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Analysis Techniques for Racecar Data Acquisition

By Jorge Segers

Data acquisition has become an invaluable tool for establishing racecar – and car/driver – performance. Now that the ability exists to analyze each and every performance parameter for car and driver, accurate use of this data can provide a key advantage on the racetrack. This book provides a thorough overview of the varied methods for analyzing racecar data acquisition system outputs, with a focus on vehicle dynamics.

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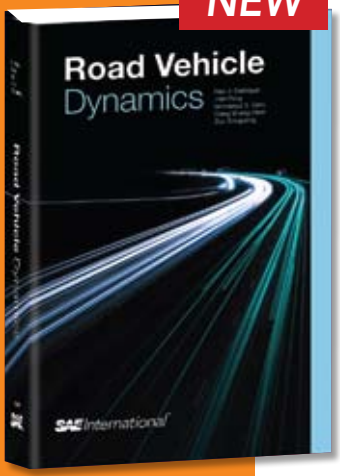

Road Vehicle Dynamics

Problems and Solutions Workbook

By Rao V. Dukkipati, Jian Pang, Mohamad S. Qatu, Gang Sheng Chen, Zuo Shuguang

This book provides a detailed and well-rounded overview of the dynamics of road vehicle systems. Readers will come to understand how physical laws, human factor considerations, and design choices come together to affect a vehicle's ride, handling, braking, and acceleration.

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- Analysis of dynamic systems
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- Ride dynamics
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- and more

The authors' emphasis on safety reflects growing consumer interest in vehicle safety. Safety considerations are covered throughout the book, with specific chapters on roll dynamics and accident reconstruction.

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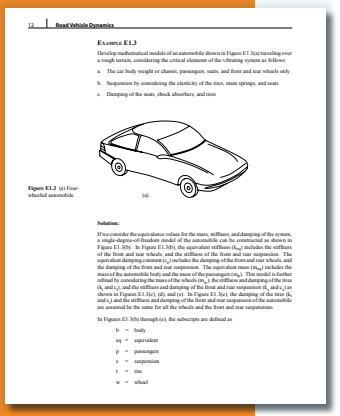

12 Road Vehicle Dynamics

EXAMPLE E1.3

Develop mathematical models of an automobile shown in Figure E1.3(a) traveling over a rough terrain, considering the critical elements of the vibrating system as follows:

a. The car body weight or chassis, passengers, seats, and front and rear wheels only

b. Suspension by considering the elasticity of the tires, main springs, and seats

c. Damping of the seats, shock absorbers, and tires

Figure E1.3 (a) Four-wheeled automobile.

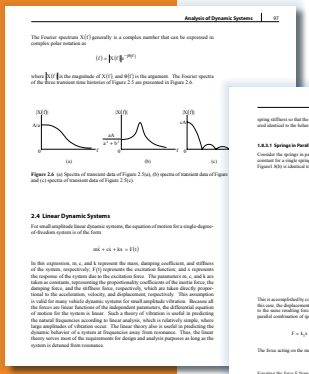
(a)

Solution:

If two consider the equivalence values for the mass, stiffness, and damping of the system, a single-degree-of-freedom model of the automobile can be constructed as shown in Figure E1.3(b). In Figure E1.3(b), the equivalent stiffness (k_{eq}) includes the stiffness of the front and rear wheels, and the stiffness of the front and rear suspension. The equivalent damping constant (c_{eq}) includes the damping of the front and rear wheels, and the damping of the front and rear suspension. The equivalent mass (m_{eq}) includes the mass of the front and rear wheels, the passengers, and the car body. The car body is further refined by considering the mass of the wheels (m_w), the stiffness and damping of the tires (k_t and c_t), and the stiffness and damping of the front and rear suspension (k_s and c_s) as shown in Figures E1.3(c), (d), and (e). In Figure E1.3(c), the damping of the tires (k_t and c_t) and the stiffness and damping of the front and rear suspension of the automobile are assumed be the same for all the wheels and the front and rear suspensions.

In Figures E1.3(b) through (e), the subscripts are defined as

b = body
eq = equivalent
p = passengers
s = suspension
t = tire
w = wheel


Analysis of Dynamic Systems 97

The Fourier spectrum X(f) generally is a complex number that can be expressed in complex polar notation as

$$X(f) = |X(f)|e^{j\theta(f)}$$

where $|X(f)|$ is the magnitude of X(f), and $\theta(f)$ is the argument. The Fourier spectra of the force transient time histories of Figure 2.5 are presented in Figure 2.6.

