Multi-Body Dynamics Simulation on MAN RK280

SIMPACK User Meeting

Presentation by

Dr Ahmed Al-Sened
Chief R&D Manager

MAN B&W Diesel Ltd
Stockport, UK

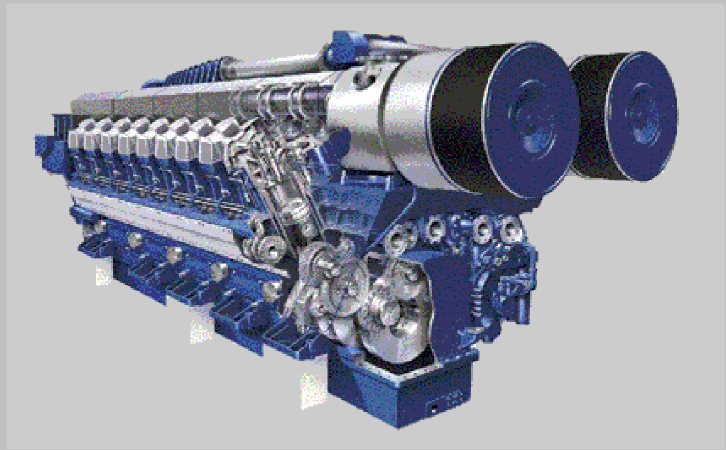
November 2004

RK280 the most powerful 1000rpm engine

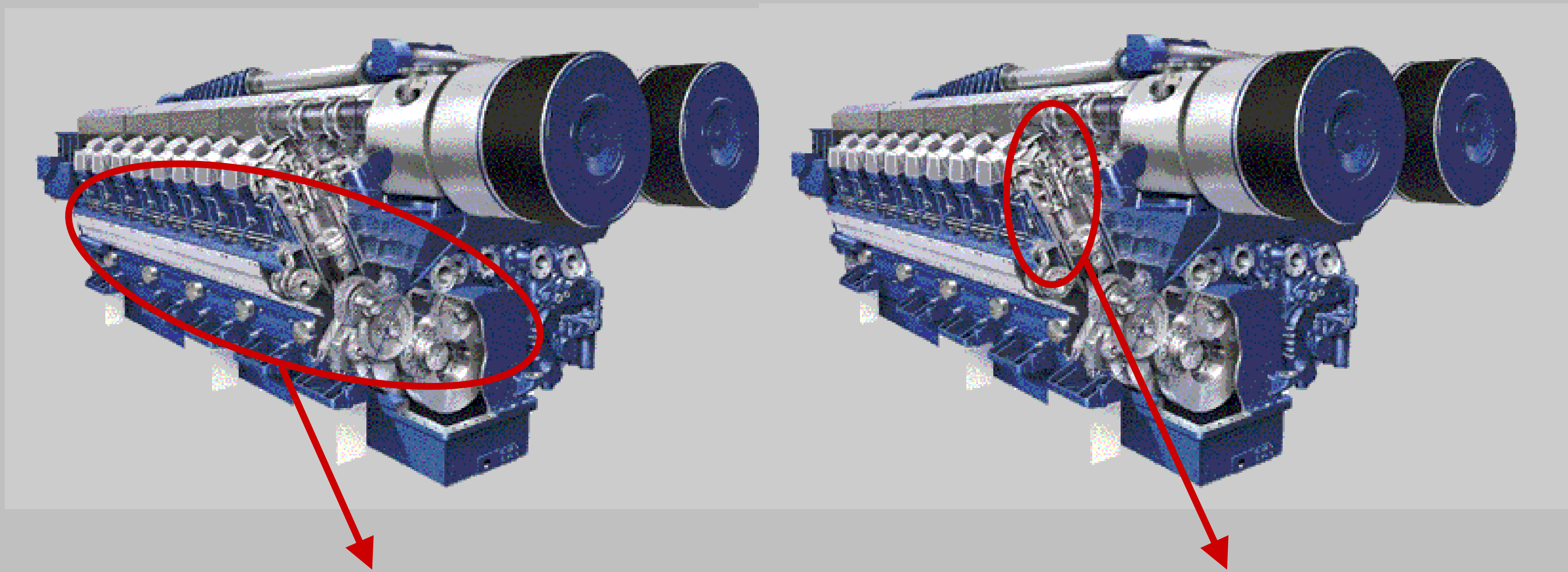
Cylinder configuration	12RK280	16RK280	20RK280
Engine Speed (rpm)	1,000	1,000	1,000
Power (kWb)	5400	7200	9000

