Report of main engine damage on xxxxxxxxxxxxxxxxx

Introduction

Breakdown on port side main Engine, happened on board m/v xxxxxxxxxxx on February xxxxxxx, when Ship was in xxxxxxxxxxxx passage in xxxxxx, at xxxxxx local time (xxxxx, UTC).

This survey has been done with assistance of: Chief Engineer – xxxxxxxxx, 2nd Engineer – xxxxxxxx and 3rd Engineer – xxxxxxxxxxxxxxxx

Main Engine is MAN B&W, type 9L32/40, ser No. xxxxxxxxx 750 rpm, 4320 kW, built 2002, on board newbuilted Ship from xxxx.

As the damage occur on February xxxx and this survey has been performed on February xx, starting from 8:45 LT , ended at 12:30, all damaged parts have been taken off from the main Engine and replaced with new ones. Damaged cylinder cover, cylinder liners and piston are placed in Ship's workshop. Damaged turbine wheel, yesterday has been transferred to MAN repair workshop in Singapore, so it was not surveyed nor Photos taken. Damaged parts found on board (in Ship's workshop), have been inspected with Photos taken.

Damaged engine parts are: *cylinder No. 7* and *the turbine* as part of turbo charger. On cylinder No. 7 damaged parts are: cylinder cover with valves, topland ring, cylinder liner, piston and connecting rod. On the turbine side of turbo charger damaged are: turbine wheel and stator nozzle. Air intake side (the blower side) of the turbo charger, is (as per crew statement) undamaged and in good condition.

Traces of damaged parts were found in charging air manifold, together with lub oil. Damaged parts, detached from cylinder No. 7, have been found: inside cylinder No 7, inside exhaust gas manifold and inside turbine part of ME turbo charger.


ME charging air side


ME view from cylinder No 9


ME exhaust gas side

Finding, description of damaged parts

Cylinder cover dismantled from Cylinder No7, has been found damaged in following areas: part of compression chamber, all 4 valves (2 air intake valves and 2 exhaust gas outlet valves) and one exhaust gas valve guide (liner). Compression chamber is damaged by metal pieces found between piston crown and cylinder cover when engine was running and metal piece was pushed by piston to cylinder cover. That metal piece (later will be explained what piece is that) was of greater dimension (thickness) than compression chamber height (when piston reaches TDC). Piece bigger than compression chamber height pressed between piston and cylinder cover, caused surface deterioration of cylinder cover and piston crown, as it could be seen on Photos below. Main engine operates with 750 rpm, so it is to conclude that metal piece has been "forged" by piston and cylinder cover. Cylinder cover was anvil part of "forging" process.

Damaged cylinder cover, charging air side

Damaged cylinder cover, exhaust gas side

Valve crowns broken and rotated

Cylinder cover valve seats

Cylinder cover bottom side

Exhaust forward valve has been found with valve crown missing, stem buckled, with fin part still on valve's stem.
Exhaust rear valve has been found with valve crown broken, rotated for 90° from original stem vertical position and pressed in valve seat; also with stem buckled and fin part separated from the stem.
Inlet forward valve has been found with broken valve crown, rotated for 90° from original stem vertical position and pressed in valve seat.
Inlet rear valve has been found not broken, just with buckled stem and punched valve crown bottom.
To conclude, only 1 valve (fresh air inlet rear valve, has been found with valve crown still connected with valve's stem.
Other 3 valves have their crown detached from valve's stem.
Valve opening pushers have been found slightly deformed (about 1,5 mm bended) on lower part (bigger diameter).


Damaged valves stems, air intake side


Damaged valves stems, exhaust gas side


Damaged air inlet valves


Valve air inlet description


Damaged exhaust gas valves


Exhaust gas valves description


All 4 damaged valves


Valves crowns


Valves opening pushers, slightly deformed

Piston crown was another (hammer) part of "forging" process inside cylinder No. 7. Piston crown has been found broken in the middle because wall thickness is the smallest. On outer diameter similar surface deteriorations are noted as on cylinder cover. It is clear that metal part when was pressed between piston and cylinder cover, squeezed out some parts of piston crown surface, same as on cylinder cover.


