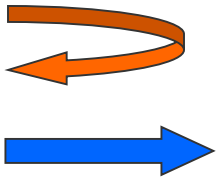
# Drive systems of machine tools

1. Technical principles
2. Main drive system

# Drive systems of machine tools

- Main drive system
- Provides main cutting movement
  - Rotational
  - Linear



- Secondary drive system
- Provides secondary cutting movement
  - Rotational
  - Linear

Auxiliary systems

# Drive system of machine

- Rotational movement

Linear movement

Parameters:

**ω, M**

**v, F**

- overall transmission ratio
- overall efficiency
- lifetime

# Drive system of machine

- **The technical principle**

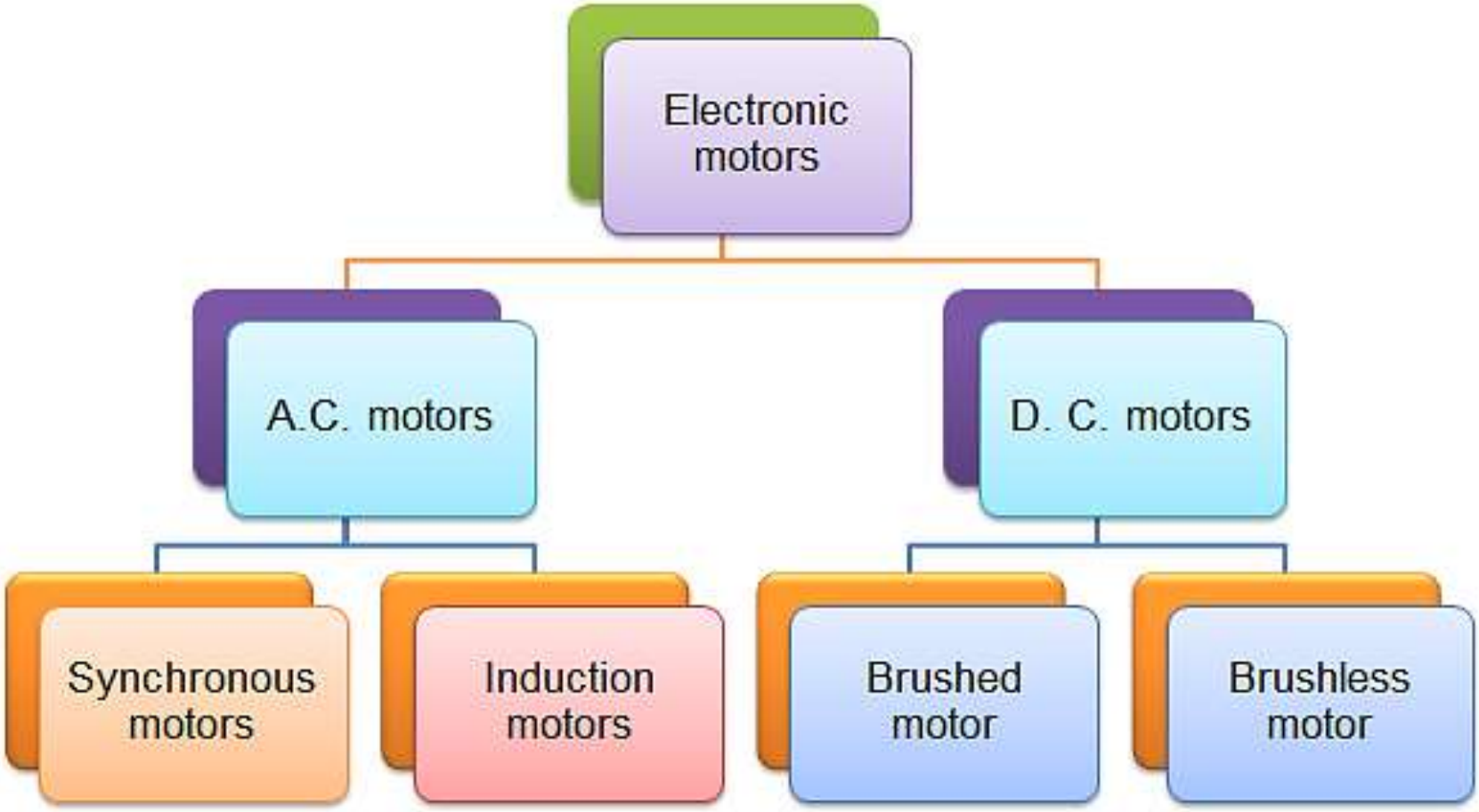
- **A. Drive member -** energy transformation
- **B. Drive mechanism -**
  - **B1. Gear mechanism -** changing range of output parameters
  - **B2. A mechanism for changing the type of movement -** changes rotary movement into linear

# A. Drive members

- ELECTROMOTORS:
- They use the principle of the generation of mechanical forces in the wire, carrying a current is placed in an electromagnetic field.

- HYDROMOTORS:
- They use the pressure energy (oil, air).