Engine Performance Parameter

Engine Speed (rpm)	1,000
Brake Mean Effective Pressure (bar)	26.5
Power (kWb)/cyl (initial release)	450
Maximum Cylinder Pressure (bar)	210
Bsfc (g/kWh)	188
Boost Pressure Ratio	4.2:1
Exhaust Branch Temperature (°C)	460
Turbine Inlet Temperature (°C)	565
Nox (g/kWh) for Marpol compliance (15% O_2)	6.7

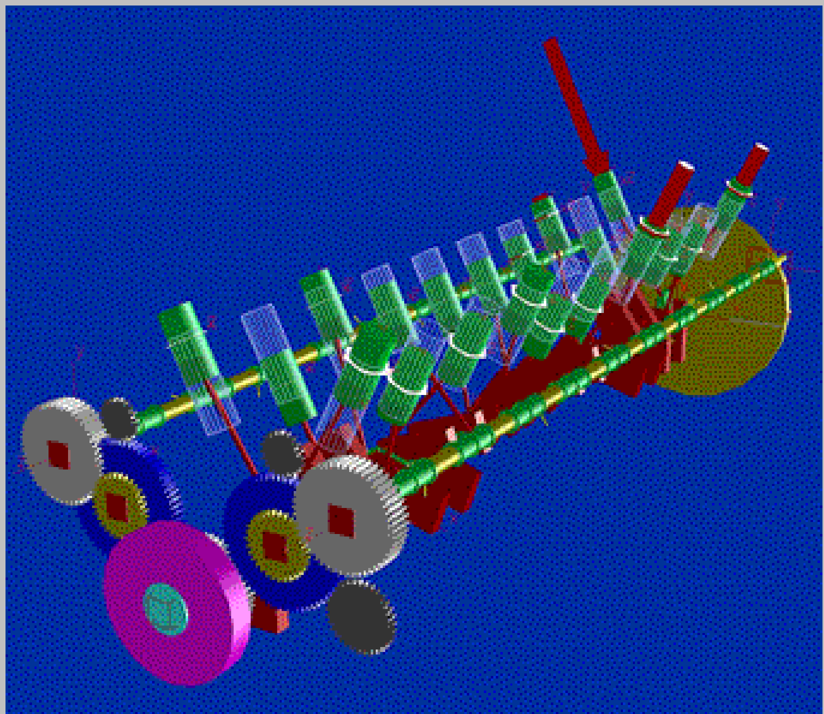


RK280 Multi-Body Dynamics Simulation



Camshaft | **Valve train**

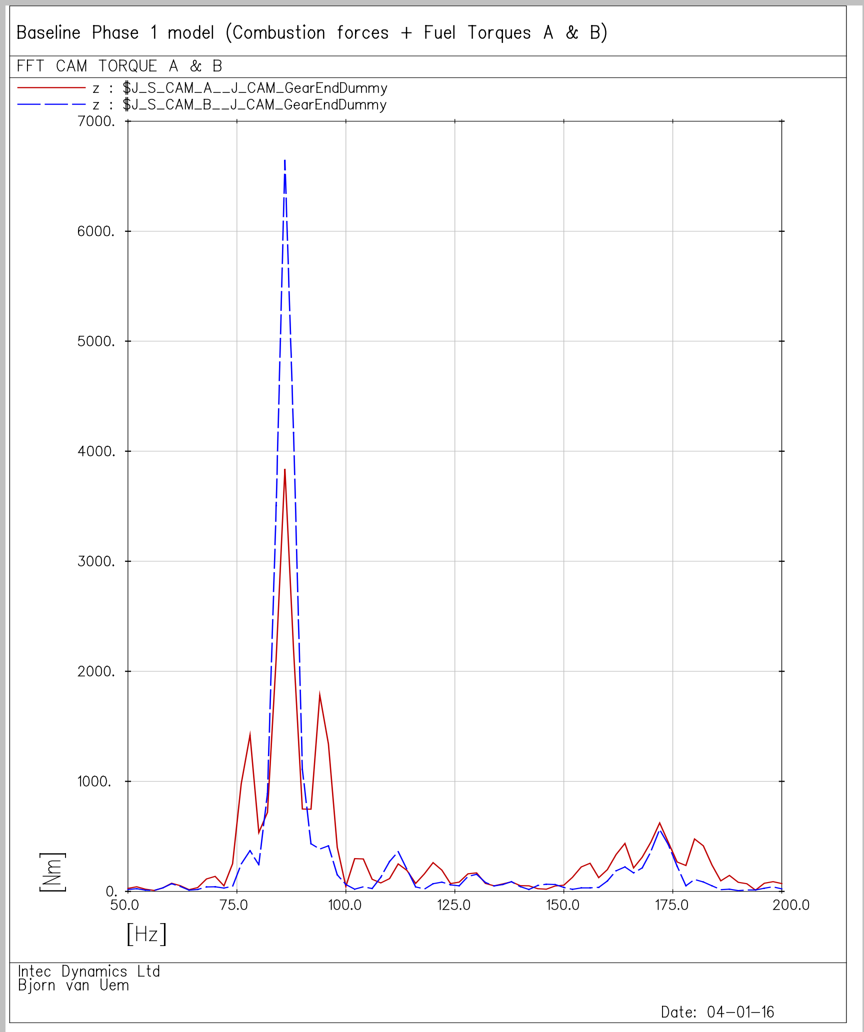