Damaged piston, top view


Damaged piston, side view


Damaged piston with broken piece of connecting rod

Topland ring (ring between cylinder cover and cylinder liner) has been found damaged on inner edges. It is clear ring's material is also squeezed out on several positions around ring.


Damaged topland ring, top view


Damaged topland ring


Local damage on topland ring

Cylinder liner has vertical scratches. Scratches are randomly placed around liner. Depth of scratches is less than 1 mm. Those scratches occurred when small detached metal parts were placed between moving piston rings and stationary cylinder liner.


Damaged cylinder liner


Scratches on cylinder liner


More scratches on cylinder liner

Connecting rod has been found damaged on it's top part above piston pin axe. Top part of the Rod is broken and detached from connecting rod. (*Broken part is visible at the top of damaged piston, on the most right Photo in Piston section).*

Turbine nozzle has two types of damage.

One type are erosion cavities on the fins, which are most likely result of use, not related to this damage. As exhaust gases pass through nozzle blades, sometimes with turbulent streaming flow, cavities occur as a result of local pressure drop on the spot.

Other damages resulting with part of fins ripped off or fin blades bended, are related with this damage. Those damages occurred when metal parts from cylinder No. 7 hit nozzle fins, enter into turbine and as a result of centrifugal force were blown back to the nozzle fins. Small parts but with great velocity (as turbine rotates with 20.000 rpm), result with big enough kinetic energy which could damage nozzle fins in such way.

Damaged turbine nozzle

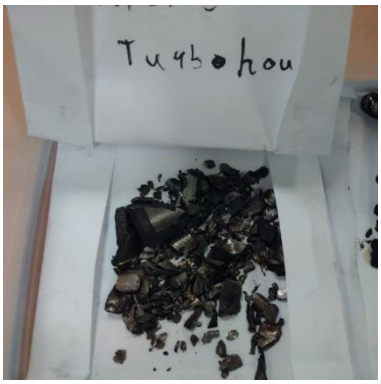
Damaged fins of the nozzle

Broken fins of turbine nozzle

Turbine has not been found on board so it has not been inspected.

Broken parts from cylinder No.7 have been found through exhaust line manifold and inside turbine housing. Heavier parts didn't reach turbine, but lighter and smaller parts did reach turbine, causing earlier explained damage of turbine wheel and turbine nozzle fins.

Parts found in exhaust line, before turbine



Parts found inside turbine housing

Broken parts from piston middle area

Opinion for cause of the damage

Cylinder No.7 has to be pointed as starting point of the damage. No foreign parts nor any indication of the damage have been found in system before cylinder No.7. Charging air system has been found clean from all defects. Lub Oil and few detached parts have been put there through air intake channel. It would be mostly detached parts from air intake valves.

Following air flow direction, it is obvious first sign of the damage is noted inside cylinder No. 7. As per crew statement they heard strange noise from cylinder No.7, at 15:13 LT. In time noise became even greater so crew decided to stop PS main Engine at 16:16 LT. Later, after dismantling cylinder cover they found all the damages surveyed today. Obviously damage started with piston hitting some metal part inside the cylinder.

Having in view all damages, it might be concluded piston got in contact with only one moving part inside cylinder (except piston itself), valves. The question is: how piston can get in touch with valves? Normally piston movement is synchronized with valves opening and closing sequences, by camshaft. I have measured cam on camshaft, 27 mm. So, valve movement from close to open position is 27 mm. Then crew has put piston on TDC and have measured allowable distance for valve movement. It was measured also 27 mm. So, normally it is very difficult (if measurement was not 100% accurate) or impossible (if measurement was accurate) for piston to get in touch with open valves in any possible situation. Only with fully opened valve (what is extremely small possibility), piston could get in minor contact with a valve. Such impact from piston to valve (fully open), would be minor and could not lead to such kind of great damage. Piston would just push valve up, probably with no noticeable damage at the time. If valve would had been in partly opened position (what could be possible for a reason, like stuck or dirt) piston couldn't get in contact with partly opened valve. To conclude, it is highly unlikely, almost impossible, piston to reach any valve in movement.