# A. Electromotors



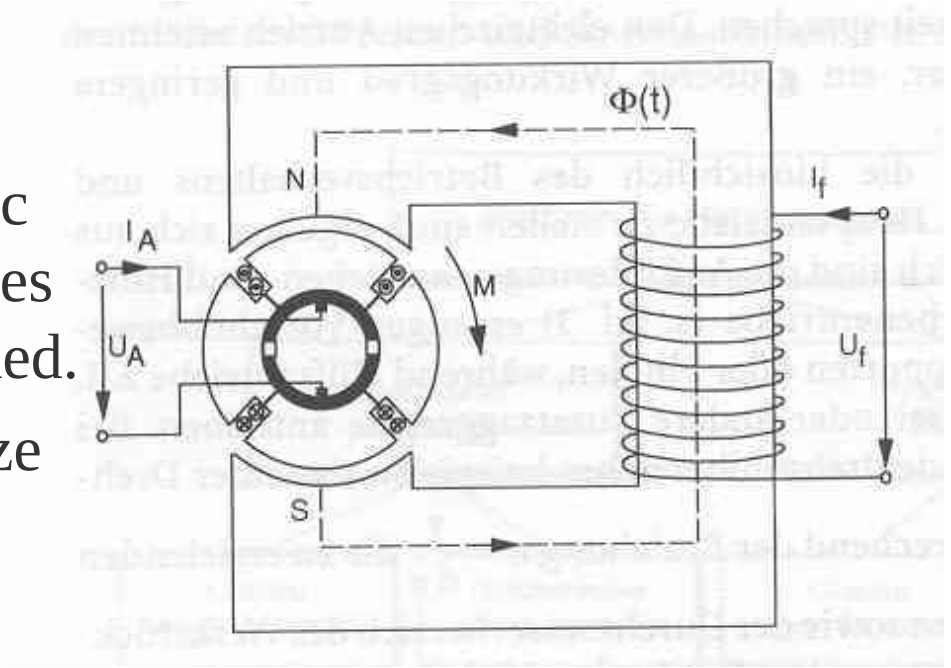
# A. Electromotors

- **DC motor:**

The excitation coil is powered from a DC source.

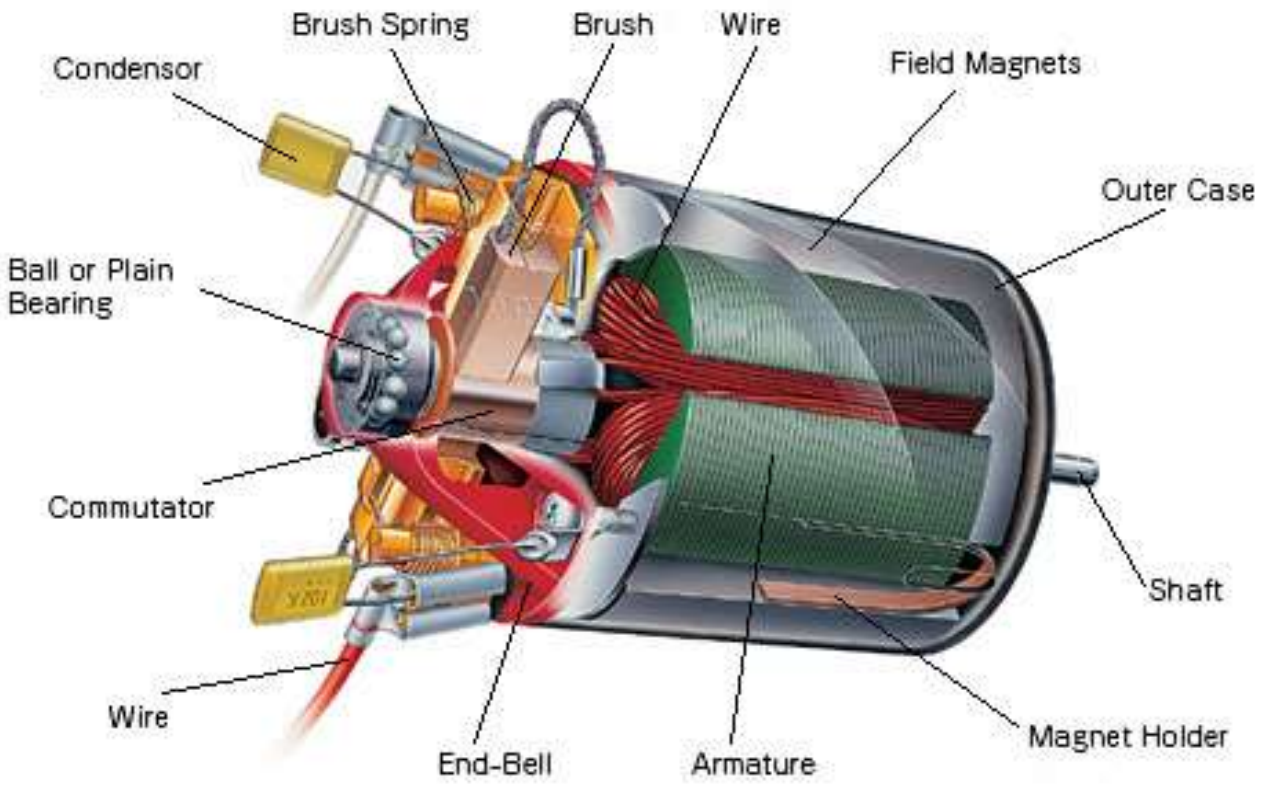
The rotor moves in the magnetic field. In its conductors induces a voltage and current is formed.

Torque is proportional to the size of I.