Camshaft: Model Description

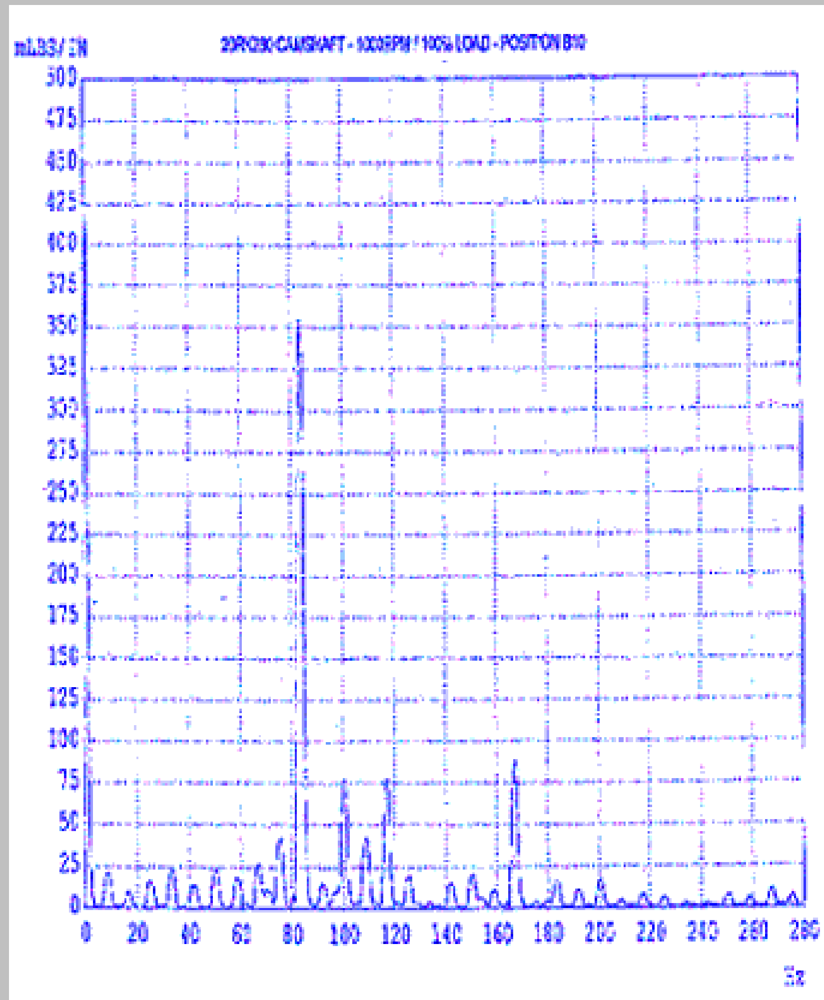


- Multi-mass crankshaft with torsional springs to study torsional vibrations
- Multi-mass camshaft with torsional springs to study torsional vibrations
- Flywheel as a lumped mass
- Crankshaft damper consisting of inner and outer part connected by torsional spring and damper
- Detailed gear modelling using the external gear force element
- Combustion forces from look-up table as function of crank angle
- Cam torques from look-up table