Camshaft

Measuring cam height

Cam height 27 mm

27 mm path marks

From MAN technicians (as per crew explanation), idea was forced that problem was in wrongly adjusted clearance between valve top and pusher. It was recorded upon valve casing opening, adjustment Nut on both valves was found loose. Loose Nut could not create precondition for this damage. It could make only shorter valve movement path, haveing for consequence to eliminate any possibility for piston-valve contact due to movement path shorter than 27 mm, depending how much greater clearance was.


Valve opening arrangement


Valve pushers with springs


Rocking arms for valve opening

My point of view was this damage started with brake down of forward exhaust valve's crown. Once the crown was broken and detached from valve stem, it was moving randomly free inside cylinder No. 7. being hit from piston toward cylinder cover. Every time piston reached TDC, detached valve's crown had been pressed by piston to cylinder cover, performing actually forging of the detached crown. Piston was acting as a hammer and cylinder cover as anvil. As a result now it is square shape metal piece showed on Photos below. In support for described forging process description, sharp and hard free laminates are placed around below showed piece, which it typical and common for all forged pieces.


Bigger part of exhaust forward broken crown


2 main parts of forged valve's crown


Comparison of damage exhaust forward valve with new one

During "forging" time, forged piece (detached exhaust forward valve crown) was compressed 750 times in 1 minute, causing all damaged on cylinder liner, piston and other damaged parts. The whole process lasted for about 63 minutes, but not always with same engine revolution (upon noise herd, crew reduced engine speed at some point). When it happened to be placed between piston and other valves crowns it damaged other valves. It could be that other valves remained open due to stuck by other metal parts and then would be hit and pressed by piston and detached crown in between. That is possible explanation for valves damage. Later on small parts were blown by exhaust gas through manifold and eventually reached turbine, damaging turbine blades and nozzle fins.

In order to support assertion that big forged piece in actually detached exhaust forward valve's crown, I measured volume of forged piece comparing with volume of original new exhaust gas valve crown. A pot with proportion scale was taken, filled with 1000 ml water. List was checked and it was 0. Forged piece was placed in the pot, giving new reading of 1100 ml of water. So, volume of big forged piece was 100 ml or 0,78 kg of weight. After, new exhaust gas valve was placed in the same pot until reading reached 1100 ml. It had to be submerged down to the position showed on the Photo in table below (around 55 mm from valve's bottom). It is to conclude, big metal piece together with another smaller piece (showed in Photo in "my point of view" section) and other much smaller pieces, undoubtedly show they are from detached exhaust forward valve's crown. Having it proved, before described damaging process is right one, in all aspects.


Pot with proportion scale


Forged piece volume measurement


New valve volume measurement

Almost the same volume of material is in missing parts of damaged exhaust forward valve and new exhaust gas valve as it is showed on photos below.

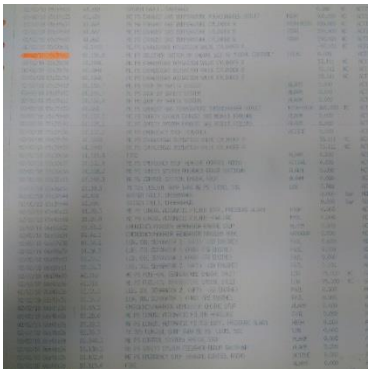
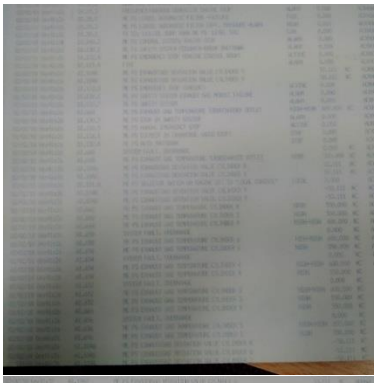
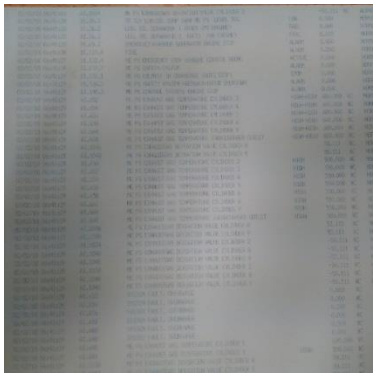
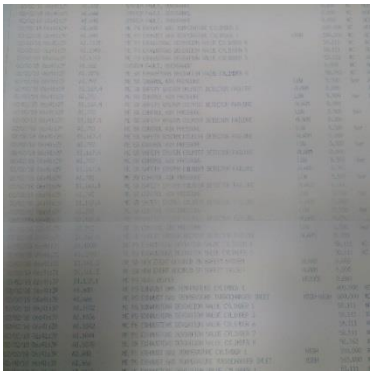
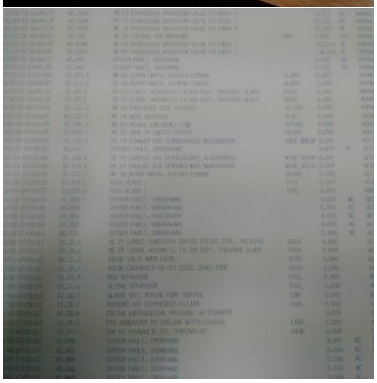

