The Locked Rotor Test Explained.

By Henk de Swardt

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Introductions

In our efforts to assist our valued customers, we often answer customers' technical questions. One such question is the significance of the Locked Rotor Test.

Basic Concepts

In order to understand this test, it is necessary to explain a couple of concepts surrounding the motor's torque.

In its simplest form, Torque is the action of a Force acting on a body to move, turn, bend or break it, acting at a specific distance and in a specific direction.

Thus:

$$\overline{T} = \overline{F} \cdot l$$

Equation 1: Torque

Where:

$\overline{T}$ = Torque, measured in N.m. (Newton meter)
$\overline{F}$ = Force, measured in N. (Newton)
l = Distance, measured in m. (meter)

Furthermore, one definition of Power is the rate of application of Torque (in a steady state condition.)

Thus:

$$P = \varpi \cdot T$$

Equation 2: Power

Where:

P = Power, measured in W (Watt)
ω = Speed, measured in rad/s (Radians per second)
T = Torque, measured in N.m.

[1] *Vector* is the Journal of the Institution of Certified Mechanical and Electrical Engineers and the Journal of South African Institute of Electrical Technician Engineer.

For an electric motor (in a steady state condition.):

$$\varpi = \frac{2 \cdot \pi \cdot n}{60}$$

Equation 3: Speed

Where:
ω = Speed, measured in rad./s.
n = Speed, measured in rpm (revolutions per minute)

We can thus see that the Power a motor consumes is directly proportional to the Torque the motor produces at a particular rotating speed.

Typical Torque Values

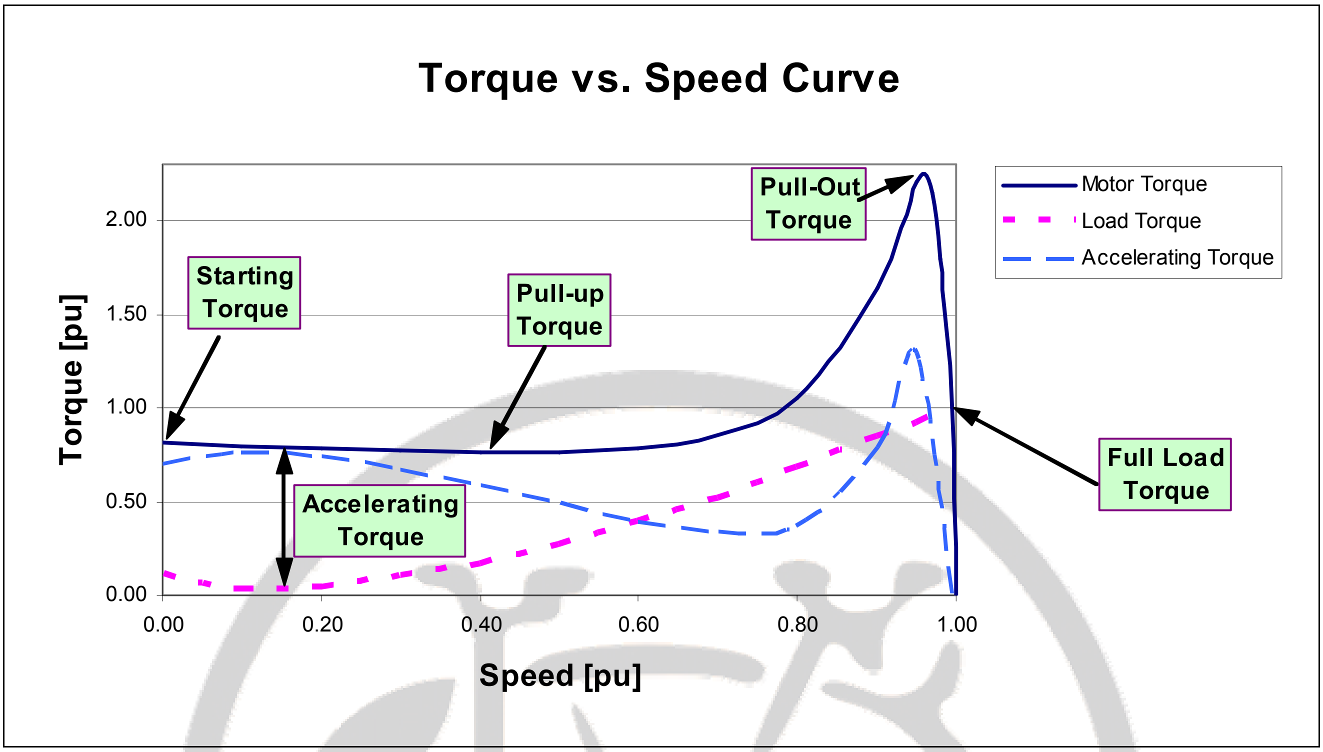
There is specific torque values commonly listed on electric motor specifications. These are explained briefly in table 1 hereunder:

