Agenda for two 3 days Domain Training Series: 2010

State-of-the-art training on Vehicle Dynamics Simulation Technology

Venue: EASi, Bangalore India. Date 25, 26 & 27

(RMZ NXT, Campus 1B, #401-402,EPIP Zone, Whitefield, Bangalore- 560 066)

By

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GOAL: The goal of this course is to provide you with the tools to calculate and predict the performance of a car or truck in accelerating/braking, ride, and handling/rollover. In the process you will come to understand the basic mechanisms and engineering principles that determine the performance of a motor vehicle, as well as develop familiarity with the terminology.

Overall, the course will help you understand the motor vehicle as a system. The design of a car or truck always involves a conflict of goals. The suspension system that is optimized for ride, is not always the best for handling. The powertain that gives best acceleration is not likely to be the most fuel efficient. By understanding the primary mechanisms for all modes of performance, you can better appreciate how to optimize the overall vehicle, because it allows you to:

1) Predict performance of a given design early in the design process,

2) Identify the conflicts in designing for optimal performance in different modes,

3) Set directions for design changes that will improve performance of a given mode.

AUDIENCE: The course will be beneficial to anyone interested in automotive performance. You should find them useful if you are:

—a professional engineer with technical interest in vehicle performance
—an engineer involved in the design and development of automotive vehicles
—a technologist working to achieve a high level of vehicle performance
—a manager responsible for vehicle design, development and testing
—an engineer who needs to understand the vehicle as a system
—involved in

- manufacturer of cars or trucks,
- manufacture of OEM components,
- manufacture of after-market components
- design and construction of specialty vehicles
- racing
- vehicle safety and accident analysis/reconstruction

CONTENT: The course provides a broad overview of vehicle performance described in terms that can be understood by the lay-person but including engineering analyses and formulas that can allow even the lay-person to calculate useful performance metrics, such as:

• Dynamic load distribution on the front and rear wheels as a consequence of center of gravity location, grades, acceleration, aerodynamic forces, and trailer towing forces.
• Loads on individual wheels during cornering,
• Acceleration capability at the traction or power limits,

- Stopping distance
- Ideal brake proportioning as a function of vehicle load and road friction conditions,
- Braking deceleration and efficiency,
- Rolling resistance and aerodynamic load forces,
- Frequencies of body and wheel-hop ride vibrations,
- Body and wheel responses to ride excitation sources,
- Turning responses to steering input
- Ackerman steering angles
- Off-tracking behavior
- Understeer/oversteer gradients, and critical speed
- Lateral acceleration and yaw velocity gains
- Effect of tire cornering stiffness and load sensitivity on cornering,
- Effect of suspension camber, roll steer, and compliance steer on cornering,
- Suspension roll center height and its influence on lateral load transfer in cornering,
- Effects of tractive forces on cornering behavior,
- Effects of front wheel drive on cornering behavior,
- Suspension roll stiffnesses and vehicle roll rate,
- Suspension anti-dive characteristics in braking, and squat/lift in acceleration,
- Suspension roll center locations,
- Steering geometry errors,
- Steering system reactions from load, cornering and tractive forces.,
- Estimates of steady-state rollover thresholds

Marketing Questions

Who is the target audience?

This course should be of interest to anyone in the automotive industry concerned with vehicle performance (as contrasted with styling, for example). It will be most appreciated by people with engineering backgrounds, who can fully understand and utilize the mathematical models to predict performance. Design and development engineers can use the principles to improve the performance of new and current designs. Managers can use it to better understand the advantages and disadvantages of alternative design choices. Manufacturing engineers can use the principles to identify critical parameters in the manufacturing process.

The course will also be interesting to people in non-engineering functions (management, legal, manufacturing, etc.) who simply want to understand the vehicle as a system and the conflicts in design.

The audience will be distributed among all companies that manufacture any rubber tired vehicle (cars, trucks, RVs, agricultural machinery, and other special vehicles), manufacturers of automotive components (all tiers of suppliers), companies that build special performance vehicles (dragsters, race cars, etc.)

Who influences the purchase decision?

1) The decision to take this course will most likely arise from individuals interested in increasing their understanding of vehicle dynamics.

2) In an industrial setting the signature of a supervisor or manager will be required for the company to cover the purchase cost.

3) Private consultants (accident reconstructions, etc.) will make the purchase decision themselves.

Who makes the purchase?

In large companies the purchase will be authorized by individual departments, although it may be processed through the purchasing department. In private firms (consultants, law firms, etc.) it may be executed by the individual user.