Damaged exhaust forward valve and new one


Closer view


Restoration with compare

Some pieces have same polished surface as new exhaust valve seating surface.

Alarm list printed for time of damaging event. Original must stay on board.

What could be the reason for such valve break down? The valve crown broke on position where diameter and shape changes from bigger to smaller. Also it occurred before fins for valve rotation. At that area exhaust gas flow has obstructions, shape and diameter changes so therefore is can't be nice laminating flow but most probably spot turbulent flow occur. At spots with turbulent flow, various problems could take place: material erosion, local temperature and pressure drop… Therefore, that position, before fins (looking in flow direction) could be noted as "weak point". Such local gas flow parameters together with possible material defect on the position and high operating temperatures, after years in use, could lead to such breakdown. In order to be sure regarding possible material defect inside valve's stem, it would be necessary to perform metallurgical testing (acid treatment) together with microscopically examination of present surface of breaking. Even the surface is now contaminated with great number of impacts in process of "forging", all the same it would be prudent to do that not complicated examination, in order to physically verify all written.

Knowing what and how has happened during damaging process, some other points should be stressed out with other possible negative affect to main engine. As piston performed hammering process, at TDC huge forces have been transmitted through piston, connecting rod, big-end bearing to the crankshaft. Piston, connection rod and big-end bearing have been changed. But several examinations would be necessary to perform on the crank-pin and main bearings for cylinder No.7. Due to extremely big impulse forces, imposed 750 times per minute on the crank-pin, there might be possibility for crank-pin deformation or other kind of crank-pin damage. Therefore detailed surface examination together with crankshaft deflection and general position measurement is necessary to be performed. If crankshaft has been damaged (closer to the surface, more dangerous) that could lead to later possible serious danger for ME itself, endangering Ship's safety in total.

Other damage related Photos


Scratches on cylinder liner

Detached pieces found in exhaus manifold


Damaged turbine nozzle


Damaged topland ring


Bended spring pusher for inlet valves


Bended spring pusher for exhaust valves


Measured 27 mm cam heigth


camshaft


New exhaust and inlet valves


Valve's crown after forging


Detached fins piece from exhaust rear valve


Pair of new valves

Exhaust fore valve's stem

Damage exhaust fore and new valve

ME turbine

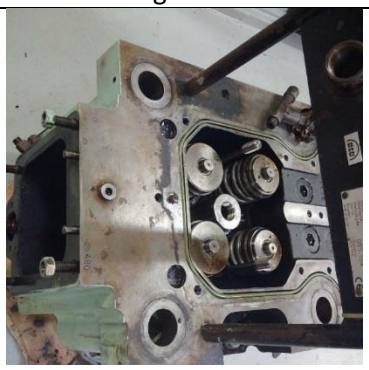
ME blower

ME charging air manifold

ME exhaust gas manifold

ME view from open end

Damaged cylinder cover with stems in place



Damaged cylinder cover side view

Damaged cylinder cover with spring pushers

Damaged cylinder cover with pushers, side view

New installed No.7 cylinder cover

 Proportion scaled pot, list 0	 The pot filled, 1000 ml water	