Module 3 : Actuators for robots

Lecture 7 : Actuators for Robots-Part I

Objectives

In this course you will learn about

- Commercial or industrial manipulator's capabilities.
- Typical electrical drives in manipulators and their control
- Characteristics of such drives

Introduction:

Typical commercial / industrial manipulator capabilities.

	Articulated	**SCARA**
Reach	2.5 meter	1.2 meter
Payload	125 Kg	10-50 Kg
Waist rotation (degree)	360	120
Rotational speeds (degree)	100 to 200/sec	Tip speed 2 meter/sec
Repeatability	0.4 mm	.03 to .05 mm
Weight	1600 Kg	30-100 Kg

Drives in Manipulators

The term servo derived from phrase “to serve”, has meaning that “the system that can be controlled.” The electrical actuators that can be controlled are DC servomotors, AC servo motors and stepper motors. Following is an explanation of such motors.

- DC servo
- AC servo
- Stepper motor

DC servo conventional motors

A PMDC servo stator has permanent magnets and the rotor is wound. Brushes are used for commutation. Brushes wear and also cause noise. Brushless motors overcome these limitations. The electronic circuit and rotor motion is sensed thru Hall's effect sensors.

In robotic applications, the servo motor is required to produce rapid accelerations. In such system one needs to have motors with low inertia. Low inertia is achieved by reduced armature diameter with increase in armature length such that desired output power is achieved. Thus except minor differences in constructional features, DC servo motor is an ordinary DC motor.

Motor Charecrerustucs

PMDC motors have Characteristics as follows (Figure 7.2.2 and Figure 7.2.3)