# A. Electromotors

- **DC motor:**

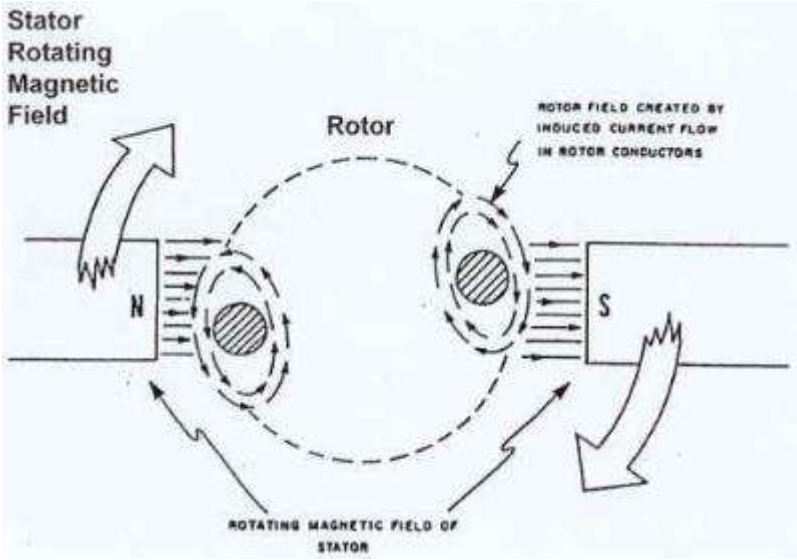


# A. Electromotors

- **AC induction motor:**

Windings on the stator is supplied with three-phase current, and generates a rotating electromagnetic field with speed.

$$n = 60\ f/\ p$$

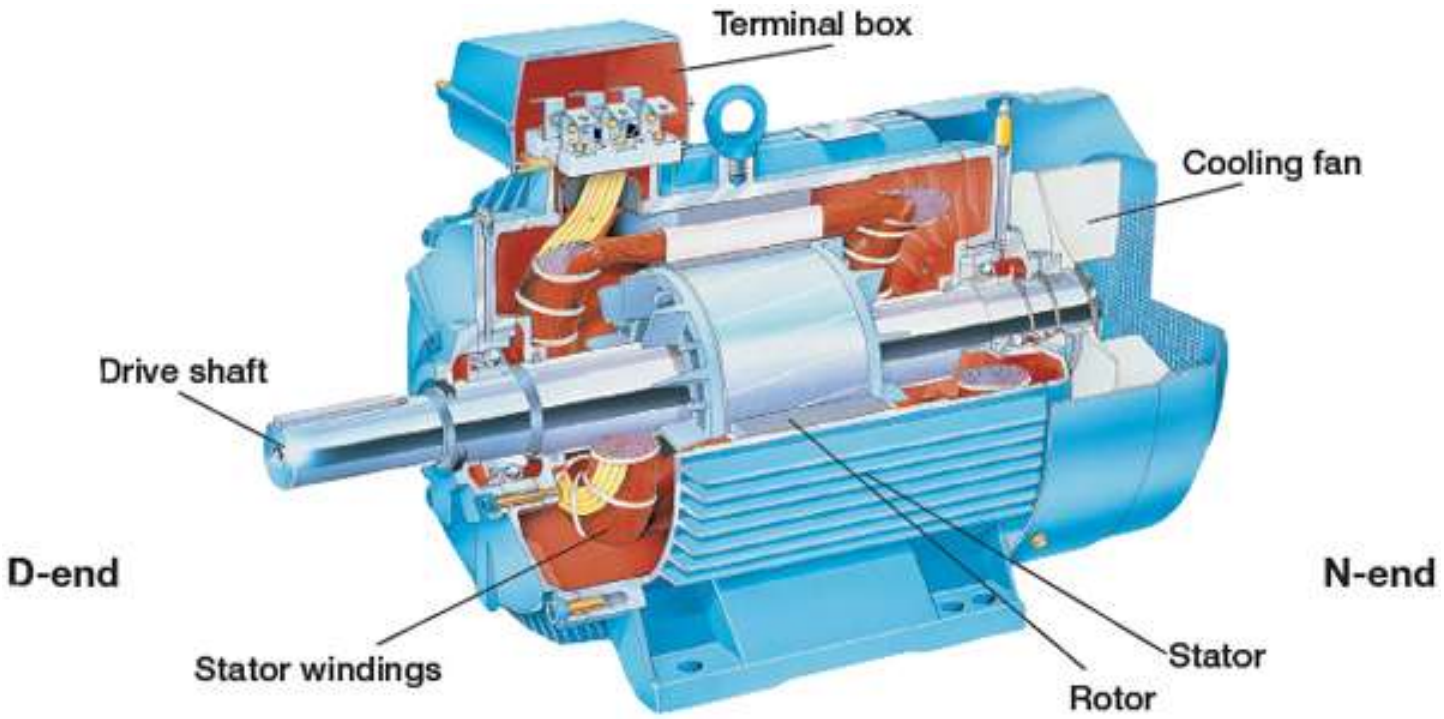



In the rotor a voltage is induced. Current flowing through the armature causes torque. (Rotating electromagnetic field tries to drift rotor with it.)

Slip of revolutions.

