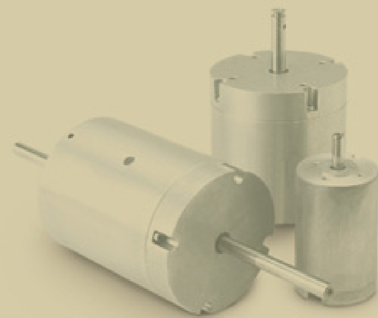
SMMA
The Motor & Motion Association

General Motor Terminology



Note: the SMMA merged with the Motion Control Association to form the MCMA (Motion Control and Motor Association) in 2015. This original SMMA glossary is not available elsewhere and may contain dated material. It is offered as originally published just prior to the SMMA-MCA merger.

Contents

GENERAL MOTOR TERMINOLOGY

Acceleration (α): The time rate change of velocity. Torque (T) developed by the rotor (armature) will cause it to accelerate. $\alpha = T / J$, Where *J* = polar moment of inertia

Acceleration – Maximum (α_m): An expression of maximum theoretical acceleration from stall (locked rotor) of an unloaded motor with maximum current (I_m) applied, measured in rad/sec².

Ambient Temperature: The temperature of the environment immediately surrounding the motor. It is measured in ºF or ºC.

Armature: The rotating portion of the magnetic structure that is found in machines with commutators.

Armature Inductance (L_a): The apparent inductance of the armature as seen by the brushes.

Armature Reaction: A magnetic field is produced by the armature current. It is shifted approximately 90 electrical degrees with respect to the direction of the stator field. It causes the armature to rotate and tends to cause demagnetization of the trailing pole tips of the stator.

Armature Resistance (R_a): The resistance of the armature winding, commutator connections and the commutator measured on the commutator bars normally spanned by a pair of opposite polarity brushes. It does not include the brush film. The resistance is usually taken at room temperature (25ºC).

Axial End Play: The shaft displacement along the motor axis which is due to a reversal of the axial force. It is measured in inches or mm.

Free End Play: The displacement measured when the moving force is removed after positioning the shaft axially from one extreme position to the other.

Cushioned End Play: The displacement measured when a force of known value causes the shaft to move axially from one position to another. When specifying cushioned end play, the force and direction of movement must also be specified.

Back EMF Constant (K_b) is equal to Voltage Constant (K_e): In a D.C. motor the constant that defines the magnitude of reverse voltage generated in the armature. It may be determined in a PMDC motor by driving the motor as an unloaded generator measuring the voltage and dividing by the speed in thousands of RPM.

$$K_b = V / KRPM$$

It has the following relationship to torque constant

$$K_b = 0.74Kt(oz - in / rpm) = V / KRPM$$
$$= 7.06x10^{-3} K_t(oz - in / rpm) = V / rad / \sec$$

It may be determined in a Brushless DC (BLDC) motor by driving the motor as a generator and obtaining the peak to peak voltage on an oscilloscope. Divide this value by two times the drive speed in thousands of RPM. In two phase BLDC motors the K_b and K_t have the approximately same relationship as the PMDC motor in the three phase BLDC motors the relationship is approximately equal to

$$K_b \approx \sqrt{\frac{3}{2}} K_t$$

Breakaway Torque: The value of torque that is required to begin motion of an armature or rotor that is de-energized and has been at rest.

Breakdown Torque: The maximum torque developed by an induction motor at rated voltage and frequency without an abrupt drop in speed.

Brush Resistance (R_b): Circuit resistance created by the brushes and the brush film in a brush type motor (universal, PM, wound field) adding to other power losses in a motor.

Cogging: A cyclical torque variation superimposed on the D.C. motor torque caused by permeance variations as the armature teeth or rotor magnets pass stator pole tips.

Commutation: In D.C. motors the switching (either mechanically or electronically) of the direction of the current in a coil or group of coils to cause a change of magnetic polarity.

Commutation Angle: In a brush type D.C. motor, the angle in electrical degrees that a coil or group of coils on an armature rotate while being commutated. In a brushless D.C. motor, the angular difference in electrical degrees between the rotor and stator poles when the current is reversed in the windings.

