Cylinder and crankcase blow-by investigation using GT-SUITE

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Fluid systems simulation expert

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Summary

01 INTRODUCTION

02 CRANKCASE BLOW-BY

03 STEADY-STATE SIMULATIONS

04 TRANSIENT RESULTS

05 CONCLUSIONS
INTRODUCTION : BLOW-BY
What is blow-by...

- The pressure into the combustion chamber causes fuel, air, moisture, and oil to be forced past the rings into the crankcase.

- These are “blow-by gases”
What is blow-by...

**Blow-by sources**

1. Gas ring leakage between the piston and the cylinder liner: 20 to 70 l/min
2. Journal bearings of the turbocharger: 16 l/min (new) to 20 l/min (aged)
3. Valve stem seals: 5 to 10 l/min
4. Vacuum pump: 5 l/min (steady) to 70 l/min (peak – severe braking)

![Pie chart showing blow-by sources](chart.png)

- Vacuum pump: 0-5% (steady) / 70-80% (transient severe braking)
- Valve stem seals: 5 to 10%
- Turbocharger: 15 to 30%
- Gas ring leakage: 70 to 80%
Blow-by regulation

Necessary to extract the blow-by gases and regulate crankcase pressure to guarantee acceptable crankcase pressure value

Reliability aspects
- Avoid oil leakage through the lip seals
- Avoid excessive oil consumption by blow-by flow rate increase

Regulation aspects
- Regulation 1974: toxic gases release in the atmosphere is forbidden
- Regulation 1996: crankcase pressure < 0 mbar on gasoline engines on 3 operating points.
Blow-by circuit functionalities

- Blow-by gases are put back to the intake to be burned into the cylinder
- Different architectures possible according to the type of engine
- Blow-by gases go back to the intake thanks to a low pressure (before the compressor of the turbocharger or after the intake throttle)

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<th>Diesel</th>
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<th>TC gasoline</th>
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<td><img src="image2" alt="Diagram" /></td>
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<td><strong>Controller</strong></td>
<td>PRV (Pressure Regulation Valve) = pressure limitation</td>
<td>orifices</td>
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DRIVE THE CHANGE
CRANKCASE BLOW-BY MODELLING
## Engine characteristics

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<td>Engine power</td>
<td>150 kW at 4000 rpm</td>
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<td>Engine torque</td>
<td>400 Nm at 1750 rpm</td>
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<td>Turbocharging system</td>
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Entire crankcase, cylinder head and blow-by circuit were modelled: volumes, lengths, sections,... in order to model pressure losses and flow rate.
Crankcase blow-by

- The geometry of the ventilation system was discretized using GEM3D
Crankcase blow-by

The PRV and fresh air valves were modeled using the Pressure / massflow rate characteristic curves of these components.

Mass flow rate regulated by a PID to respect the PRV characteristics.
Blow-by circuit modelling

Blow-by sub-model

Engine model

Cylinder head

stacks

Crankcase

Engine crankcase blow-by model

PRV_vane
Aim of the study
Crankcase blow-by – aim of the study

- Fatigue behavior of the oil drain valve due to pulsating flow was studied
- Maximum pull out pressure: 500 mbar
- Steady-state and transient simulations were performed

→ Calculation of the number of open/close occurrences for the definition of reliability endurance test rig for the oil drain valve
STEADY STATE SIMULATIONS
Steady-state results – full load comparison

- Hole diameter between cylinders and crankcase was only adjusted at 4000 rpm full load according to test results
Crankcase blow-by – entire full load curve

Orifice diameter was kept constant
(Value at 4000rpm)

- Good correlation between calculations and test bench results at other engine speeds
Crankcase blow-by – 4000 rpm

- Amplitude of 75 mbar – maximum at the PRV inlet
- Mainly H2 harmonics due to the pistons displacements in the crankcase
Crankcase blow-by – steady-state conclusions

- Amplitude of the pressure pulsations are high
- Mainly H2 harmonics due to the piston displacement
- But they are lower than the limit acceptable by the membrane
- Good correlation with tests (75 mbar / 70 mbar)
TRANSIENT RESULTS
Crankcase blow-by – transient simulations

- Blow-by simulations were performed under transient conditions
- Tip-in simulations at constant speed (2000 rpm) from 2 bar BMEP to full load
- Opening time of the PRV valve difficult to model with a PID: replaced by opening ramps (duration from 0.3 s to 1.5 s)
Crankcase blow-by – transient simulations at 2000rpm

- No effect of the blow-by on torque
Crankcase blow-by – transient simulations at 2000rpm

Turbine rack position

Time [s]

Turbine rack

0.00  2.50  5.00  7.50  10.00  12.50  15.00

0.000  0.100  0.200  0.300  0.400  0.500  0.600  0.700

0.3s  0.6s  0.9s  1.2s  1.5s

Rack Position
Crankcase blow-by – transient simulations at 2000rpm

Opening from the part load initial opening (10 mm) to the full load diameter at 2000rpm (~ 8.1mm)

Diameter necessary at 2000 rpm full load
Crankcase blow-by – transient simulations at 2000rpm

- Pressure upstream PRV decreases
- Minimum relative pressure is -10mbar
Crankcase blow-by – transient simulations at 2000rpm

- Blow-by mass flow rate peak is higher in transient (75 l/min) than in steady (62.9 l/min)
- Poor effect of the PRV opening time
**Crankcase blow-by – transient simulations at 2000rpm**

- Amplitude of the instantaneous pressures higher than in steady state
- Poor effect of the PRV opening time

**Instantaneous pressure before PRV**

- Amplitude of 37 mbar / 10 mbar average
- Steady state: 31 mbar at 2000 tr/min

37 mbar
CONCLUSIONS
Conclusions

- Simulations were performed on different engines and blow-by configurations:
  - Diesel turbocharged engine
  - Gasoline turbocharged engine
  - Gasoline NA engine

- Good correlation with experiments

- Simulation time: 5 hours for the entire full load curve on workstation

- Crankcase blow-by calculations can be used to calculate the flow inside the entire blow-by circuit

- Give interesting informations to dimension the blow-by components (PRV valve, ventilation, location of the blow-by inlet,...)
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### Comparison with/without crankcase ventilation (GT-POWER)

**blow-by mass flow rates map and crankcase pressure with GT-POWER**

**Comparison with/without crankcase ventilation (GT-POWER)**
Other applications: blow-by circuit noise reduction

Noise peaks during engine accelerations

- A noise frequency of 240 Hz was identified
- Excited by H6 (2500rpm) and H8 (1800rpm) of the engine.
- An Helmholtz resonator was used to fade the noise (-8dB)

Noise coming from the blow-by circuit has been reduced thanks to GT-POWER calculations.
Conclusions

Next steps

• Cylinder blow-by model to be used to calculate the blow-by flow rate

• Blow-by coming from the turbocharger (labyrinth seal)
Thank you for your attention!