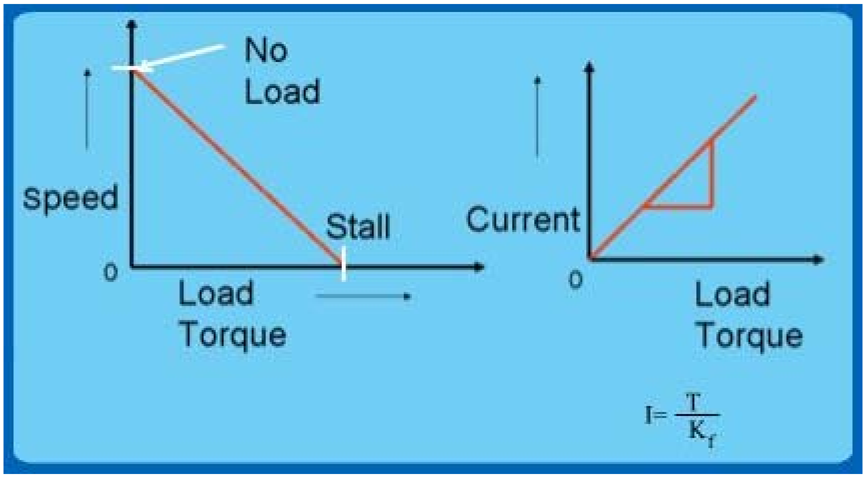

Figure 7.2.2

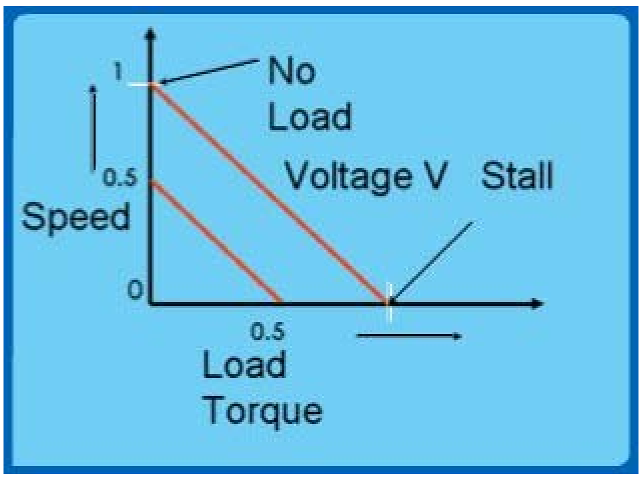

Figure 7.2.3

The power consumed by above motor has characteristics is shown in Figure 7.2.4

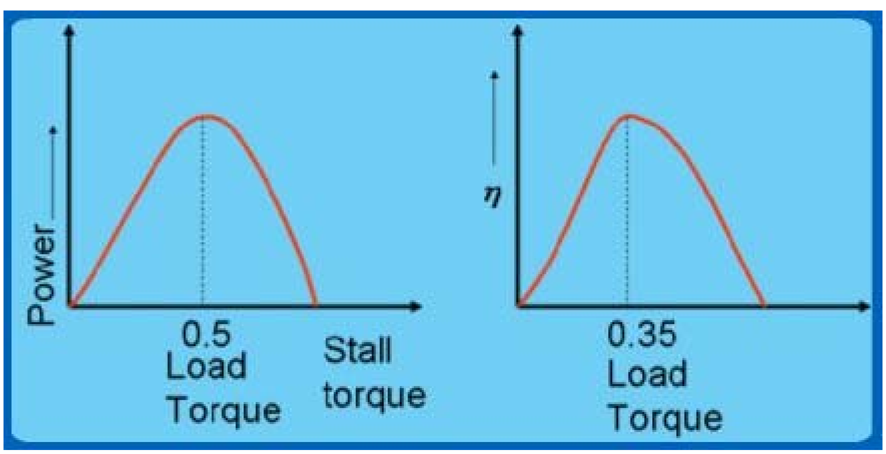

Figure 7.2.4

Contd...

Application:

1. Continuous duty operation needs check for heat generation

2. Intermittent operation / motion /duty needs calculation of RMS torque as follows

A typical Intermittent operation: (Refer Figure 7.2.5)

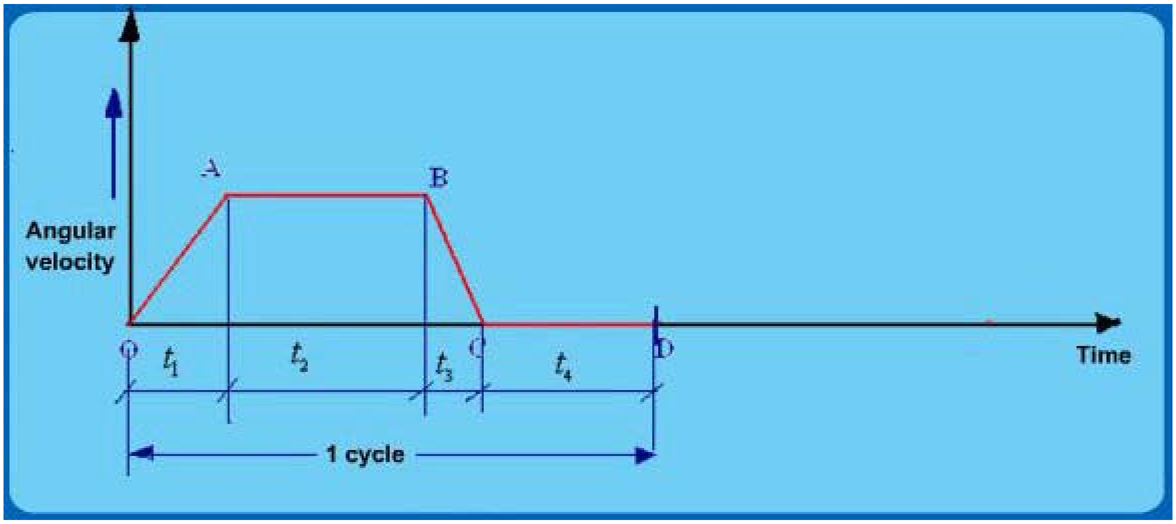

Figure 7.2.5

1. From O to A for $t_1 \rightarrow$ Acceleration.

2. From A to B for $t_2 \rightarrow$ uniform velocity

3. From B to C for $t_3 \rightarrow$ deceleration.

4. From C to D for $t_4 \rightarrow$ Dwell, vel=0; Accn=0

The motor:

PMDC motors rotate at high speeds and a gear-reducer is required to reduce the speed to requisite levels. In intermittent operations the angular velocity varies from instant to instant and choice of the gear – reduction ratio "G" is critical. We are aware that torque drops as motor speed increases. As a first step we choose

$G = \frac{\omega_l}{\omega_m} = \frac{\alpha_l}{\alpha_m}$ where ω_l = angular vel of load, ω_m = angular vel of motor and α_l = angular accn. of load and α_m = angular accn of motor

We use the following rule for the preliminary selection of G

2 (Max speed of load) = G (Max allowable speed of motor) l

SIZING THE DRIVE for INTERMITTENT MOTION

A few formulae

Now we need to size the motor – namely determine the torque and power. Let

I_m --- Motor inertia

I_l ---- Load inertia

η **----** Joint Motor and gear box efficiency

We know: $G = \frac{\omega_l}{\omega_m} = \frac{\alpha_l}{\alpha_m}$

One may compute the torque to be provided by motor to drive the load with Inertial I_l as, $I_l = I_l * \alpha_l *$ $G = I_l * G * \alpha_m * G = G^2 * I_l * \alpha_m$

We thus have:

Net torque = $I_m \alpha_m + G^2 I_l \alpha_m$

Effective inertia= $(I_m + G^2 I_l)$

We shall now determine the RMS torque as follows for the motion which is as given in figure 7.4.1. This motion consists of accelerations, uniform velocities and decelerations.

