1D DYNAMIC ANALYSIS OF VALVETRAINS WITH SLIDING CAM SYSTEMS

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This analysis focuses on the torsional dynamics of the valve train with sliding cam systems. The presentation outline is as follows:

- Introduction
- Model features
- Analysis Results
- Summary
- Q & A
INTRODUCTION

• In sliding cam systems, the torque is transmitted to the cam lobes via an internal shaft and spline connections. The system becomes more challenging dynamically for these reasons.
• The internal shaft diameter is usually limited by manufacturing and packaging constraints. The shaft has lower torsional stiffness than in conventional systems.
• The torque transmitting splines add more compliance to the system.
• The system is thus more susceptible to torsional vibrations and associated dynamic effects.
• A full dynamic analysis of the valve train can be beneficial in understanding effect of torsional vibrations on overall system performance.
**GT-SUITE MODEL LAYOUT**

- **Cam Carrier with Bearing and Stiffness**
- **Internal Shaft**
- **Spline Connections**
- **Cam Lobes**
- **Valve Train**
- **Speed Boundary**
VALVE MECHANISM FEATURES

• A finger follower valvetrain mechanism
• GT-Valve was used to input the base mechanism geometry and for base kinetic analysis.
CAM SHAFT TO CAM LOBES SPLINE CONNECTION

Currently the cam shaft is modeled only as torsional element. As such, no lateral load or bending moment is carried between the two sliding lobes via the splines. This has been confirmed by 3D FEA analysis.
• Cam lobes are directly supported by the carrier cam cover.
• JournalBearing templates are used to simulate the cam bearing.
• FEA analysis of the cam carrier cover (attached to head) was used to determine the stiffness of the bearing base for EHD joint.
**SPLINE CONNECTION MODELING**

- The splines are modeled as non-linear springs. FEA models utilized to get the stiffness values.
- The spring has a very low initial stiffness that increases rapidly as full teeth contact is established.
RESULTS: TORQUE TRANSMITTED THROUGH SPLINES

The effect of torsional dynamics on transmitted is evident.

At lower speed torque follows kinematic cam torque profile.

At higher speeds torque oscillations occur with higher frequency contents.

- Front spline carries cam torques for cylinder 1 & 2.
- Rear spline carries cam torques for cylinder 3 & 4.
- Torques transmitted along the splines at different levels of cam shaft speeds are shown.

Front Spline

Cam Shaft Angle

Transmitted Torque

Rear Spline

Cam Shaft Angle

Transmitted Torque

Cam Shaft Speed 3000
Cam Shaft Speed 2000
Cam Shaft Speed 1000

Cam Shaft Angle
ANGULAR SPEED VARIATION @ END CAM
DYNAMIC VALVE DISPLACEMENT

- Accounting for bearing clearances and support stiffness results changed duration of valve opening and closure.
- Lost valve lift and early valve closures results from overall system compliance.
- The effective valve lift is reduced by ~3-4%.
Valve tip contact force comparison quasi dynamic vs full system dynamic analysis. Peak dynamic valve load is 30% higher.
RESULTS: CAM BEARING LOADS

Cam Carrier

Bearing Load (Global Coord. System)

Journal Orbit (Global Coord. System)

Cam Speed 2000rpm

Cam Speed 1000rpm

Cam Speed 3000rpm
SUMMARY

• The sliding cam system relies on an internal shaft to transmit torque to cam lobes via splines. The internal shaft diameter is limited by packaging constraints.
• The sliding cam system is thus more susceptible to dynamic torsional effects.
• A full dynamic analysis of the valve train can be beneficial in understanding system torsional behavior.
• Model can be easily updated for changes to cam profile- for instance- or any other input parameter.
• Future model calibration and benchmarking can lead to improved system designs and better system diagnosis.