Computation of full vehicle rigid body modes their effect on ride performance of vehicle on single impact

Vaihbav Kaka, Arvind K. Jain, Indranil Bhattacharyya
Contents

• Organization Background
• Objective & Scope
• Model Building
• Load case Definition
• Results
• Conclusion
• Benefits & Challenges
• Acknowledgements
Organization Background

• **TATA Technologies**
  • Established in 1989
  • An integrated workforce of over 8500 professionals
  • Achieved $424 Million in consolidated revenue by 2015
  • We are active in North America, Europe, and the Asia Pacific region,

• **We provides services to automotive, aerospace & Heavy Machinery OEMs in:**
  • Vehicle Programs & Development
  • Engineering & Design
  • Manufacturing Automation and Control Solutions
  • Customer Relationship Management
  • Product Lifecycle Management (PLM) & Solution Integration
  • Product Development IT
  • Enterprise IT & Enterprise Resource Planning
Organization Background

AUTOMOTIVE PRODUCT DEVELOPMENT

Tata Technologies is your ideal partner for automotive product development, analysis, and validation.

Local and global, better and better.
Our global resources combined with two decades of exciting innovation can help you design and build better automobiles, more efficiently and cost-effectively.

We have extensive inshore resources and worldwide offshore capabilities with global development centers in Germany, Poland, Thailand, and the USA, plus Centers of Excellence and Research and Development in India and the UK. All those are supported by our six offices in the USA and three in the UK, as well as individual offices in Canada, China, France, Germany, India, Japan, Korea, Mexico, the Netherlands, and Singapore.

These facilities and their highly qualified and experienced personnel give us the flexibility to be wherever you want us to work. But have an extraordinary roster of skilled automotive engineers across the globe, ready to tackle any challenge. And our hard-working, innovative professionals will work closely with you to meet your budgets and schedules.

Our onshore engineering services can enable you to hand a sudden surge in development demand or usher you into developing new products. By integrating our automotive engineering services into your own development timeline, you can develop better products in tighter timelines.

AUTOMOTIVE MANUFACTURING

We understand that manufacturing is of utmost importance in the automotive industry — typically 85% of your investment will be in tooling, equipment, and facilities, while 15% is in R&D of the vehicle program.

A key question in the automotive industry is: Are you planning to produce efficiently? When a company is producing millions of units over the course of a few years, it is vital to optimize production systems to improve line ergonomics and throughput.

Tata Technologies can help you implement Design for Manufacturing (DFM) with intelligent use of DFM, on assembly lines that would normally require 40 inches. Each line could be reduced to 20 inches — with increased line speed, greater flexibility, and higher throughput. We can also assist with lean and agile line scalability, capability, and reducing defects through continuous improvement.

AUTOMOTIVE PRODUCT DEVELOPMENT CORE CAPABILITIES

- Interior Trim Systems
- E/E System and Controls
- Body Engineering
- Vehicle Safety
- Chassis, Suspension, Rides, and Handling
- Seating Systems and Occupant Comfort
- Exterior Trim Systems and Closures
- Exterior Trim Systems and Closures
- Ergonomics

PRODUCT DEVELOPMENT AND MANUFACTURING

- Design and Engineering
- Manufacturing and Assembly
- Tooling
- Machining
- Geometric Design
- Product Development
- Manufacturing Engineering
- Capital Equipment Development
- Design Development
- Computer Aided Design
-ances
- Tool Design
- Cost
- Thermal Analysis
- Fluid Dynamics
- Aerodynamics
- Structural Analysis
- Computational Fluid Dynamics
- Advanced Manufacturing
- Advanced Manufacturing
- Advanced Manufacturing
- Advanced Manufacturing
- Advanced Manufacturing

CASE STUDIES

- Tata Technologies
- Tata Technologies
- Tata Technologies
- Tata Technologies
- Tata Technologies

Trademarks and Trademarks are owned by the respective owners
Objective & Scope

**Objective:**
- Ride performance evaluation of vehicle on single bump road

**Scope:**
- Build full vehicle model with following subsystems
  - Front MacPherson suspension
  - Rear twist beam suspension
  - Linear Powertrain
  - MF Tire
- Single Sine Bump (Half) road profile
- Computation of Rigid body modes to evaluate vehicle bounce, pitch natural frequencies & its implications on Vertical acceleration.
- Computation of vertical Root Mean Square (RMS) acceleration values at different locations
Model Building - Front Suspension

