Large Diesel Pushrod Overhead Floating Bridge Valvetrain Correlation and Analysis

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Outline

• Problem statement and approach
• Modeling & correlation in GT-Suite
• Explored alternatives and proposed solution
• Improvisations and optimizations
• Conclusion and acknowledgement
Problem Statement and Approach

Significantly out-of-plane floating valve bridge and valves

Inboard Valve

Outboard Valve
Problem Statement and Approach

• The rocker arm geometry induces asynchronous opening and closing of valves, and differential lift.

• The differential valve lift leads to undesirable dynamic behavior especially at higher engine speeds and a deviation from optimized thermodynamic valve event.

• The approach involves development and parameterization of a valve train model using a multi-body dynamic solver and employing methods to improve the valve motion equivalence.

• The presentation reflects the best option of the studied alternatives.

• The model geometry was optimized to reduce valve bridge tip stress resulting from the new rocker arm geometry.
Problem Statement and Approach

Out of plane components led to the use of 3D mechanical library to render representative model.

Bridge/Valve side constraints along the valve guide not modeled due to edge loading complications between contacting geometries.
Modeling and Correlation: in GT-Suite and VT-Design

Initial kinematic evaluation using VT-Design.

Valve bridge not included for kinematic run, affects only valve dynamics.
Modeling and Correlation: Fully Dynamic Parameterized model in GT-Suite

Out of plane valve bridge drove transition from 2D to 3D mechanical library

Complex multiple edge loading at bridge/stem handled by tuning contact stiffness and damping

Transition from 3D back to 2D at the valve stem tip
Modeling and Correlation: Baseline Design
Valve Lift – Theoretical (Kinematic) vs Measured Dynamic (Idle-800 RPM)

Maqsood Khan (Rizwan) Engine Analysis
Modeling and Correlation: Predicting valve bridge rotation

Using ‘valve bridge rotation’ helps isolate the problem to one parameter, reducing complexity.
Alternate solutions investigated

• Differential spring installed loads:
  • Provide balancing spring stiffness and preload
  • Manufacturing complexity at head sub-assembly and error-proofing challenges

• Substitution of pin guided valve bridge
  • Constrain the bridge to 1 DOF
  • Additional moving mass, cost and complexity

• Individual valve actuation
  • As in overhead camshaft or individual rocker arms per valve location systems (as observed in a competitive engine)
  • Cost and packaging constraints

Proposed Solution
• Modified Rocker Arm Geometry
Baseline Rocker Arm:
Force balance shifts via rocker to bridge contact motion

Parameters studied –
- **CS** – Cam side arm L
- **VS** – Valve side arm L
- **R** – Roller follower rad
- **IA** – Included Angle

Simulation iterations confirmed the differential lift magnitude is a function of contact point travel (scrub length) between the rocker arm and valve bridge.
Modified Rocker arm:
Minimizes motion at rocker to bridge

Scrub reduced to about 1/10\textsuperscript{th} with the new geometry, minimizing bridge rotation

\* – New dimensions
Derived Dimensions –
CT – Contact pt travel
PR – New pivot point
PC – Initial contact pt wrt new pivot point
Comparison plots at low engine speed: Valve Bridge Rotation – Baseline vs New Geometry

Valve bridge rotation: Minimized to almost zero but constrained by manufacturing limitations
Comparison plots at idle engine speed: Final Lift Events: Inboard v/s Outboard Valve Lift
Comparison plots at high engine speed

Final Lift Events: Inboard v/s Outboard Valve

Slight differential lift at higher speeds induced due to friction modeling at rocker/bridge pallet – within acceptable durability

Maqsood Khan (Rizwan) Engine Analysis
Valve bridge tip stress optimization: Hertz Stress Calculation

With the aid of parameterized model the rocker geometry was refined to increase the contact patch area at the bridge pallet and reduce tip stress. Material choices and contact surface finish specs appropriately modified for new stress level.
Conclusion

A low cost, feasible solution was recommended that minimized differential valve lift, improved dynamic behavior while maintaining acceptable durability

- Valve closing velocities are significantly reduced, (80% decrease @ idle speed and 40-60% decrease @ higher speeds)
- Scrub travel and scrub work minimized at the rocker/bridge interface
- Parameterization of the model proved useful in evaluating multiple alternative solutions
- The geometry optimization included valve tip stress (based on Hertz calculation) balancing contact geometry radii, and reduction in contact patch area at the rocker/pallet interface.
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Questions?