



## Full Vehicle NVH Analysis with Rolling Tires

### Summary

In a traditional automobile noise, vibration and harshness (NVH) analysis, stationary tires are defined and subjected to vertical dynamic loading. The actual operating conditions of a tire involve rolling however, and the vibration characteristics of rolling tires are considerably different from those of stationary tires.

Abaqus offers a methodology to include the pre-loading and gyroscopic effects of rolling tires in a forced response dynamic analysis of the moving vehicle. This article closely follows SIMULIA Technology Brief TB-08-TVC-1 and illustrates the use of substructures in a typical NVH analysis for a full vehicle model with steadily rolling tires.

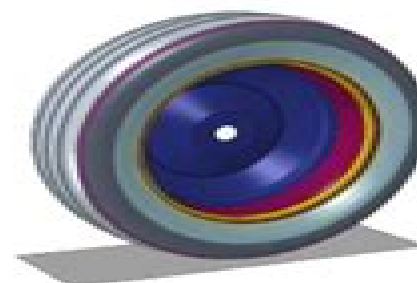
### Background

Small amplitude vibrations of a tire on the road can be treated as a linear superposition of small amplitude steady state vibrations on a highly nonlinear base state. For stationary tires, this base state is the footprint configuration of the tire. The base state contains nonlinearities arising from the load-deflection behavior of various rubber compounds, contact between the tire and the road, reinforcement behavior, etc.

In a traditional NVH analysis, the tires are stationary and subjected to vertical load. However, the vibration characteristics of rolling tires depend on the rolling velocity and are considerably different from those of stationary tires. Specifically, the rolling condition contributes loads in the fore-aft direction as well as the vertical [Ref 1].

It is common practice to employ a mixed Eulerian-Lagrangian scheme to compute the steady state rolling configuration of the tire. This methodology uses a reference frame that is attached to the axle of the rotating tire. An observer in this frame sees the tire as points that do not move, although the material of which the tire is made moves through these points. Small amplitude vibrations can then be superposed on the rolling configuration corresponding to the velocity of interest.

The dynamic substructure of a rolling tire can be created and incorporated in a full vehicle assembly, thus eliminating the need to use a fully meshed representation of the tire. With these modeling capabilities, tire manufacturers can provide automotive designers with richer, more comprehensive numeric representations of their tire's behavior – without divulging their detailed tire FE models.



### Key Abaqus Features and Benefits

- Symmetric model generation and symmetric results transfer
- A mixed Eulerian-Lagrangian scheme to compute the steady state rolling configuration of tires
- Dynamic substructures to account for pre-loading and gyroscopic effects of a rolling tire
- Subspace-based steady state dynamics for relatively inexpensive forced response prediction

The simulation presented here demonstrates the analysis methodology for including the effect of rolling tires on the vehicle forced frequency response. A dynamic substructure of a rolling tire FE model is created and assembled into a full vehicle model for NVH analysis. The automatic multi-level substructuring (AMS) eigensolver is used to extract the eigensolution of the vehicle assembly, which is then subsequently used in the steady-state dynamic analyses.

### Finite Element Analysis Approach

The model under consideration represents a typical passenger car tire. The road is modeled as an analytical rigid surface. Contact is defined between this surface and the tire. A simple Mooney-Rivlin law is used for the strain energy potential of the various rubber materials. This simulation ignores the viscoelastic nature of the rubber. The plies and belts are modeled using rebar layers embedded in the surrounding rubber matrix. Linear elastic material properties are applied to the reinforcement fibers.

# Full Vehicle Nvh Analysis With Rolling Tires

**CO Houle**



## **Full Vehicle Nvh Analysis With Rolling Tires:**

Vehicle/Tire/Road Dynamics Tan Li, 2022-11-24 Vehicle Tire Road Dynamics Handling Ride and NVH presents the connection between NVH and conventional vehicle dynamics where both tire and road play a key role In this book there is a chapter for handling dynamics that provides an introduction to ride dynamics and a chapter for ride dynamics that provides an introduction to NVH presenting better coherence and synergy between these major areas of vehicle tire dynamics Accompanying the fundamental theories case studies are given to facilitate comprehension In addition to the experimental implementations the state of the art approaches to simulating vehicle tire dynamics are presented from the viewpoint of both industry and academia This new book bridges the gap for experts in tire or pavement NVH also tire pavement interaction noise and those who are experts in vehicle dynamics Conventional vehicle dynamics e g handling braking cornering is focused on low frequency performance while NVH noise vibration harshness is focused on high frequency performance There is also another area called ride comfort stability which focuses on mid frequency Presents a closed loop system for vehicle dynamics covering handling ride and NVH Provides insights into how intelligent tires will enhance autonomous vehicle control and optimize multiple performances especially for electric vehicles Demonstrates how pavement characteristics could greatly influence vehicle handling ride NVH and improve balance these performances **Model Validation and**