- **Front McPherson Suspension**
  - LCA & other bushings were modelled as non-linear
  - Non-linear damper characteristics were used to model damper
  - Spring was modelled as linear
  - All parts were modelled as rigid bodies

- **Steering - Rack and pinion**
  - Constant gear ratio was modelled as coupler
  - Rack housing was mounted to subframe using bushes

- **Important KnC parameters**
  - Ride, roll and compliance tests were carried out to study important suspension parameters.
Model Building – Rear Suspension

- **Rear Suspension - Twist beam suspension**
  - Twist beam was mounted to body using non-linear bushes
  - Linear spring was considered for this analysis
  - Damper was modelled as non-linear
  - Damper top and bottom mounts were modelled as non-linear bushes
  - Twist beam was modelled as flexbody

- **Important KnC parameters**
  - Ride, roll and compliance tests were carried out to study important suspension.
Load case Definition

Road Profile:
• Single Bump road (Wavelength=2m, Amplitude=0.05m)

Vehicle Control:
• Steering angle is kept constant with no steer input

Vehicle Speed:
• Analysis carried out at 5, 10, 20, 30, 40, 50 (kmph)

Tires:
• MF tire was used for this simulation

Maneuver:
• Vehicle starts and stabilizes in next 4 sec
• Straight line run at constant vehicle speed with no steering angle input
Results

- **Theoretical Calculations**
  - \[ X = \frac{K_f + K_r}{M} \]
  - \[ Y = \frac{K_r \cdot c - K_f \cdot b}{M} \]
  - \[ Z = \frac{K_f \cdot b^2 + K_r \cdot c^2}{Mk^2} \]
  - Where,
    - \( K_f \) = Front spring rate
    - \( K_r \) = Rear spring rate
    - \( b \) and \( c \) are distances of CG from front and rear axles respectively
    - \( k \) = Radius of gyration
    - \( M \) = Sprung Mass of the vehicle

- **Two frequencies are calculated as follows**
  - \[ \omega_1 = \sqrt{\left(\frac{X+Z}{2}\right)^2 + \left(\frac{X-Z}{2}\right)^2 + \left(\frac{Y^2}{k^2}\right)} \]
  - \[ \omega_2 = \sqrt{\left(\frac{X+Z}{2}\right)^2 - \left(\frac{X-Z}{2}\right)^2 + \left(\frac{Y^2}{k^2}\right)} \]

- **Two points are calculated as follows**
  - Center 1 = \(-Y(X-\omega_1^2)\)
  - Center 2 = \(-Y(X-\omega_2^2)\)

- **Results were verified with above calculations**
• Vertical Acc. at WC & Strut Bottom increases with increase in speed
• Vertical Acc. at other locations reaches max. value at 20kmph as excitation frequency matches with vehicle pitch mode
Results contd..

- Strut top to bottom acc. RMS ratio shows peaks near vehicle bounce and pitch freq.
- Pitch Angle change peak is observed near pitch mode frequency (20 kmph)
Conclusion

• Attempted modelling of full vehicle with flexbodies in MotionView
• Vehicle Bounce & Pitch frequencies were evaluated using static + linear analysis
• Ride analysis carried out using Sine Single Bump road (rdf)
• Pitch angle change reaches max value at 20kmph as excitation frequency resonates with vehicle pitch frequency.
• Vehicle Bounce Mode occurs at 1.61 HZ & Vehicle Pitch Mode occurs at 2.87 HZ which results in high ratio of vertical acc. at Strut Top with respect to Strut Bottom at 10kmph & 20kmph runs respectively.
Benefits & Challenges

• **Benefits**
  • Capability to build road profiles in MotionView using .rdf files explored
  • Ride load-case developed in Motion View
  • Process to analyze results is automated
  • Hypergraph report template files are created to define report format

• **Challenges**
  • Road profile – RM marker tuned to converge the solution
  • Flex-bodies - .h3d files created to bring more accuracy
Acknowledgements

• Tata Technologies
  • Work Opportunity
  • Suspension Design Team
  • Guidance

• Altair
  • Technical Support Team
  • Event Organizing Committee
  • Providing opportunity to showcase the work