# A. Electromotors

- **AC induction motor:**

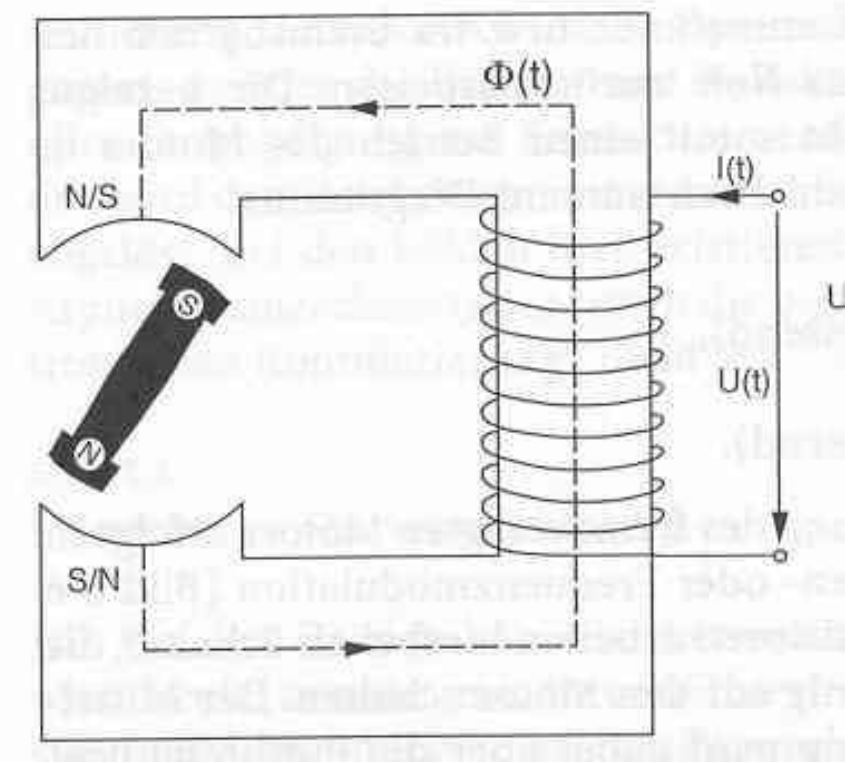


# A. Electromotors

- **Synchronous AC motor:**

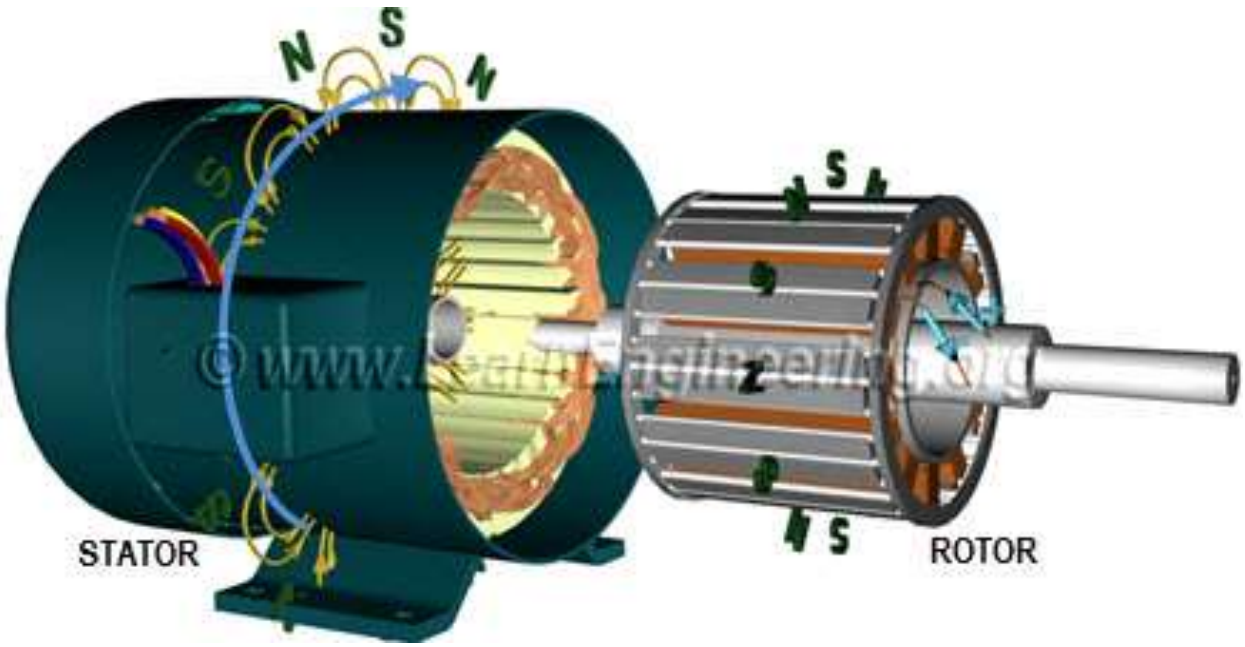
The rotor has a permanent magnet having poles that are alternately north and south.

By varying the the direction of the magnetic flux in the stator to the rotor moves.



