Engineering Tool Development

"Codification of Legacy"

Ramp-up technology  Increase competitiveness  Be knowledge centric

Three critical challenges for Indian engineering industry today

Dr. R. S. Prabakar and Dr. M. Sathya Prasad
Advanced Engineering

21st August 2013
Three Critical Challenges for Indian Engineering Industry Today

• **Ramp-up technology quickly to global levels**
  – Measure-up to the best: Create specialists.
  – Reduce technology cost.

• **Increase competitiveness**
  – Apply state-of-art simulation technologies to get-it-right the first time: Get intimate with the product even before building physical prototypes

• **Be knowledge centric instead of individual centric**
  – Create knowledge legacy: Make knowledge available for ready use within the organization for immediate use as well as posterity
Traditional Problem Solving Approach

- Physical Testing
- High Fidelity Analysis
- Preliminary Design Calculations
- Simple Hand Calculations
- Scientific Calculator
- Excel
- Commercial Software
- Physical Testing

Ramp-up technology
Increase competitiveness
Be knowledge centric
Problem Solving Approach
Conceptual Design, Detailed Design and Testing & Validation Stages

**Conceptual Design**
- Performance Analysis
- Gradeability
- Fuel Economy
- Gear Utilization
- Suspension System
  - Ride, roll rate and yaw using classical formulae
  - Nose down analysis

**Detailed Design**
- Finite Element Analysis
- Structural Analysis
- Multi-body Analysis
- Ride and Handling
- Engine Dynamics
- Flow Analysis
  - Aero Dynamics
  - Drag prediction

**Testing & Validation**
- Ride and Handling
- Highway
- Pot-hole
- Cornering
- Lane change
- Endurance Testing
- Performance Testing

**Physical Testing**
- Full Vehicle Testing

**Primary Design Calculation**
- Simple hand calculation using scientific calculators,
  Preliminary design calculations using Excel etc.,

**High Fidelity Analysis**
- 3D Modelling and Analysis Tools

**Ramp-up technology**
**Increase competitiveness**
**Be knowledge centric**
### Problem Solving Approach

#### Conceptual Design, Detailed Design and Testing & Validation Stages

<table>
<thead>
<tr>
<th>Simple Analytical Formulae using Scientific Calculators</th>
<th>Preliminary Design Calculation using Excel Sheets</th>
<th>Detailed Design</th>
<th>Testing and Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>- Simple to understand</td>
<td>- Easy understanding</td>
<td>- Standard and proven simulation methodology</td>
<td></td>
</tr>
<tr>
<td>- Easily computable</td>
<td>- Easy computation</td>
<td>- Reduce number of physical testing</td>
<td></td>
</tr>
<tr>
<td>- Quicker evaluation</td>
<td>- Reusability</td>
<td>- Better understanding with animated results</td>
<td></td>
</tr>
<tr>
<td>- Ball park inputs are sufficient</td>
<td>- <strong>Disadvantages</strong></td>
<td>- Commercial software are expensive – limited licenses</td>
<td></td>
</tr>
<tr>
<td>- Thumb rules can be used</td>
<td>- Complex problems cannot be handled</td>
<td>- More learning time</td>
<td></td>
</tr>
<tr>
<td>- Scoping and feasibility can be evaluated</td>
<td>- Dynamic analysis performance will be difficult</td>
<td>- Huge AMC and Training cost</td>
<td></td>
</tr>
<tr>
<td>- First cut results</td>
<td>- <strong>Disadvantages</strong></td>
<td>- Limited scalability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Not accurate results</td>
<td>- Simulation errors and assumptions</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Not accurate results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Detailed output cannot be captured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Complex problems are difficult to handle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Relies on experience and gut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Easy to make errors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Preliminary Design Calculation using Excel Sheets**
- **Detailed Design**
- **Testing and Validation**

- **Advantages**
- Easy understanding
- Easy computation
- Reusability
- Dynamic analysis performance will be difficult
- Not user friendly
- **Disadvantages**
- Complex problems cannot be handled
- Scoping and feasibility can be evaluated
- First cut results