Damping Coefficient (K_d): In a D.C. motor the constant that defines the braking characteristics of the motor with shorted leads.

$K_d = K_b x K_t$ (oz-in./rad./sec.)

$\frac{K_b x K_t}{R_t}$ Where R_t = terminal resistance in ohms

Dielectric Strength: A high voltage test of the motor's insulation ability to withstand an A.C. voltage. The test criterion limits the leakage current to a specified maximum at the test voltage of specified magnitude and frequency, applied between the motor case and windings.

Duty Cycle: The relationship between the operating time and the off time of a motor. Both the on time and the repetition rate must be specified.

Dynamic Braking: A control function that brakes the motor by dissipating its stored energy.

Efficiency(η): The ratio of power output to power input of a machine usually expressed as a percentage. $\eta = P_o / P_m x 100\%$

Electromagnetic Interference (EMI): Electromagnetic interference (EMI), sometimes referred to as Radio Frequency Interference (RFI), is a phenomenon which, either directly or indirectly can contribute to degradation in performance of an electronic receiver or system. EMI consists of undesirable voltages and currents that reach the victim device either by conduction through the power lines or by radiation through the air and causes the device to exhibit undesirable performance. It is usually caused by switching or winding commutation.

Field Coil Resistance: The resistance of the wire in the field coil as seen at the field leads or terminals.

Form Factor: The ratio of RMS current to average current.

Frictional Damping Coefficient (K_f): In a D.C. motor or BLDC motor, the constant that defines the braking characteristics of the motor with open leads. Units are oz-in/rad/sec; oz-in/RPM; or Nm/rad/sec.

Full-Load Torque: The torque developed at rated horsepower and speed with rated voltage and frequency applied.

Heat Sink: This is a piece of metal (usually aluminum) of a specific size and thickness to which a motor is mounted while heat rise tests are conducted. The orientation, such as vertical or horizontal, needs to be stated with the test results.

Horse Power: A unit of measure of motor output power. It is obtained by the following formula:

$$\frac{HP = T(oz-in)xS(RPM)}{1{,}008{,}000} \quad \text{or} \quad \frac{T(L_b - ft)xS(RPM)}{5250}$$

Impedance (Z): A measure of the total opposition to the flow of an alternating current. It is the vector sum of resistance, inductive reactance and capacitive reactance.

Impedance Protected: A motor which under stalled conditions will not exceed specified maximum coil temperatures. Implies that the motor can be stalled (maximum temperature condition) without overheating or damage.

Incrementing: A rapid start, move and stop motion.

Inductance (L): A resistance to a change in current. It is measured in henrys.

Locked Rotor: This is a motor test condition in which the rotating element is not allowed to move.

Magnetic Flux (Φ): A term used to describe the amount of magnetism there is in a space around a coil or permanent magnet or in the air gap of a motor. It is measured in lines or webers.

Magnetic Flux Density (B): This is the measure of concentration of magnetic flux (Φ) in a given area. It is measured in lines per square inch or tesla.

Magnetic Field Intensity (H): The vector magnetic quantity that determines the ability of an electric current or a magnetic body to induce a magnetic field at a given point. It is measured in oersterds, amps turns/inch or amps/meter.

Maximum Current (I_m): The maximum current limit beyond which demagnetization of the permanent magnet field (in a PM motor) will occur (at 20°C).

Moment of Inertia (J_l): The property of matter that causes it to resist any change in its rotational or positional state. Normally it is an important property of the armature (J_m) or rotor. It is typically measured in oz-in-sec^2, gm-cm-sec^2 , or KgM^2 (S.I.)

Motor Constant (Km): The ratio of the motor torque to motor input power. It is measured in Nm/W or oz.in./W.

Neutral Zone: The angular distance in electrical degrees between magnet poles or field poles. It is the theoretical space in which field flux is zero.

No Load Current (I_{nl}): The current generated at rated voltage with no load on the motor – a function of rotation losses, both electrical and mechanical.

