SHIP MACHINERY MAINTENANCE

- Introduction and Motivation
- Ship Machinery, Ship Power Plants
- Machinery Breakdowns
- Maintenance Methodologies
- Diesel Engine Maintenance (ME)
- Shaft lines - Stern Tubes
- Purifiers
- Pumps (centrifugal)
- Valves
- Heat Exchangers
- Maintenance Information and Documentation
- Design for Maintenance – some considerations
- Questions/Discussion
Introduction and Motivation

A ship afloat is a world in itself.

Variety of machinery on board ship

Every machine has shortcomings, some may never appear until put to real life service.

Almost quarter of maritime accidents are caused by machinery failure (IMO).

Every machinery gives signs before it fails.

Maintenance minimizes failure severity.
(Aims to avoid failures before anticipated service time)

Prevention costs less than damages incurred.
## Ship Power Plants

<table>
<thead>
<tr>
<th>Plant</th>
<th>Oil fired steam turbine</th>
<th>Low Speed Diesel</th>
<th>Med. Speed Diesel</th>
<th>High Speed Diesel</th>
<th>Aero Derivative GTs</th>
<th>Heavy duty simple cycle GTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power MW per unit or engine</td>
<td>Upto 60</td>
<td>0.3 to 100</td>
<td>1 to 25</td>
<td>Upto 4</td>
<td>Upto 50</td>
<td>Upto 40</td>
</tr>
<tr>
<td>Typical ships</td>
<td>LNG, Older ships</td>
<td>Most merchant ships</td>
<td>Merchant ships, Naval auxiliaries</td>
<td>Small ships of all types</td>
<td>Fast ferries Naval ships</td>
<td>Some fast ferries</td>
</tr>
<tr>
<td>Current status</td>
<td>Unlikely for new ships</td>
<td>Most common</td>
<td>Increasing use in merchant ships</td>
<td>Dominates small ships</td>
<td>Dominantes naval ships</td>
<td>Increasing use in fast ferries</td>
</tr>
<tr>
<td>Minimum fuel quality</td>
<td>Residual</td>
<td>Heavy blend</td>
<td>Intermediate blend</td>
<td>Light distillates</td>
<td>Light distillates</td>
<td>Selected light blends</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>High</td>
<td>Lowest</td>
<td>Lowest</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Maintenance on minimum quality fuel</td>
<td>Least</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low at sea Overall High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

*Source: Ship design & construction – Thomas Lamb*
Machinery Breakdown

General reasons:

- Equipment unfit for marine environment
- Water ingress (oil, fuel, machinery, etc)
- Marine organisms in systems (heat exchangers, pipes, valves, filters, sea chests etc)
- Not maintained properly (ill defined procedures, design flaws)
- Operator mistakes
  - Tired (less crew, more work)
  - Complicated user-interface

Particular reasons related to maintenance that introduces defects in machinery
Contraint of time, incomplete knowledge, sheer incompetence

Almost 60-70% failures occur after the maintenance has been done
(what does this indicate?)

Examples:
- Filters change but O-rings missed
- Fan/Motor insulation checked and windings connected wrong
- Wrong tightening of Staybolts, greasing forgotten etc
Machinery Maintenance Methodologies

Preventive Maintenance

Various names, PMS; MMS; CMMS

- Routine
  + Greasing, Lubricating, level checking (tanks, sump etc),
  + operator checks (buttons/switches, valves/flaps, lamps, item location etc)
  + Measurements (guages, clearances, volts/current/frequency, pres./temp)

- Planned
  + calender time (every week/each month, quarterly etc, annualy, bi-annualy)
  + operating hours

Condition Based

+ Almost all CBM are Inspections
+ VA (vibration analyses), Oil analyses (lube, hydraulic etc), Visual (endo/boro)
+ Performance based (deviation from reference datum), database building
+ Also various NDE techniques – ultrasonic thickness/leak detection etc.

Breakdown maintenance

+ An old maintenance philosophy - Fix it only when its broken e.g. filters
+ Despite all Preventive Maintenance, breakdown does occur sometimes
+ Attributable causes – engineering, human factors, operation beyond limits etc.
Main engine maintenance – continuous process

Staggered and manageable maintenance at each port (e.g. one cylinder o/h at a time!)

Seasonal trade ships – restrict planned maintenance to layup period

Major maintenance involves disassembly – Lifting arrangements is a necessity
(for example: Cylinder head lifted, piston pulled, liner inspected, wear measured, recondition piston inserted, reconditioned head installed)
+ Large engines – gantry crane overhead (electric, pneumatic operation)
+ Smaller engines – lifting beams with trolley (also DEs)

Component landing/storage areas, access routes/room must be provided at design stage. Height over main/auxiliary engine, main engine may require trunk above main deck

Oceangoing ships – considerable spares/tools stored/installed near engines
Selected spares kept in overhaul/partly assembled condition – ready for use.
For e.g fully outfitted cylinder head available for installation

Auxiliary engines maybe taken out of service while sailing – often technicians travelling with ship for that very purpose
Diesel Engine-Maintenance

