correctly the cylinder liner seat at the engine block.
- Keep all cooling system components (reservoir and/or radiator cap, hoses and clamps, thermostatic and pressostatic valves, water pump, etc.) in normal running conditions, compatible with the engine.
- Always use the corrosion inhibitor additives and the anti-freezing fluids, as recommended by the manufacturer/producer of the engine

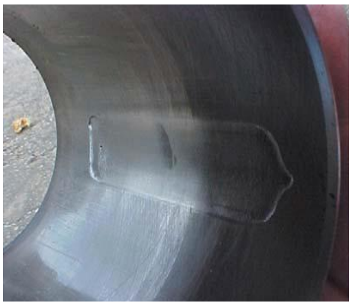
Fig.3.2a circlip explusion


Fig.3.2b cavitation with scales


Fig.3.2c scuffing on inner side

3.3 Failure of bearings

A major portion of the normal bearing wear occurs during the engine start or during its initial operation. After that, the wearing rate is considerably reduced. Under adequate preventive maintenance, only the very small and non-retained particles will be present in the abrasive process at the bearing surface. Under these circumstances, the bearings will have a fairly long life cycle.

Normal wear is generally indicated by a small quantity of scratches on the bearing surface, resulting from small particles, which haven't been retained by the oil filter. The scratches present no problem, unless they reach the base-alloy. If operation continues, these scratches might even disappear. Following failures were observed:

- Corrosion
- Hot short
- Generalised fatigue
- Insufficient oil in bearing
- Excessive clearance

3.3.1 Causes of failure

- Corrosion is a chemical attack at the bearing alloy, originated by components that exist in the lubricating oil. These components can be strange to the lubricating system, such as water, or can be produced during the engine running, as a result of the lubricant's oxidation.
- The hot short by heat condition is a consequence of excessive heat increase in some bearing zones. The excessive heat can be the result of insufficient radial clearance, impurities, crankshaft journal deformation, or misalignment of the engine block and/or the crankshaft.
- Fatigue damages can be caused by abnormal and cyclical stresses, in other words, by peak load running condition.
- The erosion by cavitation is a type of damage caused by the instantaneous explosion of low pressure oil vapour bubbles, against the anti-friction alloy of the bearing. Loads on an engine bearing fluctuate rapidly, both in intensity and in direction, during an engine's running cycle. This results in rapid changes in hydrodynamic pressure of the bearing oil film.[1]

3.3.2 Corrections

- Change lubricating oil according to specifications given by the engine manufacturer.
- Fit the bearings with the clearance recommended by the engine manufacturer;

- When changing lubricating oil, observe absolute cleanliness and when assembling the engine, eliminate all machining residues and any existing dirt;
- Before fitting new bearings, inspect carefully all journal dimensions of the crankshaft.
- If the bearing's operational life has been lower than expected, check the temperature and load conditions in which the engine has been running, and eliminate eventual existing defects.


Fig3.3a corrosion


Fig3.3b hot short


Fig3.3c generalised fatigue

3.4 Failure of crankshaft

Crankshaft is one of the main components of engine it converts liner motion to rotating motion and rotates shaft. Crankshaft failure arises mainly due to overloading of vehicle, not replacing bearing on time, not changing the engine oil for long time, hairline cracks during forging of crankshaft etc. The major failure observed are as follows:

- Excessive wearing of the journal
- Cracking of crankshaft

3.4.1 Causes of failure

- Fatigue failure: Majority of steel crankshaft failure occurs because of fatigue failure, which may originate at the change of cross-section such as at the lip of oil hole bored in the crankpin.
- Insufficient lubrication**:** If the lubrication of bearing in the crankshaft is starved, it may lead to wipe out of the bearing and failure of the crankshaft.
- Over pressurised cylinder**:** It may happen that there is hydraulic lock (water leakage) inside the liner and due to extreme pressure the crankshaft may slip or even bent (if safety valve of that unit is not working).
- Cracks: Cracks can develop at the fillet between the journal and the web, particularly between the position corresponding to 10 o'clock and 2 o'clock when the piston is at T.D.C.[2]

3.4.2 Corrections

- Alignment of crankshaft should be checked regularly.
- Bearings should be replaced at adequate timespan, all bearings should be bought from same manufactuer as different manufacturer use different materials.
- Clean and proper grade of lubricating oil should be used in engine,oil should be regularly checked for its PH value to ensure that it is not acidic in nature.
- Since the bedplate and the foundation bolts acts as a base for the proper support of the crankshaft both these should be kept in order. The bolts should be properly tightened while a rigid bedplate should be used which is of course more of a design issue rather than in the hands of the engineer on duty


Fig3.4a cracking of crankshaft


Fig3.4b wearing of journal

3.5 Failure of gasket

As gaskets go, the head gasket is probably the most important within a car. Its job is to seal the combustion chambers and the coolant and oil passages between the engine block and the head. These are very important areas to keep sealed and apart from each other as the combination of unwanted coolant entering a cylinder or the oil supply is a recipe for disaster. A head gasket therefore is generally designed to never fail or need replacing, with the long bolts of the engine block squeezing it in place to a desired tolerance[10]. The failure are as follows;

- Blown to outside coolant leak
- Blown to outside oil leak
- Compression leak to cylinder and blow-by
- Compression leak to coolant overheat

3.5.1Causes of failure

- One cause of head gasket failure is pre-ignition: As fuel is combusted at unwanted times during an engine's cycle, large pressures can occur within the cylinder head as the engine begins to work against itself. These spikes in pressure can put strain across the head gasket, causing it to fail[13].
- Overheating is another possible cause, as the gasket is placed under conditions over and above its design criteria, resulting in warping and permanent damage. This can be purely down to coolant leaks from a corroded radiator or dodgy piping, or it could be pre-existing failures in the head gasket.
- Poor gasket design can also lead to premature failure of gasket.

3.5.2corrections

- Proper coolant levels should maintained in the radiator, this will allow engine to cool properly and prevent failure
- For gasket to fit properly the surface of the engine block and head should be machined smooth and flat .
- The head bolts used to secure a gasket are important in maintaining the cylinder seal. A deformed thread in the engine block surface can destabilize the gasket's placement. Similarly, the bolt itself must be in good shape to increase the chance of a reliable seal

Fig.3.5a worn-out gasket

Fig.3.5b blown gasket

IV. CONCLUSION

From the survey of automotive component failure, it is found that failure occurs mainly from abuse and lack of maintenance, which are unavoidable. If the vehicle is maintained properly, there should be a substantial reduction of the failure. Some area must have to maintain from service point of view, these are- maintain proper ignition timing and valve timing. Timely change the engine oil, if vehicle not run up to specified km in that condition consider the time period which play very important role. Fixation of engine compartment with sufficient space especially backside of the engine for better heat dissipation space should be more. In condition of cold starting engine sudden acceleration must be avoided.

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