No Load Speed-Actual (N_o): The actual speed the motor will run with no load applied at rated voltage.

No Load Speed-True (N_{lo}): A theoretical speed to which the motor will rise when rated voltage is applied with no load. This speed is based on the point where back emf is equal to input voltage.

Peak Torque (T_{pk}): The maximum torque capability of a motor based on the maximum current limit (I_m). $T_{pk} = K_t I_m$

Power Dissipated (P_d or P_l): Power loss due to energy expended in the motor stator and rotor. It appears as heat and is expressed in watts. $P_d = P_{in} - P_o$

Power In (P_{in}): Input power as a function of volts times amps in D.C. motors and volts times amps times power factor (P_f) in A.C. motors and expresses watts.
D.C. $P_{in} = V \times I$
A.C. $P_{in} = e\,i\,P_f$

Power Factor (P_f): The ratio of actual or resistive power to the apparent or total power in an A.C. motor. The total power is the vector sum of the resistive and reactive powers.

$$P_f = \frac{P_{in}}{VA}$$

Where V= applied voltage
A= line current in amperes

Power Out (P_o): The output power computed by multiplying torque times speed times a constant. Power out is equal to the power in minus all of the losses.
$P_o = T \times S \times K$

$K = 7.397 \times 10^{-4}$ for T = oz-in
$K = 1.420 \times 10^{-1}$ for T = Lb-ft
$K = 1.183 \times 10^{-2}$ for T = Lb-in
$K = 8.877 \times 10^{-3}$ for T = oz-ft

Pull-In Torque: (synchronous motors) Pull-in torque is obtained by starting the motor from rest at a pre-set torque value and specified motor terminal voltage. The maximum torque setting which the motor will accelerate to synchronous speed is the pull-in torque. Since the inertia of the connected load greatly affects the pull-in torque, this test should be run with minimum external inertia.

Pull-Out Torque: (synchronous motors) Pull-out torque is obtained by steadily increasing the load torque from the normal operating range of a synchronous motor while maintaining specified terminal voltage. The maximum torque reading obtained without having caused the speed to drop from synchronous speed is the pull-out torque.

Pull-Up Torque: (induction motors) Pull-up torque is obtained by starting the motor from rest at a pre-set torque value and specified motor terminal voltage. The maximum torque setting which the motor will accelerate to a speed higher than the speed at which breakdown torque occurs is the pull-up torque.

Resistance (R): The property of a material that limits current through it. It is varied by the material, size and configuration. It is measured in ohms.

$$R = \frac{\rho \ell}{A}$$

where: ρ = resistivity of the material
ℓ = length
A = area

Motor terminal resistance $R = R_a + R_b$

Rotor: The rotating element of the magnetic structure which is found in non-commutator machines.

Skew: The angular displacement of the rotor or armature slots from one end to the other. It can be expressed in terms of the angular displacement from parallel. It can be expressed in degrees, bars or slots.

Slip: The difference in speed between the rotating field of an induction motor and the actual rotor speed. Slip is usually expressed as a percentage of the synchronous speed.

Speed No Load (S_{nl}): Actual motor speed in rpm with no external load and specified terminal voltage.

Speed Load: The actual motor speed in RPM with a specified external load and specified terminal voltage and frequency.

Speed Regulation Constant (R_m): The slope of the speed-torque curve in rpm/oz.in. or rpm/Nm. $R_m = R/K_eK_t$.

Speed Synchronous (n_s): The speed of the rotating field of an induction or synchronous motor. It may be calculated by multiplying 120 times the frequency of the power supply divided by the number of poles.

$$n_s = \frac{120f}{\rho}$$

Stall Current (I_s): This is the current at stall (locked rotor) with rated voltage applied. I_s = Volts/R_t.

Stall Torque (T_s): This is the actual torque at the output shaft under stall (locked rotor) conditions. $T_s = (K_tI_s)-T_f$.

Starting Current (I_{as}): The minimum current necessary to overcome static friction torque and start motor rotation.

Starting Torque: The minimum torque which is developed at rest for all angular positions of the rotor with rated voltage and frequency applied to the motor.

