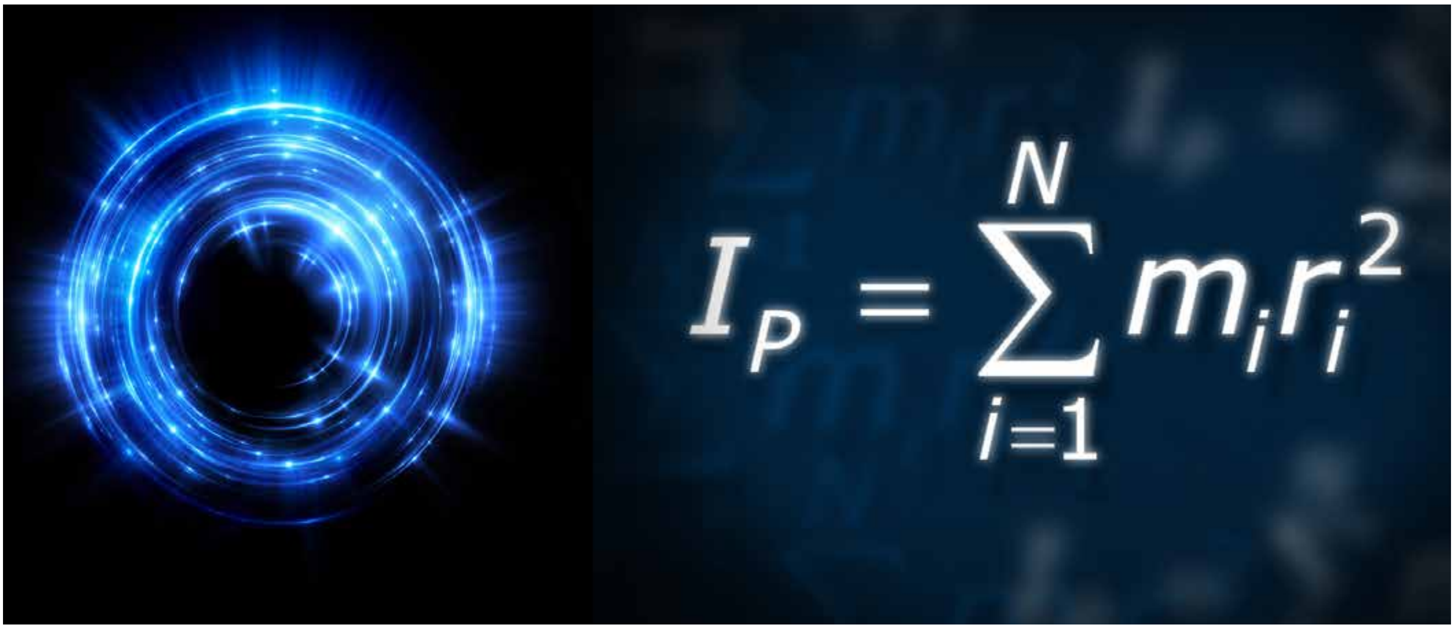
A challenging mechanical parameter in torque motor sizing



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Introduction to calculating the moment of inertia

The most difficult mechanical parameter in torque motor sizing, tends to be the moment of inertia. It is the rotative equivalent of moving mass. Its value is not only determined by the value of the moving mass, but also by the distance of the mass to the axis of rotation. Calculating the moment of inertia correctly can even be difficult with a straightforward system. This document gives insight into this physical quantity.

Definition

The moment of inertia indicates how much resistance a certain moving body has against a change in its angular velocity. This is comparable to a linear movement, in which the moving mass is acting as a resistance against linear acceleration. So a higher moment of inertia means that more torque needs to be applied in order to perform the same angular acceleration. This dependence is caught in the well-known formula

$$\tau = I\alpha,$$

The torque that a Tecnotion motor can deliver can be found in the catalogue. The angular acceleration, which may vary during the movement, can be determined from the movement profiles. The only unknown parameter left is therefore the moment of inertia *I*.

A definition of the moment of inertia is given by

$$I = \int_Q r^2 \, dm,$$

where the integration has to be performed over the full mass *Q*. The r denotes the distance to the axis of rotation, and the *m* is the mass.