**Preventive**
Schedule usually set by engine manufacturer (list of tasks based on op. hours)

For example: (Wärtsilä L46)
TBO (time between overhauls)
Centrifugal filter cleaning 250h, *Crankshaft deflection*: 6000-12000h,
Cylinder head overhaul 12000h, Big end bearing inspection 1@12000h, all @36000h

Expected life
Exhaust vv 12000h, Inlet vv 36000h, Cylinder liner 60000h, piston rings 12000h

**Condition based (trend analyses)**
key operating parameters tracked until they reach limits/show sharp trend
As number of monitored parameters increase – CBM will become more applicable

Parameter example:
cylinder exhaust temp, T/C rpm, Compression pressures, Diff. Pressure across filters/coolers,
lube oil analyses, SFC etc

Advanced techniques: increasingly applied in trend analyses
Example: electronic pressure sensors fitted to cylinders, embedded wear detectors for
cylinder/piston.
Diesel Engine Maintenance

Routine Maintenance/Inspection
Check for leakages, lube oil level makeup, important parameters (temperature, pressure, rpm) abnormal noise/vibration, turbocharger oil, fuel rack and linkages free and not obstructed, crank case doors, inlet/exhaust pipes etc. *UMS and highly automated spaces do require physical visits.*

Manhours (time and person required for a particular job)
Example: SEMT-Pielstick PC2.5

<table>
<thead>
<tr>
<th>Dismantle-refit Part</th>
<th>Mechanic level &amp; number</th>
<th>Manhours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinderhead (1750kg)</td>
<td>1 Mechanic+1 assistant</td>
<td>3h</td>
</tr>
<tr>
<td>Piston+Conrod (1050kg)</td>
<td>1 Mechanic+1 assistant</td>
<td>2:30h    (head removed)</td>
</tr>
<tr>
<td>Cylinder (2600kg)</td>
<td>1 Mechanic+1 assistant</td>
<td>1h       (head &amp; piston removed)</td>
</tr>
<tr>
<td>Bigend bearing</td>
<td>1 Mechanic+1 assistant</td>
<td>2h</td>
</tr>
<tr>
<td>Injector (20kg)</td>
<td>1 Mechanic</td>
<td>0:30h</td>
</tr>
<tr>
<td>Main Bearing</td>
<td>1 Mechanic</td>
<td>1:30h</td>
</tr>
<tr>
<td>Exhaust valve (120kg)</td>
<td>1 Mechanic</td>
<td>1:30h</td>
</tr>
<tr>
<td>Cleaning and measure</td>
<td>1 Mechanic</td>
<td>1h</td>
</tr>
<tr>
<td>of liner wear</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lifting of piston and cylinder liner large marine engine (Jib crane)

Source: Man B&W tech. paper
Example and tradeoffs
Prior fuel system maintenance fuel shifting from HFO to MDO until all fuel lines replace HFO with DO simplifies maintenance. (1/2 an hour on large engine)

When engine is shut down, indicator cocks at cylinders, drain valves at air coolers, air manifolds and exhaust manifolds opened and left open – Any Abnormality can be detected first hand!

Crankcase doors must never be opened until crank is cooled down – danger of explosion

Low oil temperatures may indicate high differential pressure at filters even alarm

Running fluid levels are different than static (turbo charger, sump, tank etc)

Vital indicators at average human eye level (not always!)
Shaft lines – Stern tubes

Propeller shaft must be inserted through stern tube or strust bearing – flange at one end only

Stern tubes bearings are lubricated by Oil or Seawater

Oil (preferred, as wear rate is less and alignment is not disturbed), or seawater (replacement after several years, more friction, shaft bronze coated against corrosion)
Shaft lines – Stern tubes

Propellor and stern-tub shafts withdrawn for inspections @ 3-5 years intervals (dry dock)

Typical Arrangement - (prop. Shaft drawn inbaord)
Fairway and propellor nut removed, propellor released from tapper (shaft), hanged from padeyes welded to hull

Last section of line shafting along with bearing is removed using overhead lifting gear (provided) and set aside on exclusive landing areas/cradles

Seals, packing glands cleared away, lifting gear/wood blocking used to support the shaft as it is pulled inboard by chainfall.

Repair or replacement transport by hole cut in side shell (area designated for this propose)
Shaft lines – Stern tubes
Shaft lines – Stern tubes

Other Arrangement – (Strut bearing arrangement)
Propellor freed and supported, fairwaters removed,
Lifting gear takes weight of shaft off the strut bearing,
Strut bearing removed from the strut by sliding it along the shaft. Which gives radial clearence in the strut housing for the shaft to be tilted, pulled foward and lowered to dock floor and placed on cradles
Inboard couplings disconnected, packing seals/glands cleared
Stern tube pulled outboard using lifting gear and chainfalls
Purifiers (separators, centrifuges)

Even the self cleaning purifiers need occasional cleaning. Non-self cleaning ones need frequent cleaning. Sludge/wax/solids cleaned from discs manually.

