FUNDAMENTALS OF POWER TRANSMISSION IN MOTORS

Permanent Magnet Brushless Motors – A System Approach

Part 5

POWER TRANSMISSION

- Need for Drives-
  - Speed-
  - Torque-
  - Different Axis of Rotation-

TYPES OF DRIVES

- Mechanical-
- Hydraulic-
- Pneumatic-
- Electrical-

TYPES OF MECHANICAL DRIVES

- Mode of power transmission-
  - Transmission by friction-
    - With Direct Contact, e.g. Friction Drives
    - With Flexible connection, e.g. Belt Drives

TYPES OF MECHANICAL DRIVES

- Transmission by mesh-
  - With Direct Contact, e.g. toothed and Worm gears
  - With flexible connection, e.g. Chain Drives

TYPES OF MECHANICAL DRIVES

- By the change of the Velocity Ratio-
  - Step by Step Change
  - No Change
  - Variable speed drives e.g. Automotive Vehicles

TYPES OF MECHANICAL DRIVES

- By the position of shaft-
  - Parallel shaft
  - Shafts at right angles
  - Intersecting shafts

CONCEPT OF PERIPHERAL SPEED

- Peripheral speed can be calculated by,

  $v_1=\omega D_1/2$

  or $v_1=\prod D_1 n_1/60$

  Peripheral speed of the driven member,

  $v_2= \omega_2 D_2/2$

CONCEPT OF PERIPHERAL SPEED

or $v_2 = \prod D_2 n_2/60$

Without slipping, the peripheral speeds should be same

$v1 = v2$

i.e. $\omega_1 D_1/2 = \omega_2 D_2/2$

or $\prod D_1 n_1/60 = \prod D_2 n_2/60$

CONCEPT OF PERIPHERAL SPEED

Whence,

$\omega_1/\omega_2=D_2/D_1=n_1/n_2$

Where D_1 and D_2 diameters

$\omega_1(n_1)$ and $\omega_2(n_2)$ are angular speeds

CONCEPT OF PERIPHERAL SPEED

- Angular speed ratio or velocity ratio

  $(VR)_{1,2}=\omega_1/\ \omega_2=n_1/n_2=D_2/D_1$

- Sign of VR will depend on the directions of the angular velocities

EFFICIENCY OF POWER TRANSMISSION

- Output power,

$P_o = P_i \times \eta_i$

M_t= torsional moment,Nm

ω=angular speed , radians/s

$M_t = kW \times 1000/\omega$

$= kW \times 1000/(2\Pi f)$

$= 9550 \times kW/rev/min$ (Nm)

EFFICIENCY OF POWER TRANSMISSION

$$Mt_i.\omega_i = Mt_1.\omega_1.\eta_{1i}$$

Hence

$$Mt_i = Mt_1.\omega_1 / \omega_2.\eta_{1i}$$

$$= Mt_1.(VR)_{1,}i.\eta_{1i}$$

Mt_2=torsional moment on the second shaft

$$= Mt_1.(VR)_{1,2}.\eta_{1,2}$$

EFFICIENCY OF POWER TRANSMISSION

- Total Speed Ratio,

  $(VR)_{1,n}=(VR)_1 \times (VR)_2 \times (VR)_3 \ldots\ldots\ldots\ldots (VR)_n$

- Total efficiency of the multistage drive,

  $\eta_{1,n}=\eta_1 \cdot \eta_2 \cdot \eta_3 \ldots\ldots\ldots\ldots \eta_n$

SELECTION OF A MECHANICAL DRIVE

- Power transmission
- Angular velocities
- Distance
- Overall dimensions

VELOCITY RATIO

- Velocity ratio obtained by
  - Toothed wheel gears
  - Worm gears

VARIOUS DRIVES IN SERIAL ORDER

1	Toothed Gears	Velocity Ratio	From 4 to 20
2	Roller Chain Drives	Velocity Ratio	From 6 to 10
3	Silent chain Drives	Velocity Ratio	Up to 15
4	V-belt Drives	Velocity Ratio	From 8 to 15
5	Flat belt with idler	Velocity Ratio	Up to 10
6	Open flat belt drive	Velocity Ratio	Up to 5
7	Friction Drives	Velocity Ratio	From 5 to 1