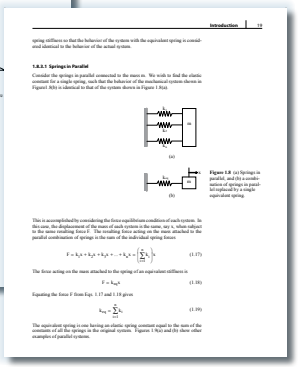
Figure 2.6 (a) Spectra of transient data of Figure 2.5(a), (b) spectra of transient data of Figure 2.5(b), and (c) spectra of transient data of Figure 2.5(c).

2.4 Linear Dynamic Systems

For small amplitude linear dynamic systems, the equation of motion for a single-degree-of-freedom system is of the form

$$m\ddot{x} + c\dot{x} + kx = F(t)$$

In this expression, m, c, and k represent the mass, damping coefficient, and stiffness of the system, respectively. F(t) represents the excitation function; and x represents the response of the system due to the excitation force. The parameters m, c, and k are taken as constants, representing the proportionality coefficients of the inertia force, the damping force, and the spring force, respectively. The terms $\ddot{x}$, $\dot{x}$, and x are related to the acceleration, velocity, and displacement, respectively. This assumption is valid for many vehicle dynamic systems for small amplitude vibration. Because all the forces are linear functions of the independent parameters, the differential equation of motion for the system is linear. Such a theory of vibration is useful in predicting the natural frequencies according to linear analysis, which is relatively simple, where large amplitudes of vibration occur. The linear theory also is useful in predicting the dynamic behavior of a system at frequencies away from resonance. Thus, the linear theory serves most of the requirements for design and analysis purposes as long as the system is detuned from resonance.


Introduction 19

spring stiffness so that the behavior of the system with the equivalent spring is considered identical to the behavior of the actual system.

1.8.1.1 Springs in Parallel

Consider the springs in parallel connected to the mass m. We wish to find the elastic constant for a single spring, such that the behavior of the mechanical system shown in Figure1.8(b) is identical to that of the system shown in Figure 1.8(a).

Figure 1.8 (a) Springs in parallel, and (b) a combination of springs in parallel replaced by a single equivalent spring.

This is accomplished by considering the force-equilibrium condition of each system. In this case, the displacement of the mass of each system is the same, say x, when subject to the same resulting force F. The resulting force acting on the mass attached to the parallel combination of springs is the sum of the individual spring forces

$$F = k_1x + k_2x + k_3x + \ldots + k_nx = \left(\sum_{i=1}^{n} k_i\right)x \qquad (1.17)$$

The force acting on the mass attached to the spring of an equivalent stiffness is

$$F = k_{eq}x \qquad (1.18)$$

Equating the force F from Eqs. 1.17 and 1.18 gives

$$k_{eq} = \sum_{i=1}^{n} k_i \qquad (1.19)$$

The equivalent spring is one having an elastic spring constant equal to the sum of the constants of all the springs in the original system. Figures 1.9(a) and (b) show other examples of parallel systems.

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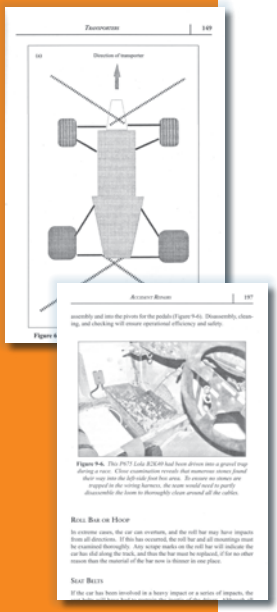

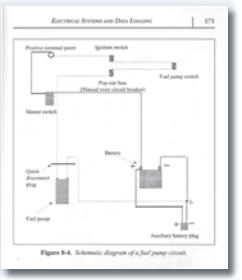

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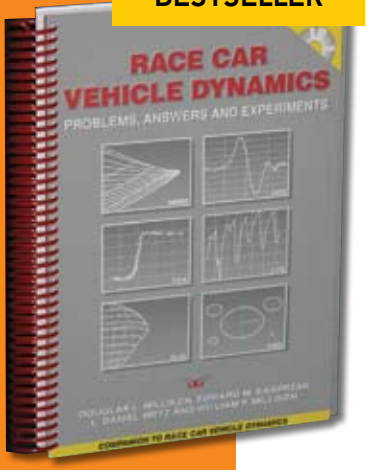

Race Car Vehicle Dynamics

Problems, Answers and Experiments

By Douglas L. Milliken, Edward M. Kasprzak, L. Daniel Metz, William F. Milliken

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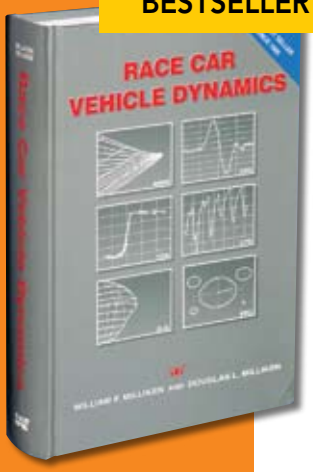

