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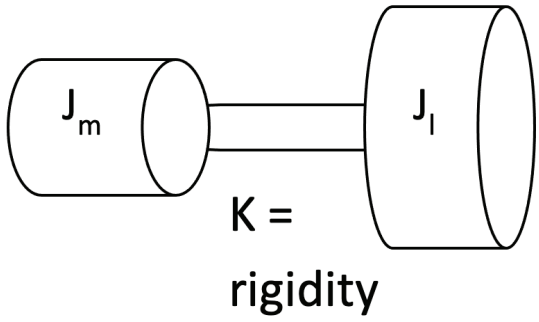
Importance of the Ratio Load Inertia / Motor Inertia

When designing a servo motor application one very important parameter to consider is the ratio between load inertia and motor inertia.

The reason is: this ratio associated with the rigidity of the load coupling will create a resonance and anti-resonance frequency which can be very prejudicial to final performance of the global system in term of dynamic, stability and positioning accuracy.



These two inertias (motor and load) coupled with a mechanical link with the rigidity K will have 2 resonance frequency equal:

Inertia ratio: $R = \frac{J_l}{J_m}$

Anti-resonance frequency: $\omega_a = \sqrt{\frac{K}{J_l}}$

Resonance frequency: $\omega_r = \sqrt{\frac{K}{\frac{J_l \times J_m}{J_l + J_m}}}$

The Key Factor is the Rigidity K

Decreased rigidity – increased compliance prevents high inertia ratio

Increased rigidity – reduced compliance allows higher inertia ratio

Rules of thumb about inertia ratio when designing a servo motor application. Note these are rules of thumb commonly admitted illustrating the difficulties to get a dynamic and accurate positioning when the ratio of inertia increases

- Ratio between 1 to 3: No problem – The range we should aim for.
- Ratio between 3 to 6: Acceptable but high rigidity compulsory – May need to adjust speed and position gain.
- Ratio between 6 to 10: May be difficult – Very high rigidity compulsory – May need to add notch filter in the control loop set at anti-resonance frequency – Compromise between dynamic and stability.
- Ratio > 10: To avoid – Need to have a large experience of motion control application and relevant design – Use of very advanced motion control algorithm (Dynamic load observer, auto adaptative notch filter…)

How to Increase the Rigidity K

In case of an application with a high inertia ratio, the whole mechanical design must be studied in order to maximize the mechanical rigidity as well the gear reducer design choice.

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A short, strong and direct load coupling will increase stiffness and rigidity: Prioritize TD or TM range

If the load is driven by a teethed belt or a chain, you need to increase teethed belt or chain tension (Inside mechanical limit of the belt or chain!).

If the driving pulley or pinion is directly mounted on gear reducer output shaft, the gear output shaft will undergo a higher radial force: Prioritize TF range

High backlash can generate instability: Prioritize very low backlash option (P1)

Conclusion

High inertia ratio parameter has a strong impact on global performance of the whole system. Not taking enough this parameter in consideration in design phase could prevents to get expected performance level. The remedy may lead to reconsider machine design and components choice which could be very costly.

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