# A. Electromotors

- **Synchronous AC motor:**



# A. Electromotors

- **Stepper motor:**

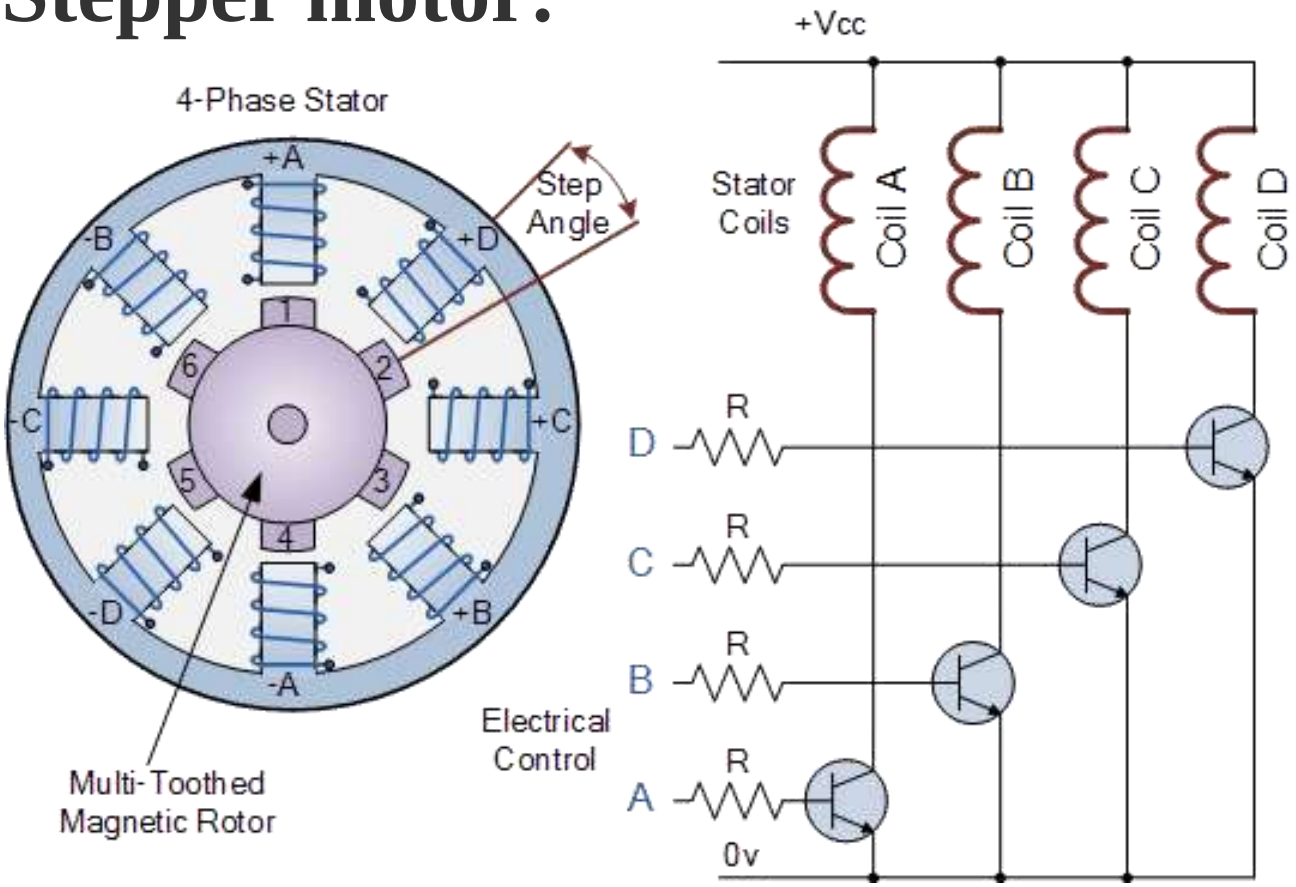
Synchronous motor with permanent magnet with a considerable number of poles.

Control current pulses are fed successively to each phase, the rotor rotates intermittently as it is progressively drawn into individual poles.

Suitable for positioning.