PERIPHERAL VELOCITY IMPACT

- Transmitted power
  - Centrifugal force
    - Increased Belt load & reduced tension
  - Limiting factors for chain drives
    - Teeth cutting in gear drives

MAXIMUM PERIPHERAL SPEEDS FOR VARIOUS DRIVES

- Flat Belts= v_{max} ≤25 m/s
- Belt (artificial fiber)= v_{max} ~50 m/s
- V belts= v_{max} ~ 25 to 30 m/s
- V belt (steel wire core)= v_{max} =40 m/s
- Chain Drives= v_{max} =25-30 m/s

TRANSMITTED POWER

- Power transmission can be increased by
  - Worm gear
  - Toothed gears
  - V belt & chain drives

MAXIMUM TRANSMITTED POWER FOR VARIOUS APPLICATIONS

Sr.No.	Application	Maximum Transmitted Power (kW)
1	V Belt	735 to 1100
2	Flat Belt	1835
3	Chain Drives	3670
4	Friction Drives	150 to 225

LOSSES IN TRANSMISSION

- Two parts of losses
  - Constant Part
  - Variable Part

LOSSES IN TRANSMISSION

Sr. No.	Type of Drive	Losses in %
1	Toothed Gears	1
2	Chain Drive	2
3	Flat-belt Drives	2.5
4	V-belt Drives	4
5	Friction Drives	4
6	Worm Gear	10 to 25

WEIGHT, SIZE AND COST OF DRIVES

- Size based on -
  - Decreasing Centre distances for various Drives-
    - Flat belt
    - Flat belt with idler pulley
    - V-Belt
    - Chain Drive
    - Toothed Gears
    - Worm Gears

WEIGHT, SIZE AND COST OF DRIVES

- Size based on width
  - Size in decreasing order of the wheels or pulleys
    - Chain
    - Flat Belt
    - Flat belt with idler pulley
    - Toothed Gears
    - V-Belts
    - Worm gear

WEIGHT, SIZE AND COST OF DRIVES

- Weight of the drives
  - Worm gear (Least)
  - Toothed gears (Largest).

WEIGHT, SIZE AND COST OF DRIVES

- Cost of the drives-
- V-belt drive is taken as unity, then for other drives
    - Flat Belt- 1.06
    - Flat Belt with idler pulley- 1.25
    - Worm gear-1.25
    - Chain drive-1.40
    - Toothed gear-1.65.

CHARACTERISTICS OF BASIC TYPES OF DRIVES

	Type of drive	Transmitted Power kW	Peripheral Speed m/s	Speed Ratio	Efficiency
1.	Friction	upto 20 (100)	upto 20	upto 7 (25)	0.80—0.92
2.	Flat belt	upto 100 (1500)	5—30 (100)	upto 4 (10)	0.92—0.98
3.	V-belt	upto 50 (1000)	5—30	upto 7 (15)	0.87—0.97
4.	Straight tooth gear	upto 10000	25	upto 6 (10)	0.92—0.99
5.	Helical tooth gear	upto 50000	25 (140)	upto 7 (20)	0.94—0.99
6.	Worm gear	upto 100	upto 35	8—100 (1000)	0.75—0.90
7.	Chain	upto 200 (5000)	upto 25	upto 15	0.94—0.98

Note : The highest known values are given in brackets.

CHARACTERISTICS COMPARISON

Characteristics	Belt Drive	Gear Drive
1. Initial cost	Cheaper	Costly
2. Maintenance cost	Low	Considerable
3. Lubrication	None	Must
4. Shock absorption	Better	Not so good, depends upon gear material.
5. Life	1—5 years	Depends upon materials. Longest service life if properly lubricated, is generally more than 10 years.
6. Environment	Can not work under all types of conditions	If properly lubricated, can work under any condition and also under high temperature.
7. Noise	Low	Can be maintained low with proper lubrication and by adjusting shaft distances.
8. Force or Loads	Very heavy loads cannot be transmitted under normal conditions	Quite heavy loads can be transmitted as the gear size is practically unlimited.
9. Direction of input and output	Can be changed but not that easily and efficiently	Can be changed easily.