扭力测量系统

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假设一个简单的扭力测量系统：电机（转动惯量J_m）与pump（转动惯量J_p）通过扭力传感器连接，电机作为驱动，pump作为负载。扭力传感器的刚度为K，damping 系数为b。电机产生的驱动力矩为T_m。 扭力传感器驱动端的动力学方程为：

$$J_m\ddot{\theta}_m + b(\dot{\theta}_m - \dot{\theta}_p) + K(\theta_m - \theta_p) = T_m \tag{1}$$

扭力传感器负载端的动力学方程为：

$$J_p\ddot{\theta}_p + b(\dot{\theta}_p - \dot{\theta}_m) + K(\theta_p - \theta_m) = 0 \tag{2}$$

resonance frequency of an undamped system

这里identify the resonance frequency of an undamped system, 忽略阻尼之后，Eq. 1和Eq. 2简化为

$$J_m\ddot{\theta}_m + K(\theta_m - \theta_p) = T_m \tag{3a}$$
$$J_p\ddot{\theta}_p + K(\theta_p - \theta_m) = 0 \tag{3b}$$

假设共振状态有：

$$\theta_m = \hat{\theta}_m \sin\omega t \tag{4a}$$
$$\theta_p = \hat{\theta}_p \sin\omega t \tag{4b}$$

带入Eq.之后，有

$$-\omega^2 J_m\hat{\theta}_m + K(\theta_m - \theta_p) = T_m \tag{5a}$$
$$-\omega^2 J_p\hat{\theta}_p + K(\theta_p - \theta_m) = 0 \tag{5b}$$

Pump的input Torque是 $T_p = J_p\ddot{\theta}_p$。T_p与T_m之间的传递函数通过简化Eq.得到：

$$\frac{T_p}{T_m} = \frac{J_p\ddot{\theta}_p}{T_m} = \frac{\frac{1}{J_m}}{\frac{1}{J_m} + \frac{1}{J_p} - \frac{\omega^2}{K}} \tag{6}$$

共振频率对测量的影响以及阻尼对测量的影响，见Himmelstein tech note: dynamic torque measurement