The easiest situation is of course when all the mass in concentrated in one or a few points. In this case the integral formula can be replaced by a sum, leading to

$$I = \sum_i m_i r_i^2.$$

When this is simplified to one particle that carries all the mass M at a distance R from the rotational axis, it can be easily seen that $I=MR^2$.

[Common rotating bodies]

Most applications have rotating bodies that cannot be described as a point particle at a given distance. To calculate moments of inertia, the integral has to be calculated. For common shapes these moments of inertias are well known.

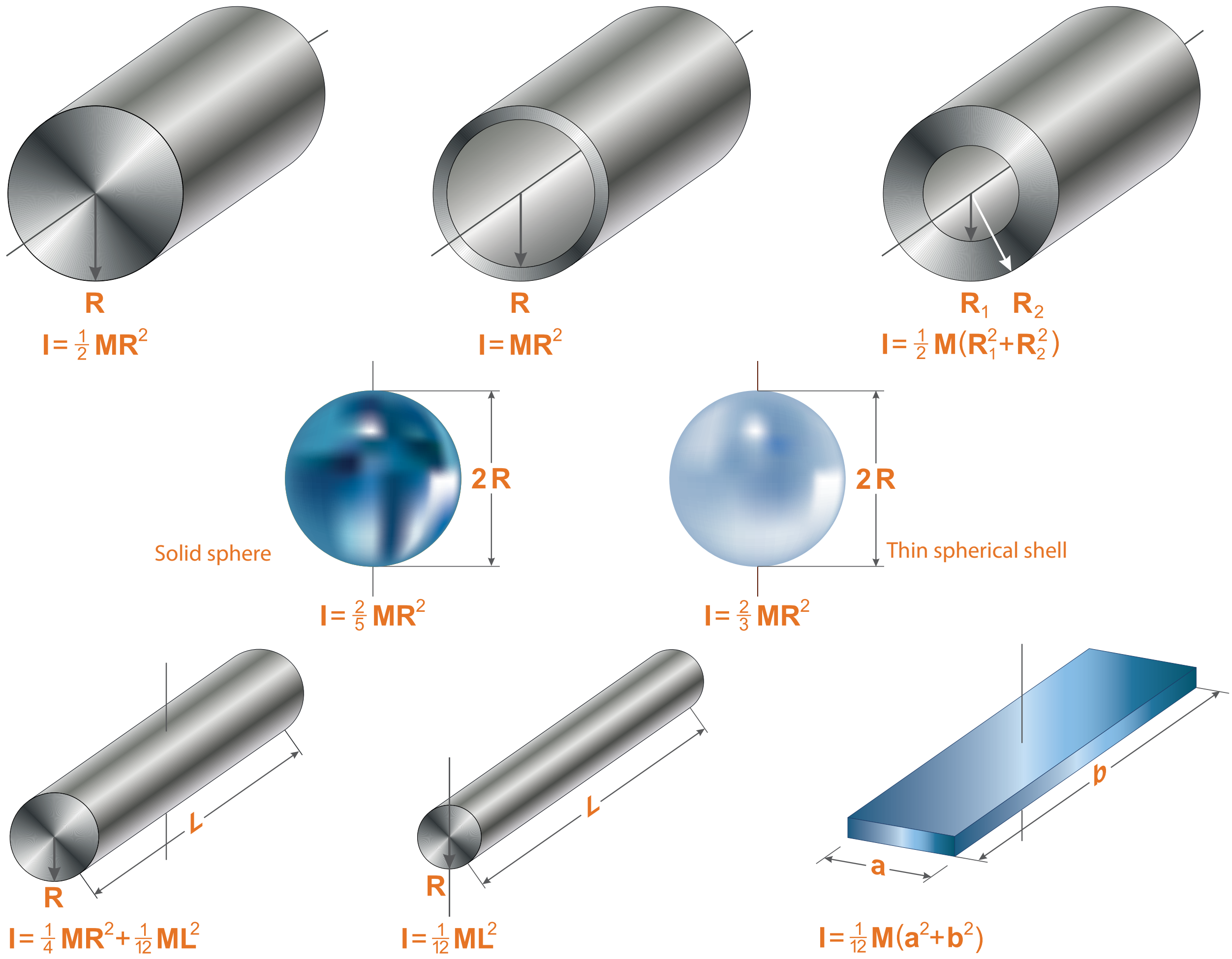


Figure 1: Common moments of inertia

In figure 1, the most important moments of inertia can be seen.