Camshaft: Validation & Results

Comparison with camshaft strain gauge measurements for cam A and B

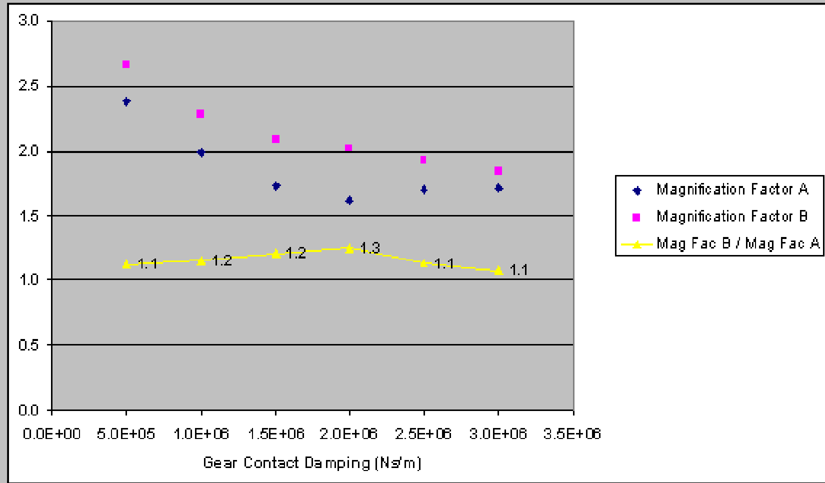


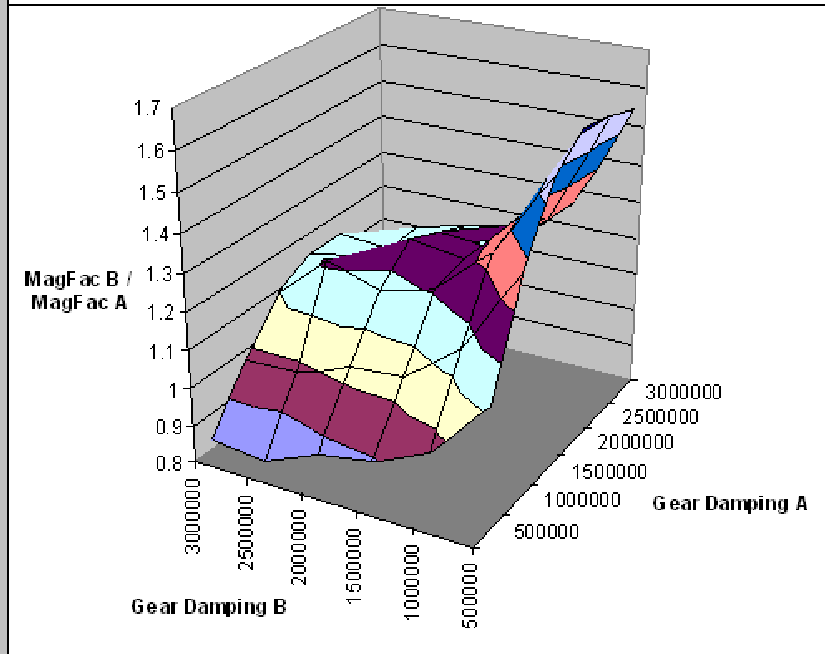


Camshaft: Parametric Study

Different Scenarios:

- Combustion Forces or constant velocity crank
- Fuel Torques on/off
- Air and Exhaust torques on/off
- Cam overlay (remove geometric asymetry)
- Change drive to other end
- Cam Damper





