Investigation of the lubrication conditions in bearings of large two-stroke diesel engines

GT-SUITE Conference
Frankfurt, 09.11.2009

François Terrettaz, Dr. Wilfried Schiffer
Wärtsilä Corporation
1. Introduction / purpose of investigation
2. Wärtsilä two-stroke diesel engines
3. Lubrication, crosshead and crank pin bearings
4. Model and simulation requirements
5. Simulation of previous generation engines
6. Simulation of new generation engines
7. Summary
8. Next steps
1. Introduction / purpose of investigation

Purpose

• simulation of the unsteady lubrication conditions for crosshead and crank pin bearings of large two-stroke engines with GT-SUITE

To be considered

• acceleration of oil due to movement of knee lever and ConRod
• crank angle based resolution of crosshead and crank pin bearings solution using appropriate boundary conditions in oil grooves and pockets
• fast motion of crosshead pin
• pressure pulsation in pipes and bores of oil circuit

-> interaction between oil circuit and bearings (crosshead and crank pin)
1. Introduction / purpose of investigation

Simulation results

- oil consumption of crosshead and crank pin bearings
- oil pressure at entry of crosshead and crank pin bearing over one revolution
  -> to be used as boundary conditions for EHD-calculations
- risk of cavitation in oil pipes and bores
- efficiency of different supply systems (-> telescopic pipe or knee lever)
2. Wärtsilä two-stroke diesel engines

- Crosshead engine
- Welded crank casing
- Semi-build crankshaft
- Power range: 5’800 to 80’080 kW
- Speed range: 61 to 137 rpm
- Number of cylinders: 5 to 14 (in-line)
- Bore range: 0.48 to 0.96 m
- Stroke range: 1.8 to 3.375 m
- Stroke-to-bore ratio: 2.60 to 4.17
- Weight range: 171 to 2’300 tons
2. Wärtsilä two-stroke diesel engines

Container vessels

RTA96C

Tanker vessels

RTA84T-D

Bulk carrier vessels

RTA48T-B
2. Wärtsilä two-stroke diesel engines

**7RTA48T-B**
- Power: 10185 kW
- Mass: 225 t
- Length: 7.6 m
- Width: 4.8 m
- Height: 9.0 m

**10RTA96C**
- Power: 57200 kW
- Mass: 1760 t
- Length: 20.6 m
- Width: 7.5 m
- Height: 13.5 m
2. Wärtsilä two-stroke diesel engines
3. Lubrication, crosshead and crank pin bearings

- pump
- ↓
- supply pipe
- ↓
- main gallery
- ↓
- knee lever
- ↓
- crosshead ➔ crosshead bearing
- ↓
- connecting rod
- ↓
- crank pin bearing

- main gallery
- knee lever
- (2 articulated pipes)
- crosshead bearing
- crank pin bearing
4. Model and simulation requirements

Crosshead bearing

Crank angle based resolution of bearing solution using Mobility method

- accurate bearing forces, including forces generated by pressure in large oil pockets
- accurate crosshead pin displacement
- oil flow rate according to Martin equation
4. Model and simulation requirements

Crank pin bearing

Crank angle based resolution of bearing solution using Mobility method

- accurate bearing forces, including force generated by pressure in oil grooves
- accurate crank pin displacement
- oil flow rate according to Modified Martin equation (s=0.6)
Knee lever (at engine full speed)

Acceleration: ± 300 m/s²

Pressure: ± 1.7 bar
4. Model and simulation requirements

ConRod bore (at engine full speed)

Oil Acceleration (at Centre)

Acceleration: ± 150 m/s²

Acceleration Pressure

Pressure: ± 2.5 bar
4. Model and simulation requirements

Coupling: pin movement ↔ oil pressure

Displacement of crosshead pin:
- fast motion in vertical direction
- engine load (= speed) dependant
- huge influence on oil flow rate
- influence on instantaneous pressure in oil bores close to crosshead and crank pin bearings and reciprocal

prediction of orbital path and oil flow rate as accurate as possible
5. Simulation of previous generation engines

- separate oil system for crosshead and crank pin bearing
- 10 ÷ 12 bar bar feed pressure
- small volume for main gallery

- pressure in main gallery influenced by each crosshead
  -> pressure not constant
  -> oil circuit must be fully modelled

high pressure main gallery

low pressure main gallery

to Crankpin Bearing
5. Simulation of previous generation engines

Results for 50% load

![Graph showing oil pressure and crank angle for GT-SUITE Simulation and Measurement with Crosshead pressure before and after lever plots.](image-url)
5. Simulation of previous generation engines

Oil consumption crosshead + crank pin bearing

![Graph showing oil consumption vs engine load]

- Measurement
- GT-SUITE Prediction

Oil Consumption [m$^3$/h/cyl]

Engine Load [%]
6. Simulation of new generation engines

- single oil circuit for almost all engine components
- 5 bar feed pressure
- big volume of main gallery, many sub-volumes connected
- constant pressure
- pressure pulsations fully damped
6. Simulation of new generation engines

Oil pressure (at full load)

GT-SUITE Simulation

Crosshead pressure before lever

Measurement

Crosshead pressure after lever
6. Simulation of new generation engines

Oil consumption crosshead + crank pin bearing

![Graph showing oil consumption vs engine load]

- Measurement
- GT-SUITE Prediction

Lub. Oil Consumption [m³/h/cyl]

Engine Load [%]
6. Simulation of new generation engines

Comparison oil consumption at full load with result for previous engines

![Bar chart showing comparison of oil consumption at full load for 5 bar and 12 bar feed pressures. Measurements and GT-SUIT predictions are shown.](chart.png)
7. Summary

Oil flow rate prediction
- at full load good compliance between simulation and measurement
- at part load correct trend
- below 40% load oil flow rate prediction is less accurate
- Martin equation used for crosshead bearing
- modified Martin equation (s=0.6) used for crank pin bearing

Pressure at entry and exit of knee lever
- new generation engines (-> constant pressure in main gallery):
  - calculated pressure in line with measurement
  - oil acceleration in knee lever and ConRod is correctly taken into account
  - crosshead / crank pin bearing behaviour accurate
- previous generation engines (-> fluctuating pressure in main gallery):
  - agreement between calculation and measurement less good
8. Next steps

- simulation of lubrication conditions using a telescopic pipe instead of knee lever
- prediction of cavitation risk in crosshead and crank pin bearing
- simulation of other engines components
  -> axial damper at free end of crankshaft
- implement oil lubrication pressure as result from GT-SUITE simulation for EHD calculations of crosshead and crank pin bearings
Thank you for your kind attention

Thanks to GAMMA Technologies and in particular

to Jon Harrison for excellent support!!