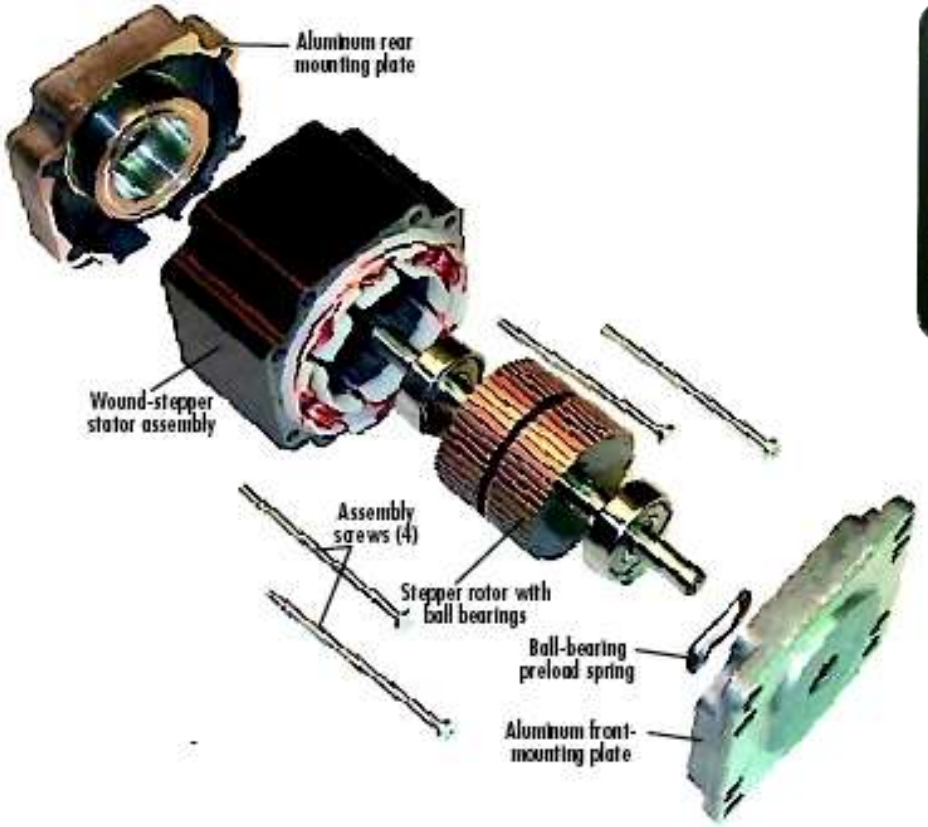
# A. Electromotors

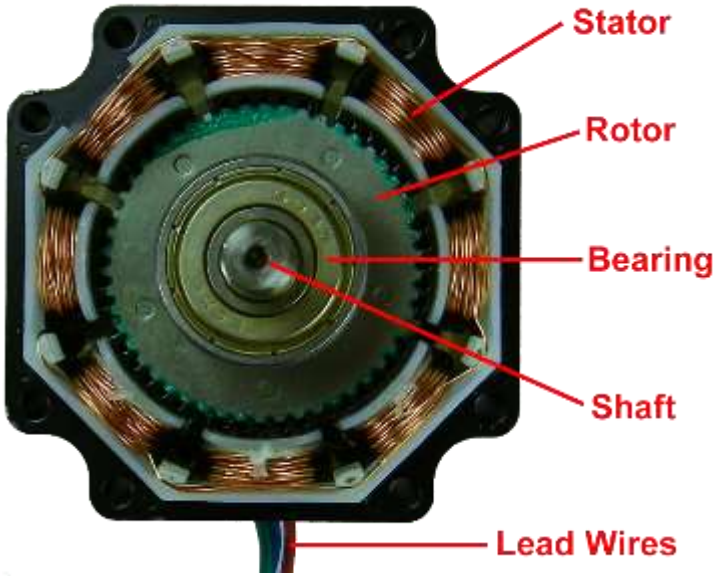
- **Stepper motor:**



# A. Electromotors

- **Stepper motor:**



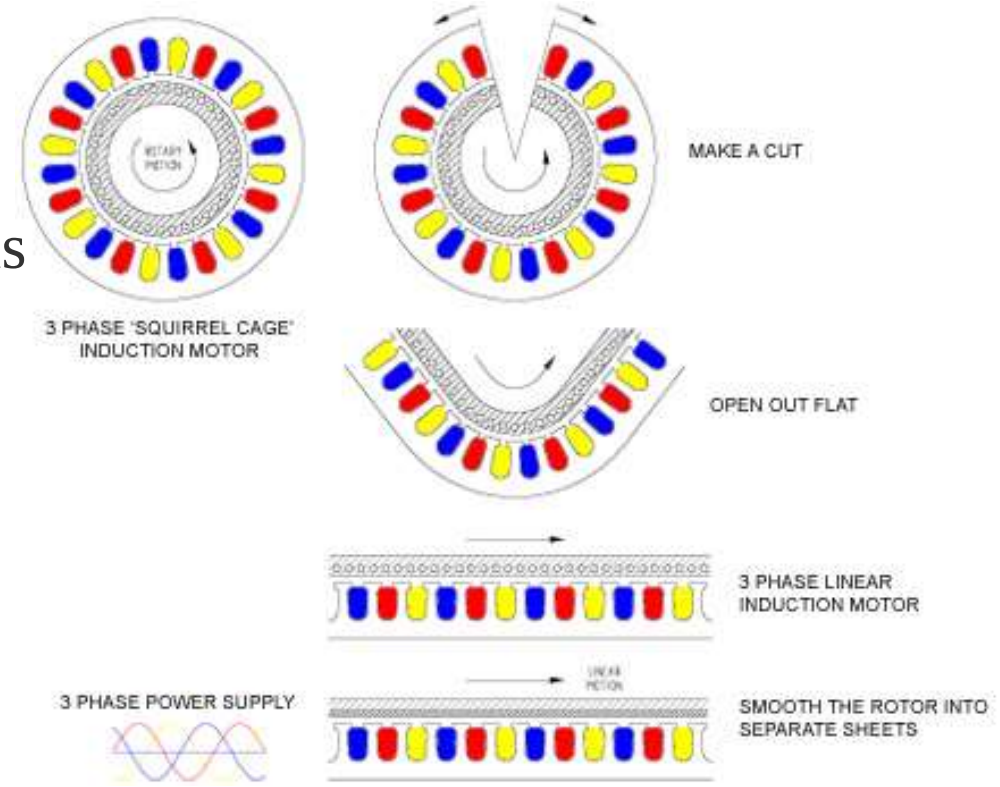
# A. Electromotors

- **Linear motor:**

It is many-pole electrical machine, which air gap is stretched flat.

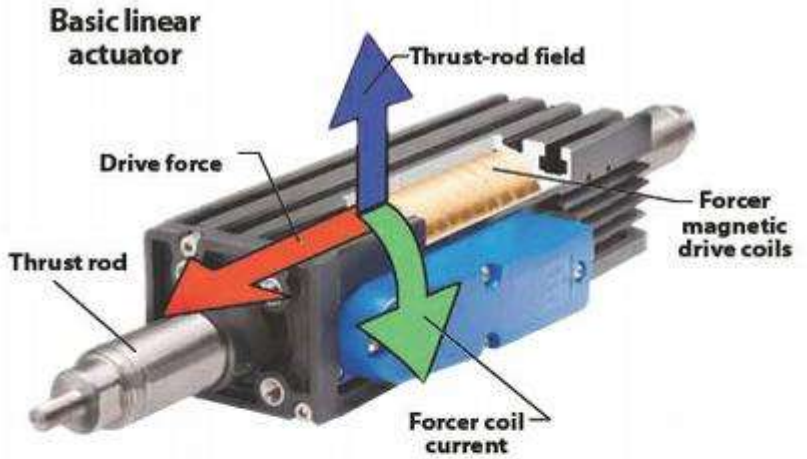
Can be synchronous and asynchronous.

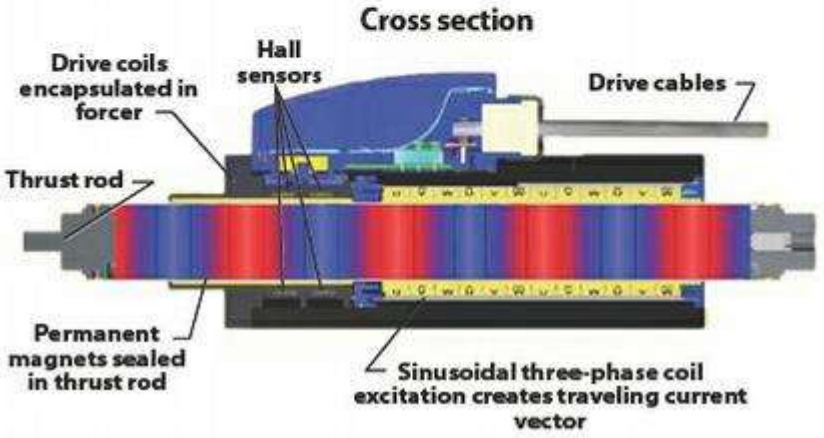
Direct drive of feedrates.