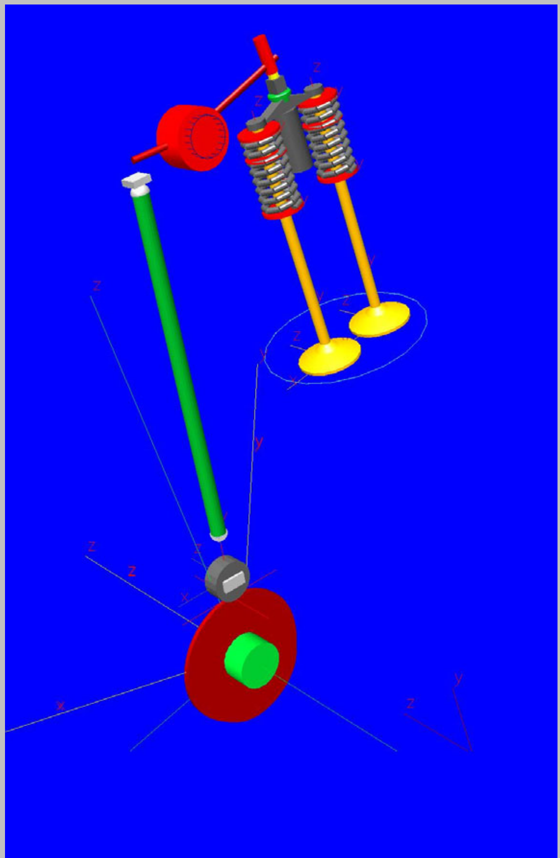
Sensitivity Study:

- Gear Contact Damping
- Crankshaft damping
- Cam Damping
- Backlash
- Interaction of Backlash and Gear Contact Damping
- Crankshaft Excitation / Combustion Force Scaling

Camshaft: Conclusions

- The measured torque difference between "A" and "B" bank, has been predicted by Simpack program.
- The measurement was re-visited and found too-high calibration parameters were used, as prediction gave lower value initially thought under predicting.
- The frequency content of the predictions is similar to the measurements, except for an additional 5.5 th. order component for "A" bank.
- Changing the drive to the other end did not affect torque levels, so it saved significant design change.
- The air and exhaust cams have little effect on torque levels.
- The gear and cam layout do not contribute to the asymmetry observed. The timing angle of 72 and its split to 20 & 52 (vee angle) was the main reason. A test case for 36 degree vee angle gives similar cam torques in each bank
- Constant velocity crank gear drive gives similar cam torques in each bank.
- A camshaft damper has been examined by the model and it was effective in reducing the torque level.
- The ratio of the torque capacity to vibratory torque of 2.12 is below the DNV figure of 2.8
- The factors of safety against pitting & bending types of failure are acceptable (ISO 6336)