The first step is to compute the torque requirements for each of these portions of the cycle. This depends on the motor and gear-box inertias, the load inertial, efficiencies and so on.

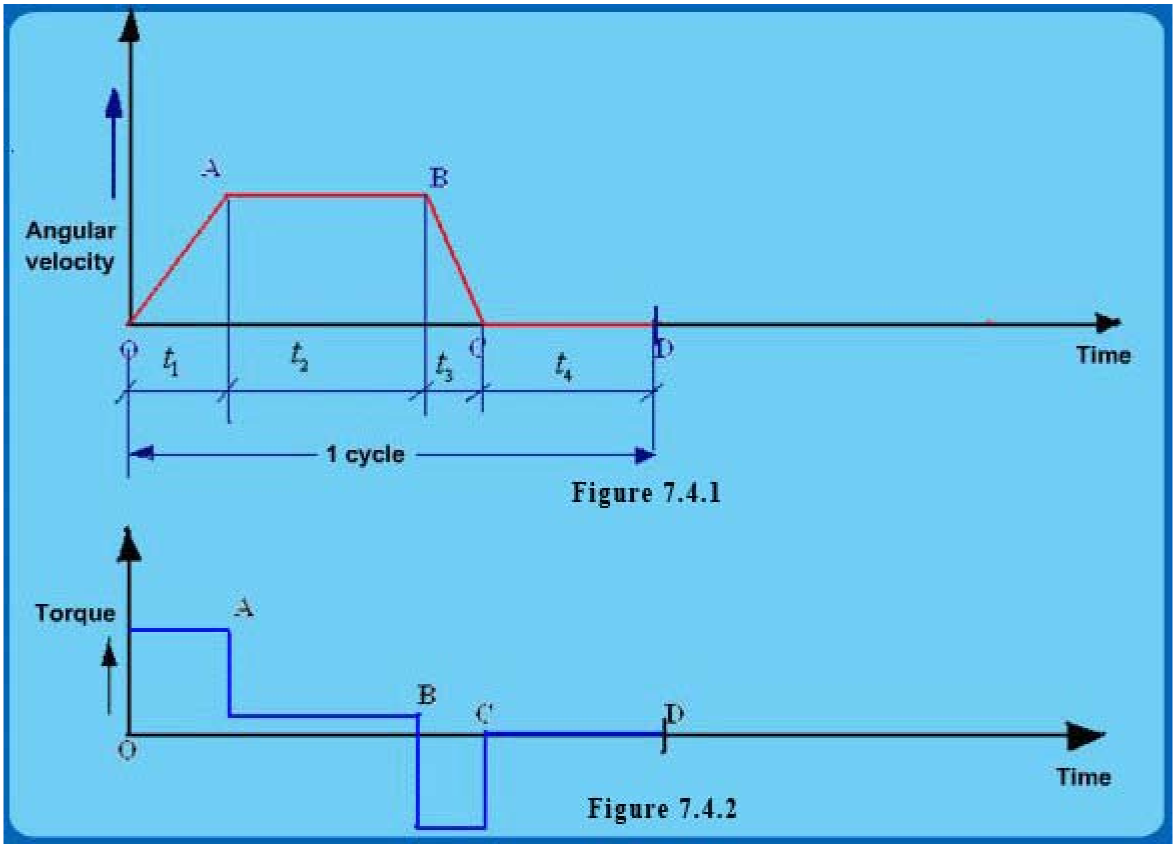

Figure 7.4.1

Figure 7.4.2

Table giving the torque computation for each portion of the cycle: (see Figure 7.4.2)

- **O to A** $\rightarrow t_1 \rightarrow$ **angular acceleration =** $\alpha_l = \frac{\omega_a - o}{t_1}$

- **Torque T 1 =** $(I_m + \frac{G^2}{\eta} I_l)\alpha_l + T_f \frac{G}{\eta}$

- **A to B** $\rightarrow t_2 \rightarrow$ **ang accn= 0** $\rightarrow$ **constant vel.**