- **Advantages**
- Easy understanding
- Easy computation
- Reusability
- **Disadvantages**
- Complex problems cannot be handled
- Dynamic analysis performance will be difficult
- Not user friendly

- **Advantages**
- Standard and proven simulation methodology
- Reduce number of physical testing
- Better understanding with animated results

- **Disadvantages**
- Commercial software are expensive – limited licenses
- More learning time
- Huge AMC and Training cost
- Limited scalability
- Simulation errors and assumptions

- **Advantages**
- Results predicted will be accurate
- Direct field data
- Real world scenario

- **Disadvantages**
- Complex Instrumentation
- Expensive – time & cost
- Multiple proto
Problem Solving Approach
Opportunity

Physical Testing
High Fidelity Analysis
Low Fidelity analysis
Preliminary Design Calculations
Simple Hand Calculations
Scientific Calculator
Excel
Customized Engineering Tools
Commercial Software
Physical Testing

Opportunity to contribute

Ramp-up technology
Increase competitiveness
Be knowledge centric
Problem Solving Approach
Low Fidelity Analysis

- Intermediate analysis between preliminary design calculation using Excel sheet and detailed design calculation using commercial software
- Reduces number of iteration to detailed high fidelity analysis
- Provide detailed insight of the analysis with minimal input parameters
- Suitable for initial first cut analysis
- Possible to play around with design parameters

Need for analyzing dynamic behaviour using simple executable tools which gives better insight of the problem and reduce the number of iteration in the detailed design stage
GUI using Matlab

Graphical User Interface (GUI) enables the user to perform interactive tasks using different components like buttons, list box, pop-up menus, text, axes etc.,

Ways to build GUI

- Use GUIDE (GUI Development Environment), an interactive GUI construction kit.
- Create code files that generate GUIs as functions or scripts (programmatic GUI construction).

Power of GUI

- User friendly
- Easy to learn
- Can be installed in any workstations, does not require license
- Less computation time
Ride and Handling – A Case Study

Objective

To develop an executable Ride and Handling software tool using MATLAB in order to guide the design/aggregate/vehicle dynamic engineers to appropriately choose the vehicle suspension parameters for better ride and handling behaviour at design stage itself with minimal input parameters.
Ride and Handling
Introduction

Road vehicles experience vibration induced by

- Road irregularities
- Aerodynamic forces
- Periodic forces from engine etc.,

Effects due to vibration

- Discomfort to the driver and passenger
- Improper steering and braking characteristics
- Small road holding forces leading to wheel hopping
- Damage to the vehicle itself
Opportunity Identification
Why Ride and handling Studies is so important?

- Satisfy demands of the customer
- Improve brand image
- Compete with global market
- Enter into premium market segment
- Mandatory requirement in application specific like ambulance.
- Tyre life
- Safety
- Maneurability
- Driver fatigue
- Unique selling proposition
Opportunity Identification
How to achieve better Ride and handling behaviour?

❖ Proper design of Leaf springs / Air Springs
❖ Shock absorber damping coefficients
❖ Appropriate Tyre Selection
❖ Better cab Mounts
❖ Vibration absorbers
Ride and Handling
Mathematical Modelling & Simulation – An Overview

**Vertical Dynamics**
- Bounce motion study using quarter car vehicle model
- Straight path can be considered
- Two degree of freedom model
- Modal natural frequencies
- Optimization

**Longitudinal Dynamics**
- Pitch and bounce motion using half car vehicle model
- Four degree of freedom model
- Straight or curved paths can be considered
- Modal natural frequencies
- Optimization

**Lateral Dynamics**
- Bi-cycle bounce and roll model using half car vehicle model
- Four degree of freedom model
- Straight or curved paths can be considered
- Modal natural frequencies
- Optimization

**Full Vehicle Simulation**
- Combination of vertical, lateral and longitudinal dynamics
- Straight or Curved paths can be considered
- Seven degree of freedom model
- Optimization

**Suspension Systems**
- Basic design study
- Roll center analysis
- Roll angle, Roll rate calculation
- System parameters Optimization