# A. Electromotors

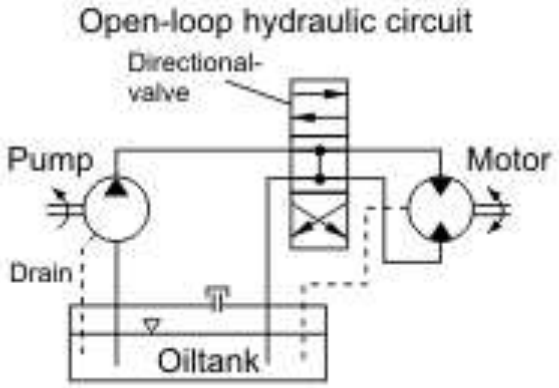
- **Linear motor:**

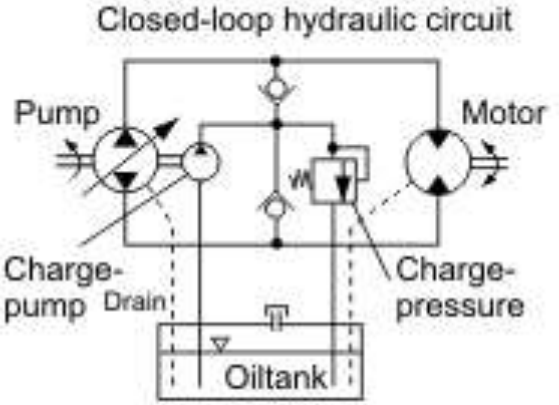


# A. Hydromotors

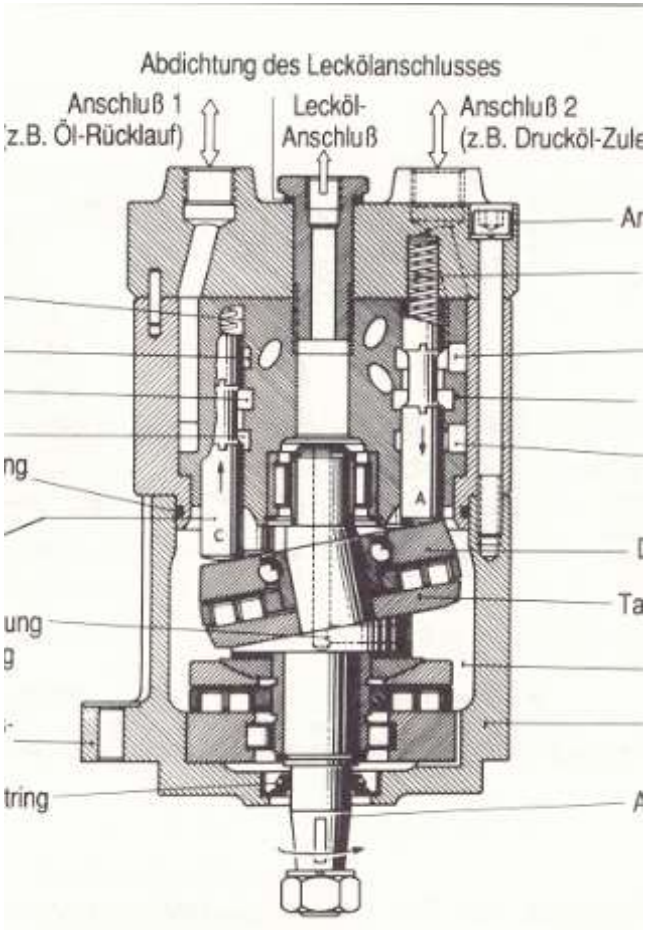
- Pump
- The flow distributor
- Hydromotor




- In machine tools are used less.