**Uncertainty Quantification, Vol. 3** Roland Platz, Garrison Flynn, Kyle Neal, Scott Ouellette, 2025-08-07 Model Validation and Uncertainty Quantification Volume 3 Proceedings of the 42nd IMAC A Conference and Exposition on Structural Dynamics 2024 the third volume of ten from the Conference brings together contributions to this important area of research and engineering The collection presents early findings and case studies on fundamental and applied aspects of Model Validation and Uncertainty Quantification including papers on Uncertainty Quantification in Dynamics Fusion of Test and Analysis Model Form Uncertainty Round Robin Challenge UQVI Uncertainty Quantification in Vibration Isolation Recursive Bayesian System Identification Virtual Sensing Realtime Monitoring Surrogate Modeling and Reduced Order Models *Road and*

*Off-Road Vehicle System Dynamics Handbook* Gianpiero Mastinu, Manfred Ploechl, 2014-01-06 Featuring contributions from industry leaders in their respective fields this volume presents comprehensive authoritative coverage of all the major issues involved in road vehicle dynamic behavior It begins with a short history of road and off road vehicle dynamics followed by thorough detailed state of the art chapters on modeling analysis and optimization in vehicle system dynamics vehicle concepts and aerodynamics pneumatic tires and contact wheel road off road modeling vehicle subsystems vehicle dynamics and active safety man vehicle interaction intelligent vehicle systems and road accident reconstruction and passive safety

**Tire Science & Technology**, 1998 **Annual Index/abstracts of SAE Technical Papers**, 2007 **International Journal of Vehicle Design**, 1997 Cumulative Index [of The] SAE Papers Society of Automotive Engineers, 1965

**Highway Safety Literature**, 1982 Advanced Tire Mechanics Yukio Nakajima, 2019-04-03 This book highlights the

mechanics of tire performance offering detailed explanations of deriving basic equations for the fundamental properties of tires and discussing ways to improve tire performance using these equations It also compares the theory with practical measurements The book commences with composite mechanics which is the fundamental theory for belt and carcass tires and covers classical modified and discrete lamination theory It then addresses the theory of tire shape and spring properties and the mechanics of tread pattern contact properties as well as the performance of various tires This comprehensive book is a valuable resource for engineers involved in tire design and offers unique insights and examples of improvement of tire performances     Technical Literature Abstracts Society of Automotive Engineers,1999     **Automotive Tire Noise and Vibrations** Xu Wang,2020-07-29 Automotive Tire Noise and Vibrations Analysis Measurement and Simulation presents the latest generation mechanisms of tire road noise The book focuses not only on tire road noise issues from the tire road structures materials and dynamics but also from a whole vehicle system The analyses cover finite element modeling mathematical simulations and experimental tests including works done to mitigate noise This book provides a summary of tire noise and vibration research with a focus on new simulation and measurement techniques Covers new measurements techniques and simulation strategies that are critical in accurately assessing tire noise and vibration Provides recent simulation progress and findings of CAE on analysis of generation mechanisms of the tire road noise Features a Statistical Energy Analysis SEA and model of a multilayer trim to enhance the sound absorption of tire road noise     **Highway Safety Literature** ,1984     **1998 IBEC Proceedings: Advanced body design and engineering** ,1998     *Tire Model Performance Test (TMPT)* Peter Lugner,M. Plöchl,2007     Announcement of Highway Safety Literature ,1984     Topics in Modal Analysis, Volume 7 Randall Allemang,James De Clerck,Christopher Niezrecki,Alfred Wicks,2013-07-03 Topics in Modal Analysis Volume 7 Proceedings of the 31st IMAC A Conference and Exposition on Structural Dynamics 2013 the seventh volume of seven from the Conference brings together contributions to this important area of research and engineering The collection presents early findings and case studies on fundamental and applied aspects of Structural Dynamics including papers on Fluid Structure Interaction Adaptive Structures Experimental Techniques Analytical Methods Damage Detection Damping of Materials Members Modal Parameter Identification Modal Testing Methods System Identification Active Control Modal Parameter Estimation Processing Modal Data     *Proceedings of the ASME Noise Control and Acoustics Division* ,1996     *Engine Testing* A. J. Martyr,M.A. PLINT,2012-04-18 Engine Testing is a unique well organized and comprehensive collection of the different aspects of engine and vehicle testing equipment and infrastructure for anyone involved in facility design and management physical testing and the maintenance upgrading and trouble shooting of testing equipment Designed so that its chapters can all stand alone to be read in sequence or out of order as needed Engine Testing is also an ideal resource for automotive engineers required to perform testing functions whose jobs do not involve engine testing on a regular basis This recognized standard reference for the subject is now enhanced with new chapters on hybrid testing OBD

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