Who uses the course?

The course will be used by the individual who requested it.

How do they use the course?

The individual who takes this course will use it in performing their job. Through the course they will be able to understand the vehicle better as a system and achieve a balance in performance.

In the automotive companies, designers will be able to predict performance at the conceptual level to achieve better designs. Development engineers will be able to make more informed decisions about how to improve the product once it is rendered as a prototype. Overall, it should reduce the time from concept to customer.

People in the product liability business (experts, lawyers, etc.) will use the course to improve their analysis of an accident situation. Experts may use the materials as a reference, or use the analysis methods in a reconstruction. Lawyers may use it to simply improve their understanding of some aspect of vehicle dynamics relevant to a suit, so that they can refine their investigation and presentation of a case.

Details of Course Content

Day One

The first day of the course focuses on longitudinal performance and will show you how to analyze the vehicle for its performance in acceleration and braking.

Introduction — It begins with a discussion of the coordinate systems necessary to describe vehicle behavior, and then examines all the forces that may act on the vehicle affecting how it accelerates and brakes. Since the driving or braking forces may be limited by the load on the wheels, you will learn how to calculate the wheel loads based on how the vehicle is loaded, the acceleration it experiences, and the influence of road grades, aerodynamic forces, and trailer towing forces.

Acceleration — The capability to accelerate the vehicle depends on whether it is limited by the power of the engine or the traction of the driven wheels. To provide you with the background to calculate power-limited performance, you will review typical engine performance characteristics and go through the elements of the drive train to reveal how they produce a drive force at the ground. You will learn the relevant functional characteristics of both manual and automatic transmissions and the final drive (differential). Building from these elements, you will be able to calculate the acceleration capability of the vehicle at any speed and in any gear.

For traction-limited performance you will see how to calculate dynamic loads on the drive wheels and see how to determine the acceleration at which the wheels will spin. This discussion includes treatment of the lateral load transfer on a solid axle which limits performance with a non-locking differential.

Braking — Braking performance is determined by the properties of the brakes and the overall design of the system to properly utilize the load on front and rear axles. The basic equations by which deceleration and stopping distance can be calculated are reviewed. The relative advantages and disadvantages of disc and drum brakes are described, along with highlights of the Federal Motor Vehicle Safety Standards applicable to braking performance. The process for designing a brake system is presented in order show how front and rear brake torques must be proportioned to achieve good performance. You will see why proportioning valves and needed, the function of the various types available, and how the anti-lock brake (ABS) system solves these problems. By the end of the session, you will be able to determine performance under varying load and road conditions, and means for evaluating the efficiency of the system under these conditions.

Introduction to CarSim – Simulation has become a very important part of the automotive development process. Participants will be introduced to simulation using the CarSim vehicle dynamic simulation program as the example. The process of simulation will be explained, along with the animation process used to illustrate vehicle dynamic principles in this course.

At the completion of this module you will be able to:

- Determine how the wheel loads on a vehicle vary dynamically as a result of loading, aerodynamic forces, road grade, trailer towing forces, and acceleration and braking.
- Describe how the powertrain works and predict the acceleration capability of the engine in each gear under arbitrary road conditions.
- Determine the traction limits of front and rear wheel drive cars with independent suspensions or solid axles, and how these limits are influenced by locking and non-locking differentials.
- Describe how the brake system works, determine how to size the brakes, and how to design a proportioning system to achieve good performance under all conditions.
- Explain the basics of vehicle dynamics simulation and how it can be used in the automotive development process

Day Two

Road Loads refers to the forces resisting forward motion of the vehicle arising from aerodynamics and tire rolling resistance.

Aerodynamics – The mechanics of air flow over the car are explained to show how forces and moments are produced. In the process, the practical consequences of air flow are discussed to help the student understand the diverse influences on such things as engine cooling, heating and air conditioning, window contamination and dirt deposition. The equations for describing the 3 forces and 3 moments acting on the vehicle are presented. Typical value ranges for the various coefficients are given.

Rolling resistance – The sources of tire rolling resistance are explained along with their sensitivity to operating conditions. Typical values of rolling resistance are presented. The impact on energy loss is discussed in the context of its effect on fuel economy.

At the completion of this module you will be able to:

- Describe the basic mechanisms responsible aerodynamic reactions on the vehicle
- Calculate the aerodynamic forces and moments acting on the vehicle
- Determine the effect of aerodynamics on wheel loads during high speed travel
- Estimate rolling resistance forces acting on the vehicle
- Understand the primary sources of energy losses on the vehicle at speed

Ride Performance – This module will shows how to design a vehicle for good ride.