**Tyre Dynamics**
- Contact patch
- Longitudinal, Lateral and Camber Forces
- Tyre stiffness
- Mathematical modelling of Tyre using Magic formula
Ride and Handling
Full Vehicle Model – Equation of Motion

Generalized Equation of Motion

\[ M\ddot{X} + C\dot{X} + KX = F(t) \]

\( M \) – Mass Matrix; \( C \) – Damping Matrix; \( K \) – Stiffness Matrix

State Space Approach

\[ \dot{X} = AX + DW(t) \]

\( X \) – State Variables; \( A \) – System Matrix;
\( D \) – Excitation Matrix; \( W \) – Road input vector

Road Profile Model

\[ \dot{h}(t) + \alpha Vh(t) = W(t) \]

where \( W(t) \) is a white noise process with covariance function

\[ E[W(t)W^*(t)] = Q \delta (t - T) \]

\( Q \) is the spectral intensity given by \( Q = 2\alpha^2\sigma^2 \)

Sprung Mass
1. Bounce Motion
2. Pitching Motion
3. Roll Motion

Unsprung Mass
4. Vertical Motion – Front Left
5. Vertical Motion – Front Right
6. Vertical Motion – Rear Left
7. Vertical Motion – Rear Right
The power spectral density function of road irregularity is assumed to be of the form

$$S_h(\omega) = \frac{\sigma^2}{\pi} \frac{a_r V\sigma^2}{\pi(\omega^2 + (a_r V)^2)}$$

Where $V$ is the vehicle forward velocity, $\omega$ is the circular frequency, $\sigma^2$ is the variance of road profile, and $a_r$ is the coefficient of the road profile.
Software Development Cycle

1. Need
2. Scope
3. Mathematical Modelling
4. Software Identification
5. Programming and Validation
6. Data Collection
7. Documentation and Handover
8. Expansion if any

Ramp-up technology
Increase competitiveness
Be knowledge centric
ARISE
A Ride and Handling Tool

A 4x2 Haulage Truck with suspended cab is taken up for analysis. It requires sprung and unsprung masses, suspension parameters - stiffness and damping, tyre stiffness, inertia and CG locations (depending on analysis type - Quarter car or Half car or Full car analysis) for the analysis. Since the cab is suspended, it also requires mass of the cab, inertia properties, CG and cab mounting locations and cab mount's stiffness and damping coefficients.

MathWorks
ASHOK LEYLAND

Ramp-up technology
Increase competitiveness
Be knowledge centric
The ride comfort is the measure of vertical bounce acceleration. The bounce accelerations can be obtained at CG of the cab and vehicle, driver seat and also at user specified locations.

These vertical accelerations are compared with the ISO 2631 standards - ride index and the results are discussed. The results are also plotted in the frequency domain, to know better understanding of the vertical acceleration levels over the wide range of frequencies.
Tool Capabilities

- Ride comfort level prediction for different vehicles, terrains and suspension systems
  - ISO comparison with ride index
  - Helps the designer to guide in suspension parameters selection
  - Optimize suspension for better ride comfort
- Minimal Inputs required
- Analysis of modal natural frequencies and mode shapes
- Graphical outputs to readily understand ride
- Both time and frequency domain analysis can be performed
- Vehicle ride prediction for different terrains
- Comments is provided for the user to interpret the results
- Very Less time for computing
Tool Advantages

- Tailored to specific needs
- Play around with parameters
- Ideal for trial and error
- Reduced learning time
- Unlimited licenses and No AMC
- User friendly

Advantages
- Ramp-up technology
- Increase competitiveness
- Be knowledge centric
Summary

- Able to develop a standalone tool using MATLAB GUI environment
- Quickly predict the ride comfort behaviour of the vehicle with minimal input parameters
- Able to compare the ride comfort with ISO standards and arrive at a feasibility criterion of ride
- Helpful in designing the suspension parameters at design stage, when details are not available
- Optimization of ride elements
- Requires very less time to compute
Thank You