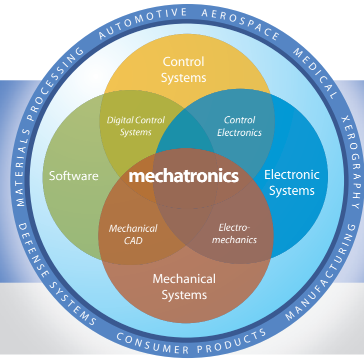
MECHATRONICS IN DESIGN



Where to Begin & the Tough First Step

The ability to physically model differentiates engineers; it is not a commodity.

Can physical system modeling be taught? Is it an art or a science? Many engineers have little experience, and, hence, little confidence in doing it. Physical system modeling, either applied to an existing system or a concept in the design process, leads to thorough understanding, differentiates engineers, and gives companies a competitive advantage as it leads to innovation.

There is a hierarchy of physical models possible in response to the question: Why am I modeling? Engineering judgment and simplifying assumptions applied to the physical system lead to the physical model, which must capture the essential multidisciplinary attributes of the physical system. A working knowledge of multidisciplinary physics is essential. Always, the simplest model that meets the need is best.

Here are two examples. Figure 1, shows an internal combustion engine connected to an eddy-current dynamometer. The physical model is shown in Figure 2. The engine is considered a nonlinear angular velocity source (ϖ_E) modulated by the throttle setting $\theta(t)$. The main energy storage is associated with the rotating inertia J_E, lumped at the output of the engine shaft. The torque transmission shaft has compliance and energy dissipation, and is modeled with a rotational spring K_S and rotational damper B_S. The shaft inertia is neglected. The dynamometer consists of a toothed rotor J_R that rotates (ϖ_R) in the magnetic field created by passing current (t) through the stator windings. A voltage is induced in the conductive rotor rotating in the stator magnetic field (Faraday's Law). This induced voltage creates eddy currents in the rotor that generate a magnetic field (Ampere's Law), which opposes the stator magnetic field (Lenz's Law). The stator inertia J_S, mounted in trunnion bearings, is free to rotate, but is restrained by a torque arm to measure the torque developed. The spring K and damper B represent the compliance and energy dissipation associated with the torque measurement.

Figure 3 shows a portion of a web-handling system between two sets of driven rolls. A physical model is the first step to predicting and controlling both the tension and velocity of the web. What is most interesting here is that a failure to understand the fundamental physics of web transport led to inaccurate modeling for many years. The Law of Conservation of Mass is applied to a control volume encompassing the web span, where the physical model allows for the transport of strain ε from the upstream web span to the downstream span, an essential characteristic validated by experimental observations. T is the web tension, assumed constant in any web span of length L.

Successful physical modeling requires a fundamental understanding of multidisciplinary physics and a commitment to do it and not fall back on the old design-build-test approach. This is the most direct path to innovation. **DN**

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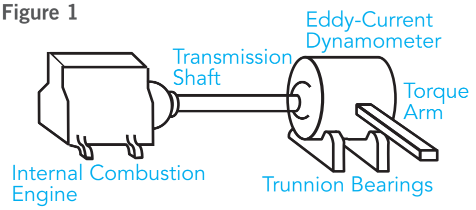
Figure 1



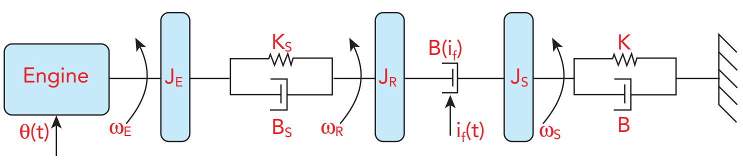


Figure 2

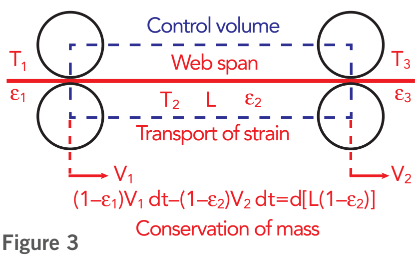


Figure 3