With these formulas the moment of inertia of relatively simple configurations is calculated. However, the applications that are encountered in the field can be much more complex than this. Therefore, it is often necessary to estimate the moment of inertia of the application or have software perform the necessary calculations.

Parallel axis theorem

In order to determine the correct moment of inertia as an input value in the our simulation tool, the given list of common moments of inertia is sometimes not yet sufficient. Luckily, the step from the known common values to real life values can be relatively small. The definition of the moment of inertia, $I=\int r^2 dm$, has the intrinsic property that independent contributions will add up to the final value of the moment of inertia.

Another important tool to determine a correct moment of inertia is the parallel axis theorem. The previously mentioned values assume that the axis of rotation is through the centre of mass of the object. If this is not the case and the body is rotating around an parallel axis at a distance d from the mass centre of mass the inertia can be calculated as below:

$$I = I_{cm} + md^2$$

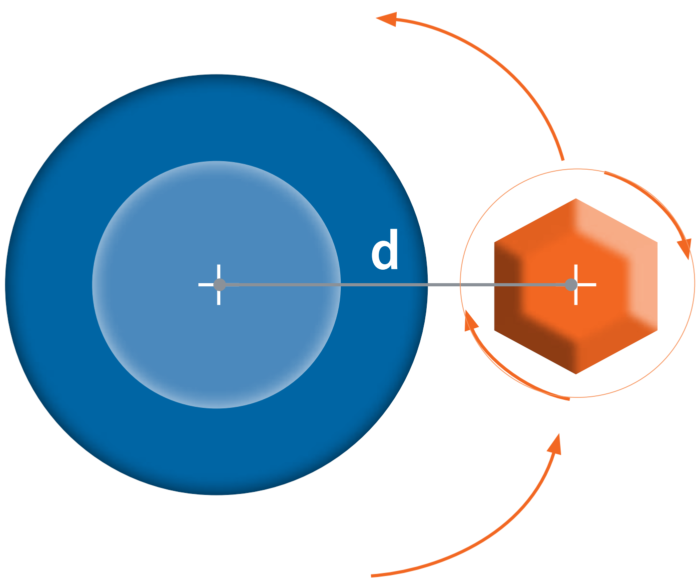


Figure 2: Parallel axis theorem

Simulation tool

Our online simulation tool on the Tecnotion website offers a calculation tool to determine the moment of inertia of a rotating solid cylinder around a central axis. *See figure 3 on the next page.*

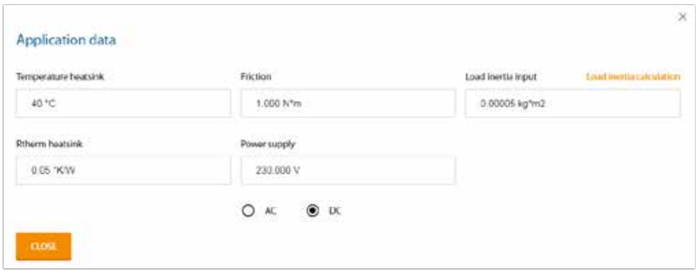
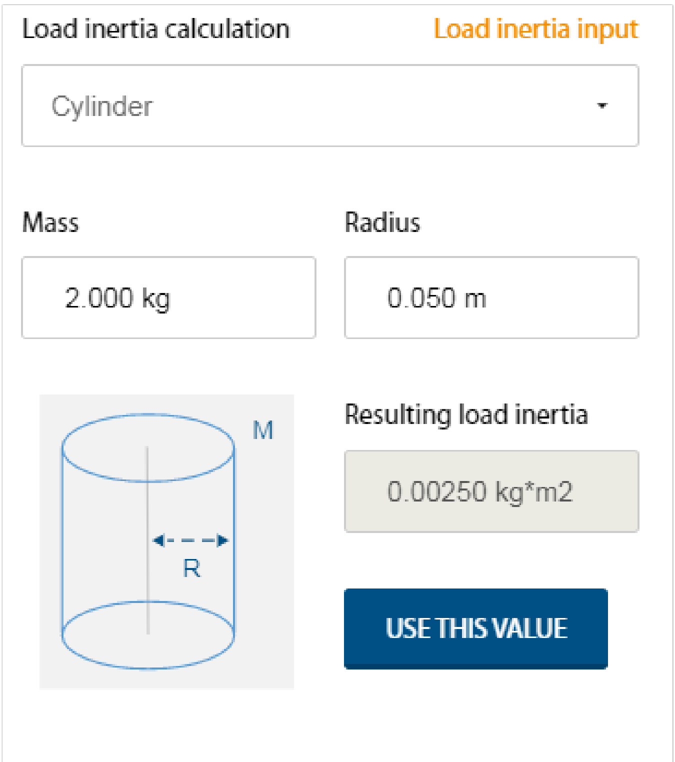