Static Friction Torque (T_f): A measure of the resistance to angular motion. It is due to bearing friction and cog friction. Cog friction is the magnetic drag between the permanent magnet and rotor laminations in a PM motor. It may be taken as the average of four readings taken 90° apart with a torque watch.

Temperature Rise: The increase in temperature in ºC or ºF of the excited winding coil above ambient temperature at locked rotor or any designated load condition.
$T_{rise} = T_{(total)} - T_{Amb\ Hot)}$

Terminal Resistance (R_t): The resistance of a motor as seen by the power supply. It is measured at the motor power leads or terminals.

Thermal Capacity (T_c): The ability of a motor to dissipate changing amounts of power.

$$T_c = \frac{T_h}{R_{th}}$$

$$\frac{\text{Watt – minute}}{\text{°C Rise}}$$

Thermal Dissipation Factor (Thermal Resistance) (R_{th}): A motor's ability to dissipate heat. It provides a means of evaluating winding temperature as a function of outside surface temperature under steady state conditions, and is measured in ºC/watt.

Time Constant, Electrical (T_e): This is the time required for the armature or winding current to reach 63.2% of its steady state conditions. It can be mathematically derived from the following formula:

$$T_e = \frac{L_a}{R_t}$$

Time Constant, Mechanical (T_m): The time required for an unloaded motor to reach 63.2% of its final velocity after applying the armature or winding voltage. This constant can be mathematically derived from the following formula:

$$T_m = \frac{J_m R_t}{K_t K_e} \text{ seconds}$$

J_m = motor inertia (oz-in-sec ^{2})
R_t = terminal resistance (ohms)
K_t = torque constant oz-in/amp)
K_e = voltage constant (volts/rad/sec)

Time Constant, Thermal (T_h): The time required for a motor to reach 63.2% of its final temperature under known input and load conditions. It is measured in minutes. (The value depends on mounting and motor speed).

Torque (T): A property which produced, or tends to produce, rotation. A force of one pound applied to the handle of a crank, the center of which is displaced one foot from the center of the shaft produces a torque of one pound-foot, provided the force is applied perpendicular to, and not along, the crank.

Torque Constant (K_t): In a D.C. motor the torque produced per unit armature current.

$$K_t = \frac{T(oz-in)}{I(Amp)} \text{ or } \frac{T(N_m)}{I(Amp)}$$

Torque Ripple: This refers to the cyclical variation of generating torque within one revolution. The torque variation superimposed on the D.C. torque component. The torque variation is a result of the permeance variation which occurs as the rotating member moves with respect to the stationary member.

Torsional Resistance: The instantaneous change velocities in a motor-load system caused by the elasticity or compliance of the shaft. In certain driving modes, the frequencies of the various parts of the motor-load system or motor-tachometer load system are in opposite directions.

Velocity: A measure of speed or rate of motion. It is measured in revolutions per minute (RPM) or radians per second.

Power Conversion (P)

	HP	watts	oz-in/sec
HP	1	746	1.056×10^{-5}
watts	1.34×10^{-3}	1	141.61
oz-in/sec	9.47×10^{-6}	706×10^{-3}	1

Torque Constant Conversion (K_t)

	Nm/amp	Lb-in/amp	oz-in/amp
Nm/amp	1	8.85	141.61
Lb-in/amp	0.1130	1	16
oz-in/amp	7.062×10^{-3}	0.0625	1

Voltage Constant Conversion (K_b)

	V/rad/sec	V/K RPM
V/rad/sec	1	104.72
V/K RPM	9.55×10^{-3}	1

Damping Coefficient Conversion (K_d, K_f)

	oz-in/RPM	oz-in-sec	Nm-sec
oz-in/RPM	1	9.55	6.743×10^{-2}
oz-in-sec	0.1047	1	7.062×10^{-3}
Nm-sec	14.83	1.4161×10^{2}	1

