1.6 CHARACTERISTICS OF STEPPER MOTOR

Stepper motor characteristics are

Static characteristics

Dynamic characteristics

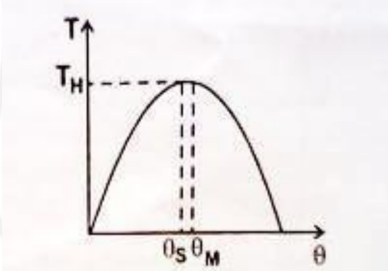
STATIC CHARACTERISTICS

(i) Torque Angle curve

(ii) Torque current curve

(i)Torque-Angle curve

Torque angle curve of a step motor is shown in figure. it is seen that that Torque increases almost sinusoid ally, with angle Θ from equilibrium.



Torque Angle

Figure 1.6.1 Torque-Angle curve

[Source: "special electric machines" by R.Srinivasan page:2.52]

Holding Torque (TH)

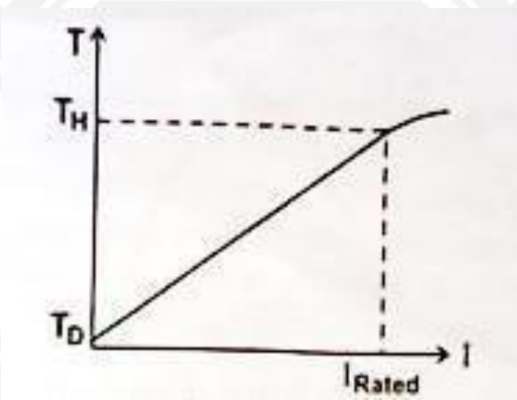
It is the maximum load torque which the energized stepper motor can withstand without slipping from equilibrium position. If the holding torque is exceeded, the motor suddenly slips from the present equilibrium position and goes to the static equilibrium position.

DETENT TORQUE (TD):

It is the maximum load torque which the un-energized stepper motor can withstand slipping. Detent torque is due to magnetism, and is therefore available only in permanent magnet and hybrid stepper motor. It is about 5-10 % of holding torque.

TORQUE CURRENT CURVE

A typical torque curve for a stepper motor is shown in fig.1.6.2. It is seen the curve is initially linear but later on its slope progressively decreases as the magnetic circuit of the motor saturates.



Torque-current Curve

Figure 1.6.2 Torque-current curve

[Source: "special electric machines" by R.Srinivasan page:2.54]

Torque constant (Kt)

Torque constant of the stepper is defined as the initial slope of the torque-current (T-I) curve of the stepper motor. It is also known as torque sensitivity. Its units N-mA, kg-cm/A or OZ-in/A

Dynamic characteristics

A stepper motor is said to be operated in synchronism when there exist strictly one to one correspondence between number of pulses applied and the number of steps through which the motor has actually moved. There are two modes of operation.

Start-Stop mode Also called as pull in curve or single stepping mode.

Slewing mode

In start –stop mode the stepper motor always operate in synchronism and the motor can be started and stopped without using synchronism. In slewing mode the motor will be in synchronism, but it cannot be started or stopped without losing synchronism. To operate the motor in slewing mode first the motor is to be started in start stop mode and then to slewing mode. Similarly to stop the motor operating in slewing mode, first the motor is to be brought to the start stop mode and then stop.

Start Stop mode

Start stop mode of operation of stepper motor is shown in figure1.6.3 In this second pulse is given to the stepper motor only after the rotor attained a steady or rest position due to first pulse. The region of start-stop mode of operation depends on the operation depends on the torque developed and the stepping rate or stepping frequency of stepper motor.