Figure 3: Moment of inertia in the simulation tool

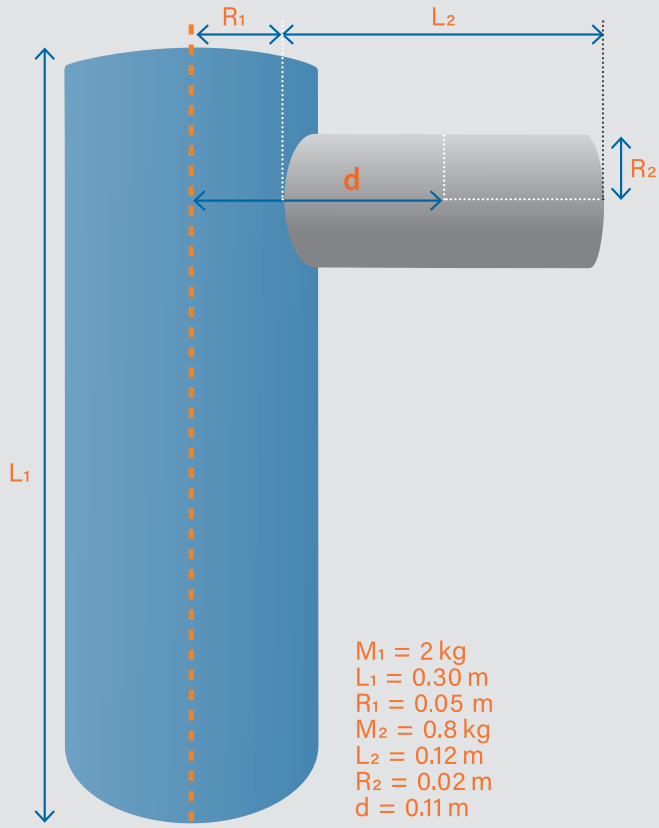
To use this tool option, select a torque motor in the main menu and then select open the application data menu. The load inertia calculation tool can be accessed by clicking the orange link above the load inertia input box.

After entering the mass and radius of the load the load inertia is calculated and will be automatically imported into the load inertia input field.



[Example]

Object 1 is a solid cylinder rotating around a central axis, object 2 is a solid cylinder attached to object 1 rotating around a central diameter outside of the center of mass.



$I_1 = \frac{1}{2} M_1 \cdot R_1^2 = \frac{1}{2} \cdot 2 \cdot 0.05^2 = 0.0025 \text{ kg m}^2$

$I_2 = \frac{1}{4} M_2 \cdot R_2^2 + \frac{1}{12} M_2 \cdot L_2^2 + d^2 \cdot M_2 = \frac{1}{4} \cdot 0.8 \cdot 0.02^2 + \frac{1}{12} \cdot 0.8 \cdot 0.12^2 + 0.11^2 \cdot 0.8 = 0.01072 \text{ kg m}^2$

$I_{tot} = I^1 + I^2 = 0.01322 \text{ kg m}^2$

Conclusion

The common moments of inertia are a good start to find the moment of inertia for the application load. It might be everything you need for the calculation. If there are more rotating parts, the additive behavior of the moment of inertia can be used, and sum all the components that are contributing. If the shape is complex and/or the shape is not rotating through the center of gravity, the parallel axis theorem can be used in order to estimate the inertia.

[End note]

Our team of Application Engineers can support in your calculations for finding the moments of inertia. Please contact us at: support@tecnotion.com or at: +31 546 898 475.

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About Tecnotion
Tecnotion is the global authority on direct drive motor technology. We are the world's only unbundled manufacturer of linear and torque motors. We specialize solely in the development and production of direct drive motors. This specialization allows us to provide expertise, customer service and product quality that are unmatched by other direct drive manufacturers.

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