Excitation Sources—Ride is a response to excitation of the vehicle from road roughness, tire/wheel nonuniformities, and drive train and engine sources. You will learn how road roughness is measured and characterized, the relevant properties causing vehicle vibration, and how to represent it as an excitation source for predicting performance. Nonuniformities in the tire and wheel assemblies in the form of imbalance, runouts and stiffness variations will be described so that you will be able to characterize the direction, magnitude, and frequency of excitation at the spindle arising from these sources. You will also learn how to characterize the excitations produced by the driveline. Imbalances in the drive shaft and forces arising from the secondary couples of universal joints will be explained. You will review engine sources of excitation, including imbalance forces produced by the engine, torsional oscillations around the torque axis, and how these are isolated from the vehicle body.

Vehicle Response—The response of the vehicle body to ride excitations depends on the location of the input and its frequency. You will learn how to predict the vertical response of one corner of the vehicle (the quarter-car model) to road and tire/wheel inputs, calculate resonant frequencies of the body-bounce and wheel-hop vibrations, and determine how shock absorber damping can affect these responses.

A more comprehensive treatment of the vehicle response recognizes that the vehicle has front and rear wheels that encounter road bumps sequentially exciting bounce and pitch vibrations. The response in each case depends on how the wheelbase relates to wavelengths in the road producing wheelbase filtering. You will learn how this phenomena causes different vibration response at different locations on the vehicle and how to calculate the frequencies and motion centers for bounce and pitch vibrations. The Olley Ride Criteria are reviewed so that you can use these tools to design front and rear suspensions to achieve good ride balance. Active suspension technology will be reviewd in conjunction with this discussion to illustrate how it can improve low-frequency bounce and pitch control, and the source of its limitations in improving high-frequency vibration isolation.

Ride Perception—You will review the state of knowledge on human tolerance to vibration as a basis for judging ride vibrations, and become familiar with the frequency and directional sensitivities. By examining actual ride test results you will learn which inputs are important to the rider, causing degradation of the ride perception.

At the completion of this module you will be able to:

- Describe the basic mechanisms responsible for ride excitation on a vehicle.

- Calculate the rigid-body ride parameters such as natural frequencies and damping ratios.
- Calculate transmissibility properties for road inputs and tire/wheel inputs to sprung and unsprung masses
- Understand how ride is measured and evaluated

Basics of Handling — Handling refers to the cornering, turning or directional response behavior of the vehicle. The behavior is examined in two regimes of low-speed and high-speed cornering

Low speed cornering is governed by the geometry of the vehicle. Each steered wheel requires a separate angle for compatibility in the turn. The relationships of steering angles to radius of turn establish the Ackerman geometry

In high speed turning the cornering properties of the tires come into play. Equations are written showing how the required steer angle depends on the radius of turn and the lateral acceleration. From this analysis the concept of understeer gradient is developed. The understeer gradient is related to the yaw rate and lateral acceleration gains that become the basis for setting understeer guidelines. Other relevant handling terms are explained, including critical speed, characteristic speed, sideslip angle and static margin.

Introduction to TruckSim — Simulating the dynamics of trucks is quite similar to that for cars except for certain distinctive mechanical properties of trucks. The simulation software, TruckSim, will be used to illustrate those distinctions related to steering systems, suspensions, tires and brake systems. Animated examples of truck dynamics will be presented using the TruckSim animator,

At the completion of this module you will be able to:

- Calculate steer angles for each of the front wheels in a given radius of turn
- Understand the tire cornering stiffness and how it affects understeer gradient
- Calculate steering angle as a function of turn radius in high speed turning
- Explain how vehicle dynamic simulation models of trucks differ from that of passenger cars

Day Three

Suspension Effects on Handling — Tire cornering stiffness is not the singular source of understeer behavior on a vehicle. A number of other properties related to the tires, steering, and suspensions and their interactions are involved. This presentation addresses the principle other mechanisms affecting handling: roll moment distribution, camber change, roll steer, lateral force compliance steer, aligning moment and steering caster. The physical explanation for each of these mechanisms is explained. Procedures for measuring understeer gradient by the constant radius and constant speed methods are presented.