Name	Explanation	Typical Values	Other Names
Starting Torque	This is the torque value of the motor when stationary, where the electrical power is applied.	0.3 – 1.2 pu[2]	Locked Rotor Torque
Pull-up Torque	This is the minimum torque value that the motor's torque curve will dip to during the starting sequence.	0.8 – 1.2 pu	Minimum Torque
Pull-out torque	This is the maximum value of the motor's torque curve during the run-up cycle.	1.8 – 3.0 pu	Tip-up Torque
Full Load Torque	This is the stabilised torque when the motor is delivering the rated power output at the rated speed.	ALWAYS 1.0 pu	Running Torque
Accelerating Torque	This is the difference between the motor's torque, and the load's required torque. This torque is the torque that is accelerating the motor. The higher this value, the faster the motor will accelerate.	Varies	
Motor Torque vs. Speed Curve	This is a curve plotting the torque that the motor can deliver against the motor's rotating speed during the run-up cycle.	Varies	
Load Torque vs. Speed Curve	This is a curve plotting the load's (e.g. pump, fan, compressor, etc.) torque requirement against the load's rotating speed during the run-up cycle.	Varies	

Table 1: Common torque values specified for electric motors.

2 Explanation: "pu" refers to the base value, for instance: 1 pu Torque refers to 1.0 x Full load Torque value.

The following curve will help to explain these concepts further:



Graph 1: Torque speed curve explanation.

The motor's torque vs. speed curve is specific to each motor, and is extremely important in defining the motor's performance.

The acceleration speed (and run-up time) of the motor from stationary to full speed is dependant on the accelerating torque (the difference between the load torque vs. speed curve, and the motor's torque vs. speed curve).

With these brief explanations of some of the concepts involved in the motor's torque, we can now progress to explaining the locked rotor test.

The Locked Rotor Test

The locked rotor test is done by mechanically holding the motor shaft from turning, and applying a reduced Voltage on the stator. The restraining on the shaft should be coupled to a scale or load cell in order to measure the torque. The Voltage supplied to the stator is reduced to prevent damage to the motor. Effectively a stall condition is applied.

The test can be done at different Voltages. Normally the values are recorded at 1 pu., 1.5 pu., and 2 pu. current. This is to ensure that the values are consistent.

Typical examples of such recorded values are shown in table 2 hereunder:

Locked Rotor Test					
Power	**800 kW**				
Voltage	6600 V				
Speed	1494 rpm				
Full load current	84 A				
Full load torque	5112.0 Nm				
Arm length	1.0 m				
Test Values				**Results: Locked Rotor**	
Scale	**Current**	**Voltage**	**Torque**	**Torque**	**Current**
1.5 kg	32.6 A	575 V	14.7 Nm	0.38 pu	4.45 pu
5.0 kg	55.8 A	961 V	49.1 Nm	0.45 pu	4.56 pu
15.0 kg	90.4 A	1529 V	147.2 Nm	0.54 pu	4.65 pu

Table 2: Locked rotor test results for 800kW, 4 Pole, 6600V TEFC motor.

From the test results we need to clarify the following:

The retaining arm length is important to determine the torque values. As noted in equation 1, the torque can be calculated from the measured force. This force was measured in weight, and thus this must be converted to Newton, by multiplying it with the gravitational constant. The torque measured will thus be according to equation 4:

$$T_{Measured} = F \cdot l = (\text{Weight measured}) \cdot 9.81 \cdot (\text{Arm length})$$

Equation 4: Measured torque in locked rotor test.

Normally the current is measured on all phases, and the average value is used.

The motor's locked rotor torque expressed as a per unit value is obtained by firstly normalizing it to the rated Voltage, and then by dividing it by the motor's rated full load torque, as shown is equation 5:

$$T_{pu} = \frac{T_{Measured} \cdot \left(\frac{V_{Rated\ Voltage}}{V_{Test\ Voltage}} \right)^2}{T_{Rated\ Full\ Load}}$$

Equation 5: Normalized locked rotor torque.

The motor's locked rotor current expressed as a per unit value, is obtained by firstly normalizing it to the rated Voltage, and then by dividing it by the motor's rated full load current, as shown in equation 6:

$$I_{pu} = \frac{I_{Measured} \cdot \left(\frac{V_{Rated\ Voltage}}{V_{Test\ Voltage}} \right)}{I_{Rated\ Full\ Load}}$$

Equation 6: Normalized locked rotor current.

Conclusion

To summarize, the locked rotor test is used to measure the motor's starting torque and current. This is extremely important to ensure that the motor has sufficient torque to be able to accelerate the motor when driving a specific load.

It must be noted that the change in Voltage significantly reduced the motor's locked rotor torque. This is of particular importance when using reduced Voltage starters, etc. For more information about this, see the author's article published in the October 2003 issue of Vector, entitled: "*Star-Delta Starting and Dual Voltage Motors explained.*"

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About the Author:

Henk de Swardt has a B. Sc. in Electrical and Electronic Engineering. He has more than eleven years of electric motors experience, both in the electric motor repair industry, as well as the electric motor manufacturing industry. He was employed for several years by the Largest OEM in South Africa. He also received specialized training in France on the designing of Electrical Motors. He is currently serving the Electric Motor industry at the Largest repairer of MV and HV motors in Africa. For a full C.V. visit http://www.qtime.co.za/CV_Main.html

Other articles written by the Author:

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