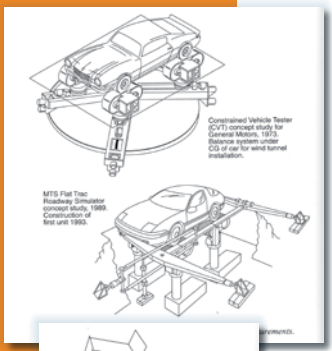

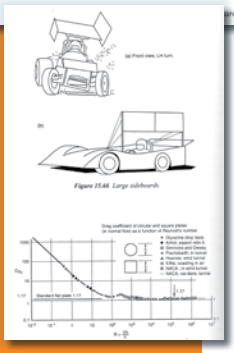

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The book also includes an extensive listing of references and a list of symbols, conveniently located on the inside front and back covers for ease of use. Well-illustrated with over 450 figures and tables.

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Race Car Vehicle Dynamics Book and Problems, Answers and Solutions Set

By William F. Milliken, Douglas L. Milliken, L. Daniel Metz, Edward M. Kasprzak

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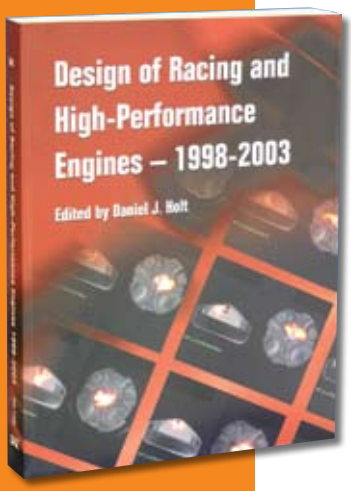

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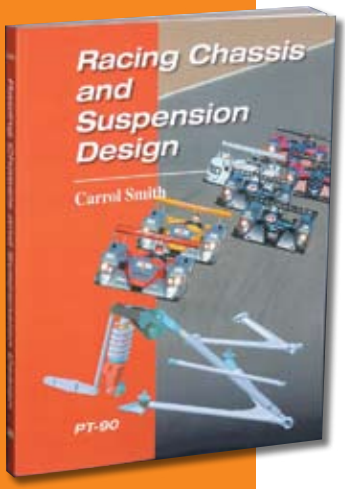

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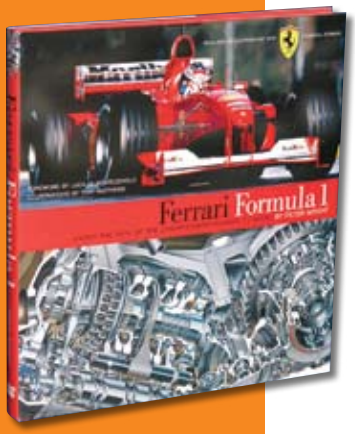

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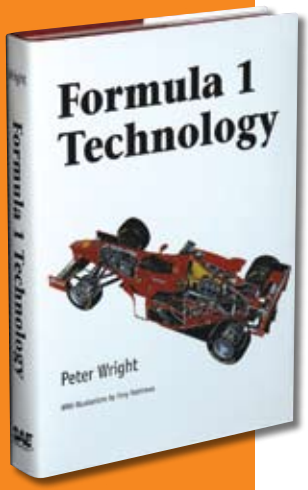

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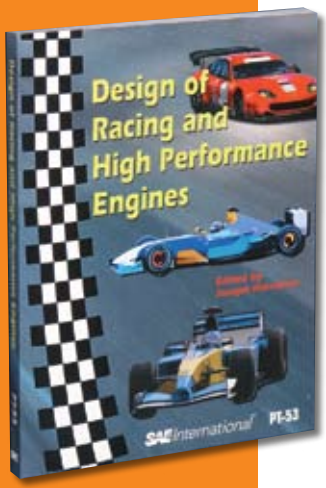

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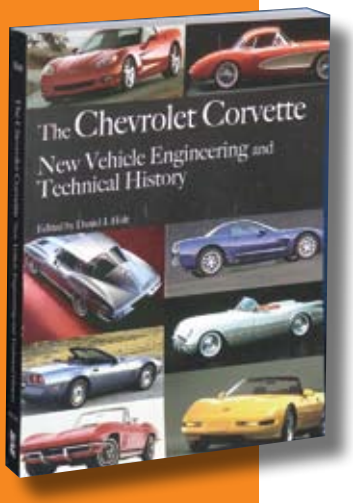