At the completion of this module you will be able to:

- Explain the mechanisms by which tires and suspensions influence vehicle understeer
- Understand what tire and suspension properties are important to handling
- Estimate understeer contributions from these mechanisms given certain tire and suspension properties.
- Understand how to experimentally measure understeer gradient

Suspension Design and Analysis — Suspensions have been shown to have primary influence on ride and handling. Yet there are many types from which to choose. This presentation reviews the performance requirements for suspensions and then examines the principle types of suspensions and how each functions. Coverage is given to solid axle suspensions of the Hotchkiss, four link, DeDion and twist beam types. Independent suspension types discussed are the trailing arm, short-long arm, MacPherson strut, multi link, trailing arm, semi-trailing arm and swing axle types.

In this discussion the mechanics of anti-dive and anti-squat are explained. In addition, the roll center concept is explained using graphics and animations to aid in understanding the roll center influence on vehicle behavior.

At the completion of this module you will be able to:

- Name and describe the various types of suspensions in common use on vehicles
- Understand the advantages and disadvantages of each
- Explain how suspension geometry affects anti-dive and anti-squat
- Determine where the roll center is on a suspension

Steering Systems — Steering systems are more than just a convenient method for the driver to steer the front wheels remotely. Steering systems are one of the most significant contributors to vehicle handling. The typical architecture of the gearbox and rack and pinion steering systems is described. The geometry of the steering linkages acting in combination with the suspension is examined to reveal different types of steering geometry errors affecting drift, wander, pulls and roll steer. The geometry of the steering axis at the road wheels is examined to explain caster, kingpin inclination, and offset at the ground as the key properties affecting steering behavior. The action of the three forces (vertical, lateral and longitudinal) acting on the tires, and the aligning moment is analyzed to show how they interact with the steer axis geometry to produce torque reactions in the steering system. A simple steering compliance model is introduced to illustrate how these reactions affect handling. Analysis of a front wheel drive vehicle is presented to reveal the additional interactions of the drive system with the steering system and the constraints it places on steering geometry of front wheel drive vehicles. The advantages of four wheel steer systems will be discussed and illustrated with videos.

At the completion of this module you will be able to:

- Understand the primary architectural features of a steering system
- Understand the principle geometric properties of the steering linkages and how they should be designed
- Understand the principle geometric properties of the steering axes at the road wheels and how they should be designed
- Understand the interaction of drive systems with steering systems that are primarily responsible for the unique feel of front wheel drive systems

Rollover — The rollover behavior of motor vehicles has come under increasing scrutiny because of the high incidence of injuries and death in rollover accidents. The mechanics of the rollover process are presented beginning with the simple metric of the ratio of track width to center of gravity height. Additional mechanics are reviewed to inform the designer about how to optimize resistance to rollover.

Safety regulations relating to rollover are discussed since they are becoming broadly applied to the automotive industry. Test procedures for the Fishhook, FMVSS 126 and UN/EXE 13 regulations are reviewed and demonstrated using simulation. The principles for rollover mitigation by electronic stability controls and roll stability controls are explained.

Introduction to BikeSim — A unique class of highway vehicles are those with two wheels in line – scooters, motor bikes, motor cycles, etc. Simulating these vehicle requires dynamic models much different than that for vehicles with 3 and more wheels. The BikeSim vehicle dynamics simulation software will be demonstrated to acquaint students with the principle mechanics of these vehicles

At the completion of this module you will be able to:

- Explain the primary mechanisms involved in the vehicle rollover process
- Estimate rollover thresholds of vehicles based on certain nominal properties
- Understand how electronic control systems function to prevent rollover
- Be familiar with global standard procedures for conducting rollover and stability tests

Agenda for the 3 day Technical Training session at EASi, Bangalore

#	Session Overview	Date	Speakers	Time
1	Registration	25 Feb. 2010		09:00 - 9:30 AM
2	Welcome Address Mr. Sural will discuss about EASi	25 Feb. 2010	Mr. Sural (EASi)	09:30 – 10:00 AM
3	Dr. Gillespie's Introduction Day 01 – Technical training session	25 Feb. 2010	Dr. Gillespie	10:00 – 4.30 PM
4	Day 02 – Technical training session	26 Feb. 2010	Dr. Gillespie	09:00 – 4.30 PM
5	Day 03 – Technical training session	27 Feb. 2010	Dr. Gillespie	09:00 – 4.00 PM
6	Vote of thanks: Mr. Ramesh Venkatesan	27 Feb. 2010	Mr. Ramesh Venkatesan	04:30 – 05:00 PM