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Synergy

Robotics and Motion newsletter

For ABB Channel partners in India

Learning series 1

Understanding the importance of Torque-Speed curve and load inertia for motor selection

Electric motor converts electrical energy into mechanical energy. This mechanical energy is used to drive mechanical equipments. During running, the motor should deliver the required power and torque demanded by the equipment, selection of motor for running an equipment is straight forward, match the demanded torque and power at the required speed. However, starting the equipment and running to its full speed is a different challenge. In this article we will focus on two main aspects of load, which determine motor selection w.r.t starting. They are load inertia and load Torque Speed curve.

Moment of Inertia (Also referred as GD^2 or GD Square)

Moment of Inertia is a measure of an object's resistance to changes (to make it rotate from standstill and to accelerate). It depends on the body's mass and axis of rotation. Higher the inertia, higher is the force required to change its rate of rotation. Moment of Inertia is equal to $GD^2/4$ and its unit is kgm2.

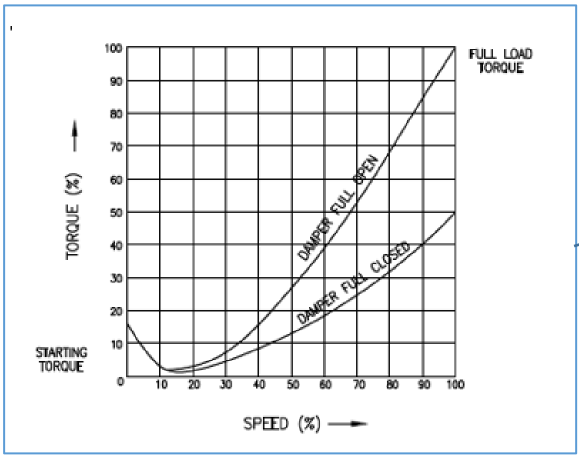
Applications like Pumps have low inertia and application like Fan and crushers are with high inertia.

There is also a myth that the motor inertia should be equal to load inertia. There is no relationship between motor inertia and load inertia, except for some very special application and purposes.

Torque-Speed Curve

The torque speed curve of a load is a plot showing its torque requirement on the y-axis versus the speed on x-axis. It's the torque requirement of the load from zero speed to full speed. Its application/load specific and varies with different load types.

Loads like centrifugal pumps and fans follow quadratic speed torque curve, where torque varies square times the speed. Other loads like conveyors, crushers have constant torque requirement from zero speed to full speed. These are also called as constant torque loads or applications.



Torque speed curve of a FAN

How these details are used for motor selection:

The above details of Moment of inertia and load torque speed curve determine the starting time of the motor (with load) and this along with the starting current plays a major role in motor selection.

Starting time (in secs) of the motor is roughly calculated using the formula

$$Sta = \frac{\text{Total } GD^2 \times \text{Motor RPM}}{375 \times \text{Acceleration torque}}$$

Total GD^2 is the sum of Load GD^2 + Motor GD^2 + Coupling GD^2.

And Acceleration torque is difference between motor torque and load torque.

$$Sta = \frac{\text{Total } GD^2 \times \text{Motor RPM}}{375 \times (\text{Motor torque} - \text{Load torque})}$$

This shows that the starting time is directly proportional to both GD^2 (moment of inertia) and load torque requirement. Hence both these factors play a major role in motor selection.

Starting time is always compared with withstand time of the motor and it's a requirement that starting time should be less than withstand time.

Withstand time is the duration for which the motor can withstand starting current. Generally withstand time hot and cold values are given in the motor datasheet. Thermal withstand time depends on how the motor is designed and is fixed for a given design of a motor

Withstand time of a motor is irrespective of the application/load.

Higher the load inertia **and load torque requirement**, the time to start the load is longer and because the stator and rotor experiences prolonged starting current, the heat generated in the motor is higher.

As the temperature rise during start is high, it limits the possibility of number of consecutive starts (typically 3 Cold and 2 Hot starts are OK, but for very high inertia values number of consecutive starts are further reduced)

To determine motor thermal suitability, it is essential to calculate starting time and compare it with thermal withstand time.

If the motor starting time is higher than the withstand time, a higher size motor is recommended or in larger machines a speed switch is used.

The difference between starting time and withstand time is used for designing motor protection.

Different popular applications

Application	Inertia	Torque-Speed
Centrifugal Pumps	Low	Variable torque (Quadratic)
Fans	Medium – High	Variable torque (Quadratic)
Crushers	Medium – High	Constant Torque
Centrifugal Compressors	Medium	Variable torque (Quadratic)
Conveyors	Medium	Constant Torque

The case of motor started with Variable frequency drive

Though both Moment of Inertia (GD^2) and torque speed curve are relevant for motors driven by VFD, they are not critical in motor selection. Both play the same role in determining starting time as in case of the direct online supplied motors. However, as the withstand time in VFD driven motor is infinite, there is no problem in respect to the number of starts or starting time being more than the withstand time. One of the several advantages that comes with VFD is that the starting current is almost equal to the rated current of the motor. So, the terms withstand time and starting current become non-relevant for motors driven by VFD.

Higher inertia load will still take longer starting time (from zero speed to full speed), however it will not cause any excessive heating in the motor.

Applications like Fan with high GD^2, can be started with a standard frame size VFD driven motors, which would have caused motor selection in a higher frame size with DOL supply.

Method of starting and its relation to GD^2 and Torque speed curve:

We have different starting method requirement from the customer depending on factors like network availability and capex. Four major methods used for starting a LV motor are DOL, Star-Detla, Soft Starter and VFD. Each has its own advantages and disadvantages over other methods. GD^2 and Torque speed curve are critical in motor selection for first three methods, whereas not so critical for VFD driven motors.

Conclusion:

It is desirable to know the Load inertia and T S curve of application, more so for high inertia loads like fans or high torque demanding loads like conveyors and crushers. Both these factors have a major influence in motor selection, method of starting and designing motor protection scheme.

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