Sludge disposal timer (self cleaning), RPM, correct temperature of fluid are important

Cleaning intervals determined by experience.
In general: HFO purifier cleaned weekly, LO and MDO purifiers cleaned Monthly

LO purifiers on propulsion engines stopped after 12-24 hrs running since engine shut down

Alcap Purifiers

Source: Alfa-Laval Brochures
Pumping Systems

Centrifugal pumps:
Impellor never touches casing
Small clearances, Eroded by liquid

Many pumps have wear rings both at impellor and in casing, replacement restores performance

Pump shaft sleeve and seal prevents leakage, but wear out over time
Seal/shaft sleeve renewal restores performance

Suction and Discharge Pressures
First hand performance indicators

No flow running boils water, cavitation and serious pump damage may occur
Valves

Function describes name (stop, check, relief, regulating, reducing etc)

Basic Maintenance
External leakages: Renew glands/pack/rings/seals

Unable to close tightly: damage, foreign matter trapped (seat/reseat is a good practice)

Valve subject to throttling: erosion/cutting of disk or seat. GATE VALVES disk/seat difficult to repair, not recommended for cracked flow

Globe valve seats/disks repaired by replacement or lapping

Stuck open/closed: jam when hot, closed only to stop flow, reassembling: anti-sieze compounds

Gaskets material – must withstand temperature, chemically stable with fluid

Copper gaskets can annealed and be used again, packing must be replaced, soft gasket coated with sealing compounds
Bulk fluid flow outside tubes/plates,

By design, in most installations sensitive fluid has more pressure than bulk fluid e.g. oil cooler

Loss of performance due to fouling (Micro organisms, small fish, mud, sand etc)

Manual cleaning /canning, chemicals etc
Aim – Avoid excessive repairs and unnecessary early replacements
- Minimizes downtime – maximizes efficiency of equipment/system

Correct database of what is installed: (Devil is in the detail)
Make, Model, Serial No., Manufacturer, Original cost, Estimated Life, Complete Vendor information, Warranty period, Location, Maintenance schedule, Repair history, Maintenance history, Complete maintenance procedure
Maintenance Information

From Maintenance point of view, every system/machinery must have;

- Scheduled maintenance intervals
- Equipment operating log
- Lubrication procedures and schedules
- Repair and maintenance parts details, fields of notes, diagrams, photographs
- Complete listing of instrument required during maintenance procedures
- Maintenance personal (level of competence and manhours expected)
- Repair and maintenance history recording
- And above all, universal and simplified technical vocabularies

Much of the information be included in Job Information Card.
Old system, physical paper/cards
In new systems Job information is provided in databases (computers)
Major responsibility, (yet a gray area)
IACS, (international association of classification societies) guidelines;

Categories of Information – Should be arranged according to use

➢ Purpose and planning (what is the system/equipment for)
➢ Handling, Installation, storage and transit (how to prepare it for use)
➢ Technical description (how it works)
➢ Operating Instructions (how to use it)
➢ Fault action list (how to keep it working)
➢ Maintenance Instructions (what is done and when)
➢ Parts list (what it consists of)
➢ Modification Instructions (how to change it)
➢ Disposal Instructions

CHIRP (confidential reporting)- reports
Manuals hard to understand 50%
Instructions inadequate 50%

Operator feedback is very important!
Design for Maintenance!!

Ship profile and manning
Dictates maintenance time available and manhours

Access points for visual inspections or conduct of maintenance
Should be Practical and take into account various machinery arrangement possibilities
Least amount of hinderance / dismantling is desirable

Markings
Clear markings on equipment, for example inspection doors, sampling cocks/points

Safety and Ergonomics
Ergonomics = economics
Too cumbersome maintenance schedule may lead to shortcuts or even skipping
Associated hazards identified (electrical, chemical, mechanical etc)
Rotating machinery guards, for example belt drives, pump motor couplings etc
Engine room deck/floor plates and associated hand rails, stairs
Insulation / thermal shields, if need to be removed be of pads type

Piping, Valves and cocks
Open/close indicators for manual operations, Solenoids/Actuators indicators, relief valves,
expansion allowances, filters (inline, differential) catcher trays, bypass lines, UMS concept
should not override physical clarity of systems
Maintenance Intervals

Inspection Schedule

- planned maintenance based
- Conservative Integrity Target
- Integrity Target based on RBI
- RBI based

Service Life

Integrity Index
Failure Rate

Graph showing the failure rate over time, with three distinct phases:
- **Decreasing Failure Rate**
  - Early "Infant Mortality" Failure
  - Observed Failure Rate

- **Constant Failure Rate**
  - Constant (Random) Failures

- **Increasing Failure Rate**
  - Wear Out Failures
In Vibration analysis a machine is reduced to its operating parts such as gears and bearings. This permits identification of the specific component failures by recording the amplitude and frequency of the machine. For example a shaft with a 25 tooth gear rotating at 350 rpm will produce a signal at 25 times 350 or 8750 rpm.
Reference/Further reading

*Introduction to Practical Marine Engineering – SNAME Publication (vol.1 & 2)*

*The Running and Maintenance of Marine Machinery - IMarEST Publication*

*Ship Design and Construction, Vol 1 - Thomas Lamb (chapter 24)*

*Alfa Laval Online brochures*

*Man B&W Online papers*

*Wärtsilä Project guides*