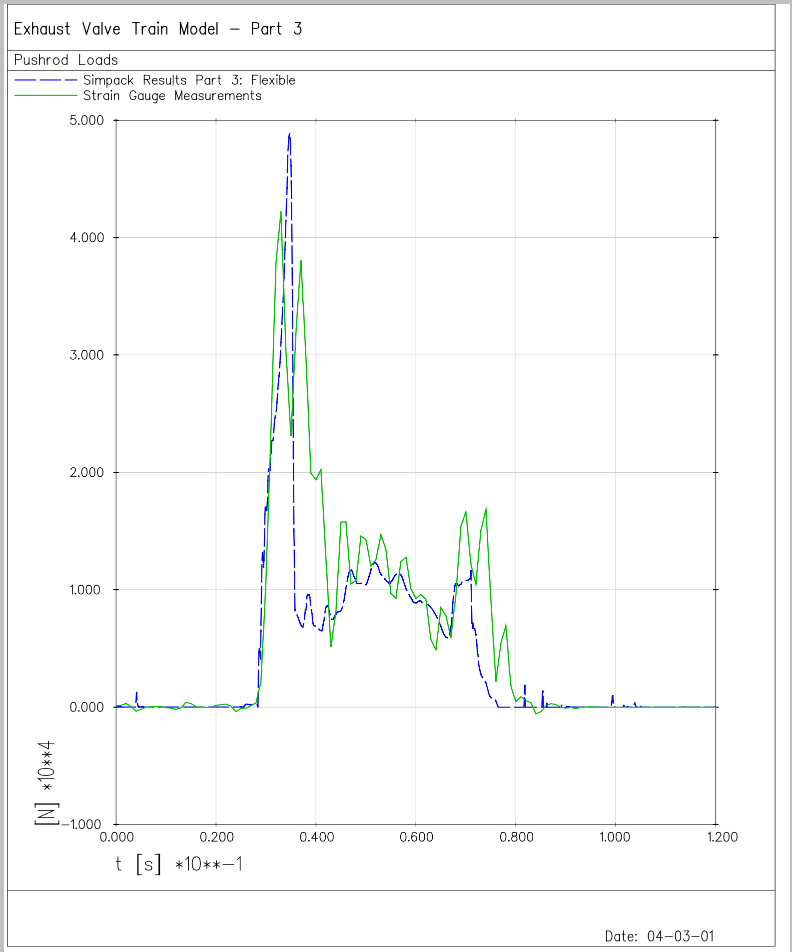
Valve train: Model Description



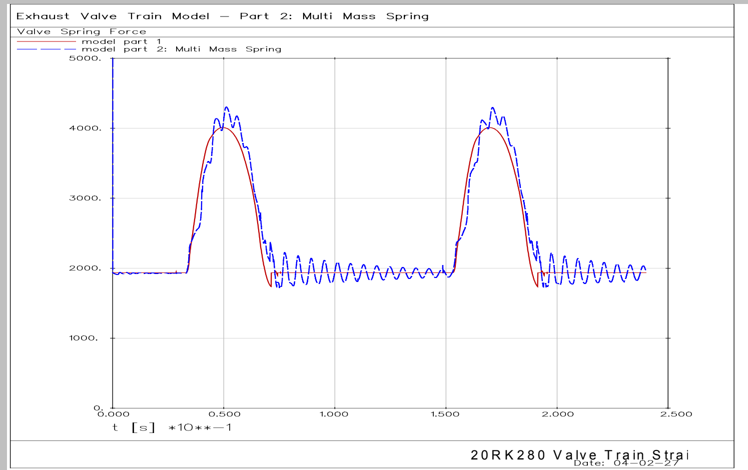
- Multi-mass valve springs created using the automatic dynamic spring generator
- Flexible pushrod modelled with SIMBEAM
- Flexible exhaust valves from FE
- Flexible rocker from FE
- Flexible bridge piece from FE
- Flexible bridge guide modelled with SIMBEAM
- Gas gorces from look-up table
- All contacts modelled with unilateral spring
- Cam to roller contact modelled with 2d contact markers
- Bridge piece to bridge guide contact modelled with moved and congruent markers

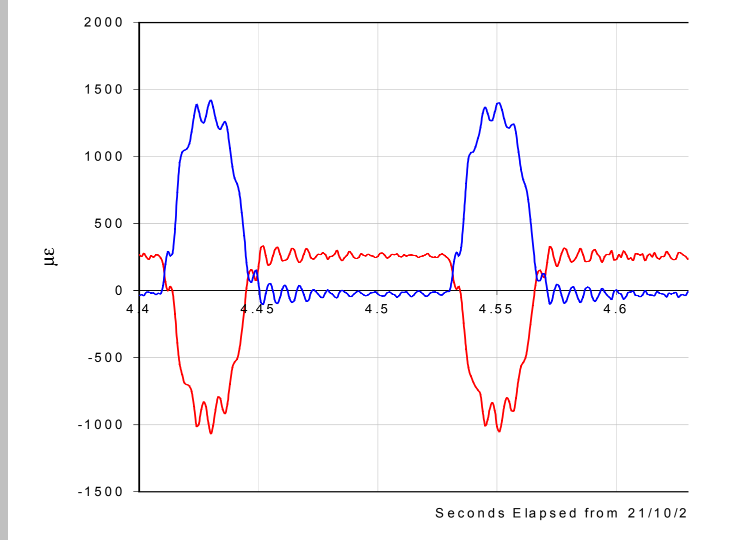
Valve Train: Validation & Results

Pushrod Loads



Spring Forces





Valve Train: Conclusions

- The correlation between the measured and simulated pushrod loads is good. The differences can be attributed to a number of sources such as the residual pressure modelling and the contact stiffnesses and damping, which are due to tribological aspects.
- Out of plane bending components in forces, stresses and strains have been measured and gave doubt for concern. This has been studied by the program and it has been explained by the solution as a results of the offset between the plane of valve and the bridge piece guide.
- A new design has been put together as a results of the program prediction and new measurement has shown lower forces and therefore the safety margin has been enhanced by such changes..

- The multi mass approach for the valve spring shows very good correlation of measured strains versus simulated forces.