- **Torque T 2 =** $T_f \frac{G}{\eta}$

- **B to C** $\rightarrow$ **t 3** $\rightarrow$ **ang accn=** $\alpha_3 = \frac{\omega_b - 0}{t_3}$

  Torque T 3 = $(I_m + \frac{G^2}{\eta} I_l)\alpha_3 - T_f \frac{G}{\eta}$

  (Friction torque is subtracted here since friction aids deceleration)

  The RMS torque is thus given by:

$$T_{Rms} = \sqrt{\frac{(T_1^2 \times t_1) + (T_2^2 \times t_2) + (T_3^2 \times t_3) + (zero)t_4}{t_1 + t_2 + t_3 + t_4}}$$

Selection of Motor

The final selection of motor depends on the peak speed and peak torque requirements **,** where $T_{Peak} \rightarrow$ Max of (magnitudes) T_1 , T_2 , T_3 ....

We use this data and the RMS value of torque to select the motor from the performance curves provided by the manufacturer. In addition to the above one has to check the heat generated by the motor as well as the natural frequency of the drive.

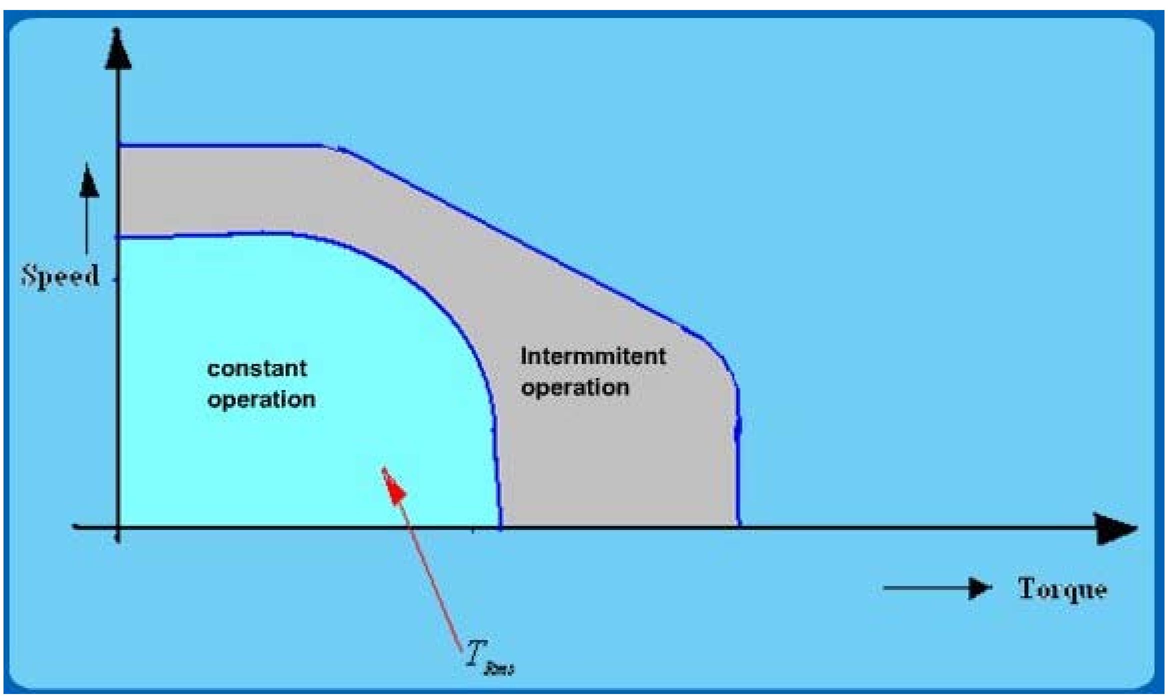

Figure 7.5

Selecting Drive Electronics:

Having selected the motor – now we have to determine the basic parameters (current and voltage) required to select the dive electronics.

We use the following formulae to determine the same:

Current $I=T/K_t$

Voltage $V=RI+K_eW_m$

W_m $\rightarrow$ motor speed

K_t $\rightarrow$ torque constant

K_e $\rightarrow$ electrical constant

R $\rightarrow$ motor resistance

I $\rightarrow$ current

V $\rightarrow$ voltage

Recap

In this course you have learnt the following

- DC Servo motors drive
- DC servo motor selection for intermittent operation

Congratulations, you have finished Lecture 7. To view the next lecture select it from the left hand side menu of the page.