Using Energy, Power, Force and Torque Analysis

for Rigid Body Motion

- Energy Analysis is based on conservation of energy and identifies a necessary condition for a part to achieve a desired motion (but energy analysis alone is not sufficient to guaranteed that the desired motion will occur). The governing equation is:

$$E_{in} = E_{out} + E_{losses}$$

- Power Analysis adds a time component to the energy analysis, and identifies the necessary power needed to achieve motion within a specified time period. The governing equation is:

$$P_{in} = P_{out} + P_{losses}$$

- Force/Torque analysis determines if a part will be in equilibrium or will accelerate. Force/Torque analysis is a necessary and sufficient condition to determine whether a part will move. The governing equations are:

$$\Sigma \mathbf{F} = m\,\mathbf{a} \qquad \text{(translational acceleration)}$$
$$\Sigma M_{CM} = I_{CM}\,\alpha \qquad \text{(rotational acceleration)}$$

  where M_{CM} is the moment about the Center of Mass, I_{CM} is moment of inertia about the Center of Mass, and α is the angular acceleration.

  For static or quasi-static analysis:

$$\Sigma \mathbf{F} = 0 \qquad \text{(translational equilibrium)}$$
$$\Sigma M_a = 0 \qquad \text{(rotational equilibrium)}$$

  where M_a is the moment about any point.

- Force/Torque analysis can also be used to determine the speed of motion, but this typically requires integrating forces and torques over time.

Using the Methods

- Energy and Power Analysis are used to determine viability of a design early in the design process and match an energy source to an appropriate machine component.

- Force/Torque analysis is used to determine appropriate gear ratios and mechanical advantage at the detail design stage. It is also used in a wide range of problems such as linear sliders and jamming analysis.

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