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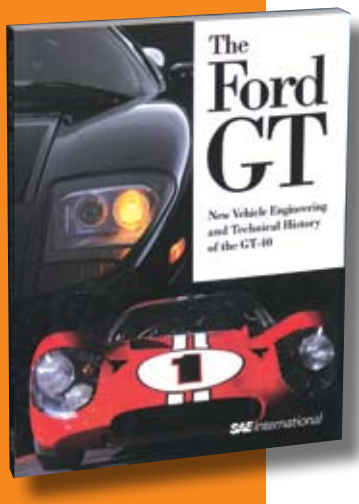

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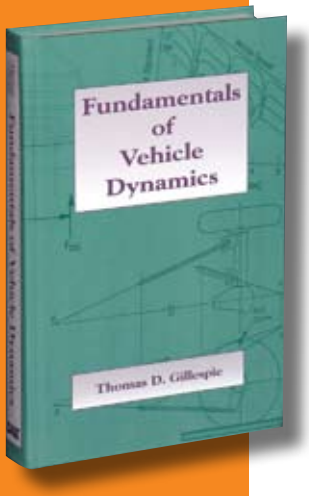

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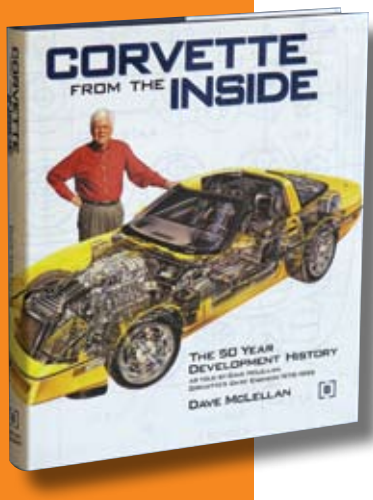

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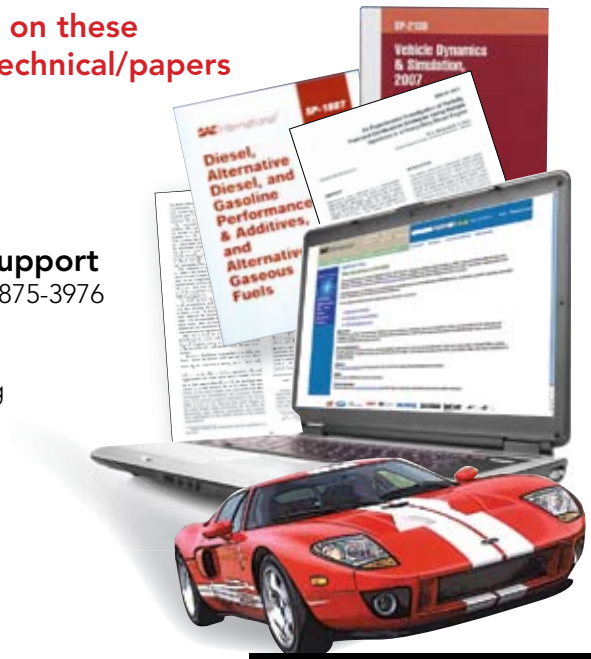

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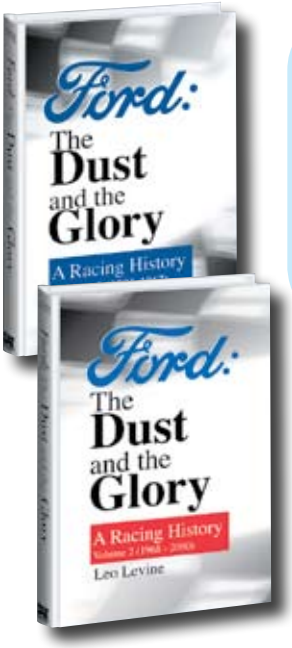

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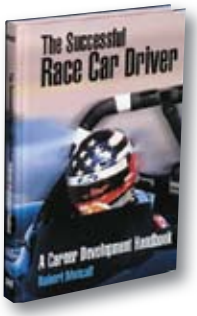

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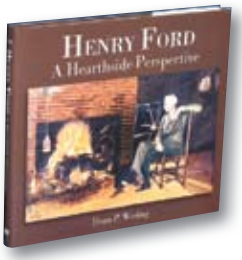

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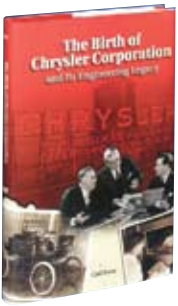

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