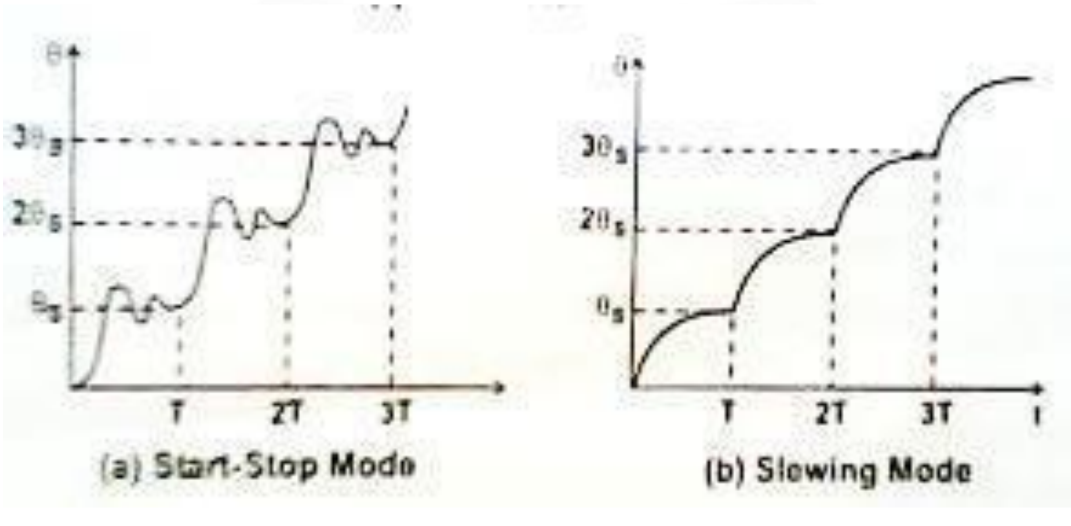


Figure 1.6.3 **Dynamic Characteristics**
[Source: "special electric machines" by R.Srinivasan page:2.56]

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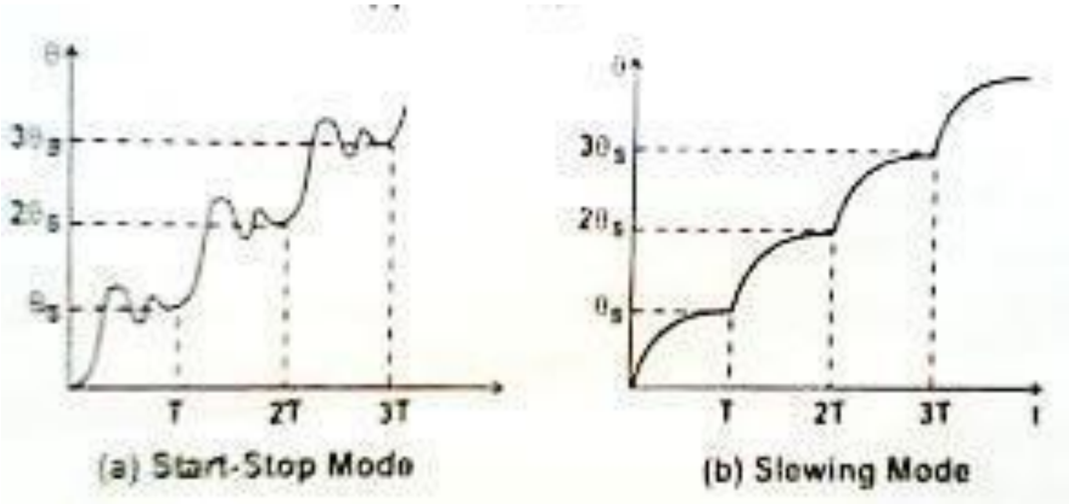

Figure 1.6.3 Dynamic Characteristics
[Source: "special electric machines" by R.Srinivasan page:2.55]

TORQUE-SPEED CHARACTERISTICS

Torque developed by the stepper motor and stepping rate characteristics for both modes of operation are shown in fig.1.6.4.the curve ABC represents the "pull in" characteristics and the curve ADE represents the "pull-out" characteristics.

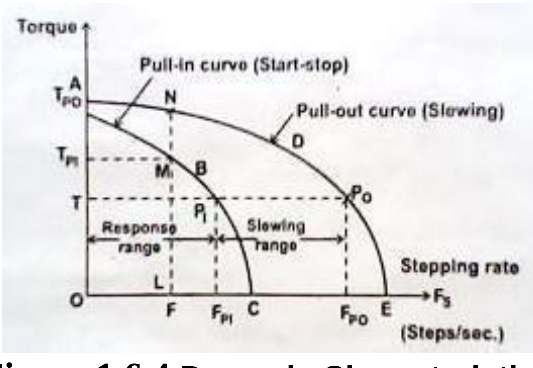

Figure 1.6.4 Dynamic Characteristics
[Source: "special electric machines" by R.Srinivasan page:2.56]

The area OABCO represents the region for start stop mode of operation. At any operating point in the region the motor can start and stop without losing synchronism. The area ABCEDA refers to the region for slewing mode of operation. At any operating point without losing synchronism to attain an operating point in the slewing mode at first the motor is to operate at a point in the start-stop mode and then stepping rate is increased to operate in slewing mode, similarly while switching off it is essential to operate the motor from slewing mode to start-stop mode before it is stopped.