Torque Conversion

	Lb.Ft.	Lb.In.	Oz.In.	Dyne-Cm	Nm	Ncm	Kpm (kgfm)	g-cm
Lb.Ft.	1	12	192	1.356×10^{7}	1.356	1.356×10^{2}	0.1383	1.383×10^{4}
Lb.In.	8.333×10^{-2}	1	16	1.1298×10^{6}	0.113	11.3	1.152×10^{-2}	1.152×10^{3}
Oz.In.	5.208×10^{-3}	6.250×10^{-2}	1	7.062×10^{4}	7.062×10^{-3}	0.7062	7.201×10^{-4}	72.01
Dyne-Cm	7.376×10^{-8}	8.8509×10^{-7}	1.416×10^{-5}	1	10^{-7}	10^{-5}	1.0197×10^{-8}	1.0197×10^{-3}
Nm	0.7376	8.8509	1.4161×10^{2}	10^{7}	1	10^{2}	0.10197	1.0197×10^{4}
Ncm	7.376×10^{-3}	8.8509×10^{-2}	1.4161	10^{5}	10^{-2}	1	1.0197×10^{-3}	0.10197
Kpm (kgfm)	7.233	86.796	1.389×10^{3}	9.8067×10^{7}	9.8067	980.67	1	10^{5}
g-cm	7.233×10^{-5}	8.680×10^{-4}	1.389×10^{-2}	980.67	9.8067×10^{-5}	9.8067×10^{-3}	10^{-5}	1

BASIC MOTOR PARAMETERS

QUANTITY	PARAMETER	UNIT symbol	
symbol		(English)	(SI)
α	Acceleration	in/sec^2	m/sec^2
α_m	Maximum Acceleration	rad/sec^2	rad/sec^2
B	Magnetic Flux Density	$lines/in^2$	tesla
E	Voltage	V, volts	V, volts
E_g	Generated Voltage	V, volts	V, volts
f	Frequency	Hz	Hz, cps
H	Magnetic Field Intensity	A-turn/inch	Amps/meter
I_{as}	Starting Current	amps	amps
I_m	Maximum Current	amps	amps
I_{nl}	No Load Current	amps	amps
I_s	Stall Current	amps	amps
J_L	Moment of Inertia	$oz\text{-}in\text{-}sec^2$	$Kg\ m^2$
J_m	Armature Moment of Inertia	$oz\text{-}in\text{-}sec^2$	$Kg\ m^2$
K_b, BEF	Back EMF Constant	V/1000 rpm	V/(rad/sec)
K_d	Damping Constant	oz.in./(rad/sec)	Nm/(rad/sec)
K_e	Voltage Constant (same as K_b)	"	"
K_f	Friction Damping Coefficient	oz.in./rpm	Nm/rad/sec
K_m	Motor Constant	oz.in./Watt	Nm/Watt
K_t	Torque Constant	oz-in/amp	Nm/amp
L_a	Armature Inductance	henries	henries
N_{lo}	True No Load Speed	rpm	rpm
N_o	Actual No Load Speed	rpm	rpm
n_s	Synchronous speed	rpm	rad/sec
P_{in}	Power In	"	"
P_L or P_d	Power Loss	Watts	Watts
P_o	Power Out	"	"
R_a	Armature Resistance	ohms, Ω	ohms, Ω
R_b	Brush Resistance	ohms, Ω	ohms, Ω
R_m	Speed Regulation Constant	krpm/oz.in.	krpm/Nm
R_T	Motor Terminal Resistance	ohms Ω	ohms Ω
R_{th}	Thermal Resistance	°C/W	°C/W
S_{nl}	Speed, no load	rpm	rad/sec
T	Torque	oz.in.	Nm
T_e	Electrical Time Constant	sec	sec
T_f	Static Friction Torque	oz.in.	Nm
T_h	Thermal Time Constant	sec	sec
T_m	Mechanical Time Constant	sec	sec
T_{pk}	Peak Torque	oz.in.	Nm
T_s	Stall Torque	oz.in.	Nm
X	Reactance	ohms, Ω	ohms, Ω
Z	Impedance	ohms, Ω	ohms, Ω
Φ	Magnetic Flux	lines	weber
η	Efficiency	%	%

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