Pull in torque

It is the maximum torque developed by the stepper motor for a given stepping rate in the start-stop mode of operation without losing synchronism. In the fig.1.6.4 LM represents the pull in torque (i.e) TPI corresponding to the stepping rate F (i.e.) OL.

Pull out torque

It is the maximum torque developed by the stepper motor for a given stepping rate in the slewing mode without losing synchronism. In fig.1.6.4 LN represents the pull in torque (i.e.) TPO corresponding to F (i.e.) OL.

Pull in range

It is the maximum stepping rate at which the stepper motor can operate in start-stop mode developing a specific torque (without losing synchronism).In fig. 2.36 PIT represents pull in range for a torque of T (i.e.) OP. This range is also known as response range of stepping rate for the given torque T.

Pull out range

It is the maximum stepping rate at which the stepper motor can operate in slewing mode developing a specified torque without losing synchronism. In fig.1.6.4 PIPO represents the pull out range for a torque of T. The range PIPO is known slewing range.

Pull in rate (FPI)

It is the maximum stepping rate at which the stepper motor will start or stop without losing synchronism against a given load torque T.

Pull out rate (FPO)

It is the maximum stepping rate at which the stepper motor will slew, without missing steps, against load torque T.

Synchronism

This term means one to one correspondence between the number of pulses applied to the stepper motor and the number of steps through which the motor has actually moved.

Mid frequency resonance

The phenomenon at which the motor torque drops to a low value at certain input pulse frequencies.

FIGURES OF MERIT (FM'S)

Figures of merit (FM'S) are performance indices which give quantitative information on certain aspects of performance and design of actuators such as stepper motors. DC or AC servomotors etc.

1. Electrical Time constant (Te)

Te=Lm/Rm

where Lm-Inductance of motor winding

Rm- resistance of motor.

Te governs the rate at which current rises when the motor winding is turned on. It also determines how quickly the current decays when the winding is turned off.

In motion control, the speed of response is of importance. Hence electrical time constant Te must be minimized.Te dependent upon inductance and resistance of the motor winding. Inductance is determined by magnetic circuit. (i.e.) magnet iron volume as well as volume of copper used in the motor design. Once these have been designed, neither reducing conductor size nor increasing the number of turns will reduce Te. Otherwise magnetic circuit itself has to be redesigned.

2. Motor time constant (Tm)

Tm=J/(Ke.KtRm)=JRm/Ke

J-moment of inertia of motor (kg-m2)

Rm-resistance of the motor winding (Ω)

Ke-back Emf constant (volt s/ rad)

Kt- torque constant (Nm/A)

Motor back Emf and torque constants are determined by magnetic circuit and phase winding design. Winding resistance also from winding design. Moment of inertia is determined by mechanical design. In this way motor time constant Tm combines all the three aspects of motor design viz, magnetic circuit, electrical circuit and mechanical design. Achieving a low Tm requires excellence in motor design. As a thumb rule the ratio of Te/Tm 0.1

Initial Acceleration (a0):A0=T/J(rad/S2)

Where T-rated torque (N-M)

J-moment of inertia (kg-m2)

A0 gives a quantitative idea of how fast the motor accelerates to its final velocity or position. Maximization of a0 calls for good magnetic circuit design to produce high torque in conjunction with good mechanical design to minimize rotor inertia. The moment of inertia of the load coupled to motor also determines a0

Motor Constant (km) $Km=T/\sqrt{\omega}$

Where T- rated motor torque

ω -rated power (w) of the motor

$Km=\sqrt{Kt\ Ke/Rm}$

This shows that maximizing km causes minimizing R, maximizing Ke and Kt. Maximizing Ke and Kt. Call for optimization of magnetic circuit design, decreasing electrical time constant Te which is undesirable. A tradeoff between electrical and magnetic circuit design is necessary to achieve a good km.