# A. Hydromotors

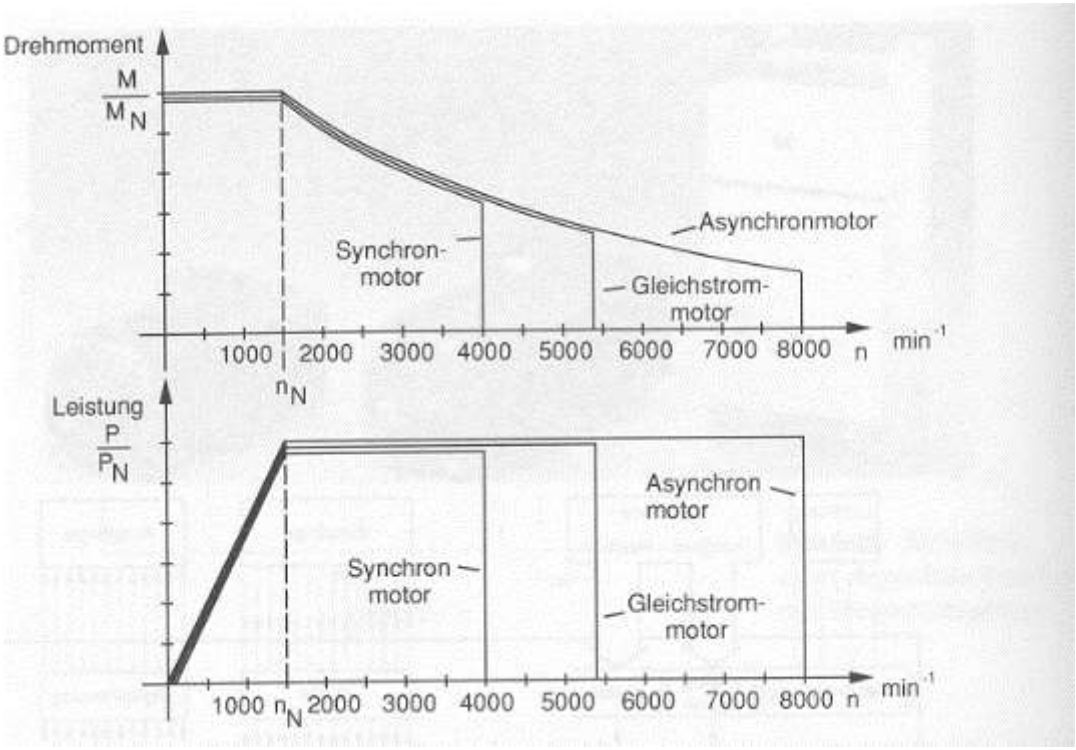
# A. Selection of drive member

Required properties:

- functional
- operating

Different required properties for:

- Main DS
- Secondary DS




Economic evaluation.

# B1. Gear mechanisms for speed change

- gear mechanisms used to extend the range of the output speed and torque of the drive member
- **1. The stepped speed change**
- **2. Continuous revs regulation**

  - Requirement for optimum cutting speed

# B1. Gear mechanisms for speed change

**Electric way**

**The stepped change**

- Switching the number of pole brushless motor
- (Up to three output speed)

**Fluent change**

Regulating motors:

- DC with thyristor converters
- AC with frequency converters

# B1. Gear mechanisms for speed change

**Mechanical method**

**The stepped change**

- Gears
- Belts (changing diameter of pulleys)

**Fluent change**

- Variable transmissions
  - Belts
  - Chains
  - Harmonic gearbox

# B1. Gear mechanisms for stepped speed change

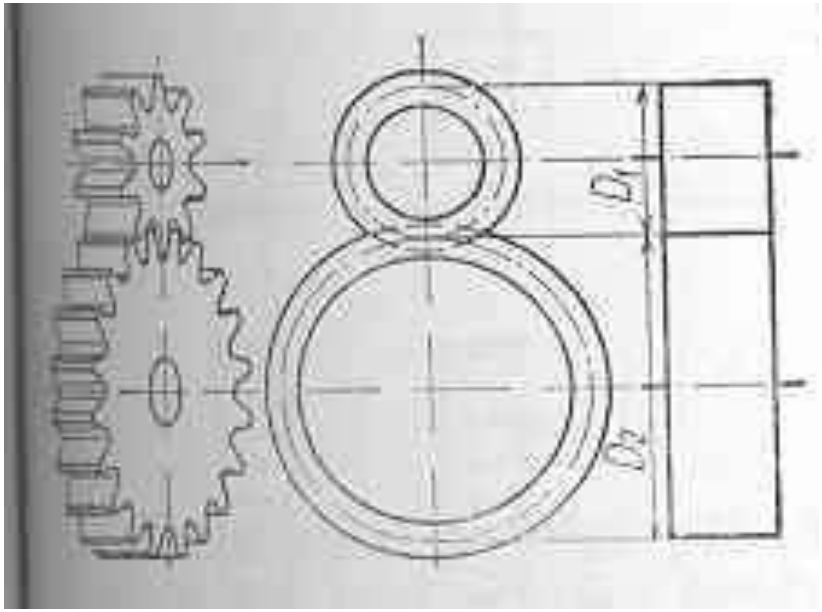
- **Gears**

Basic terms:

**Simple drive:**

$i = n1/n2 = \omega1/\omega2$
$= d2/d1 = M2/M1 = z2/z1$

Step-down gear – reduction , $i>1$
Step-up gear – multiplier



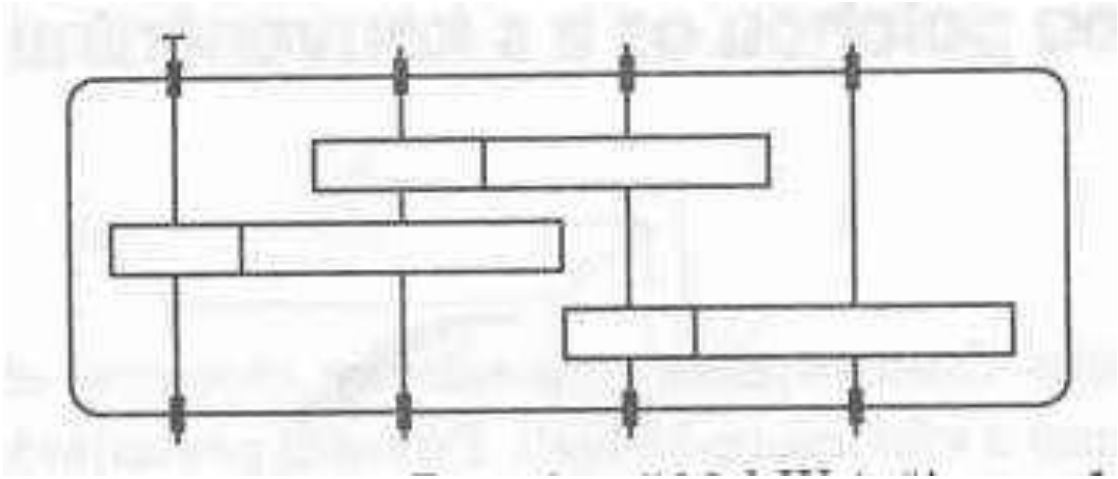
# B1. Gear mechanisms for stepped speed change

- **Complex drive:**

Gear ratio of individual gears:

$i_{12} = n_1/n_2$, $i_{34} = n_2/n_3$,….

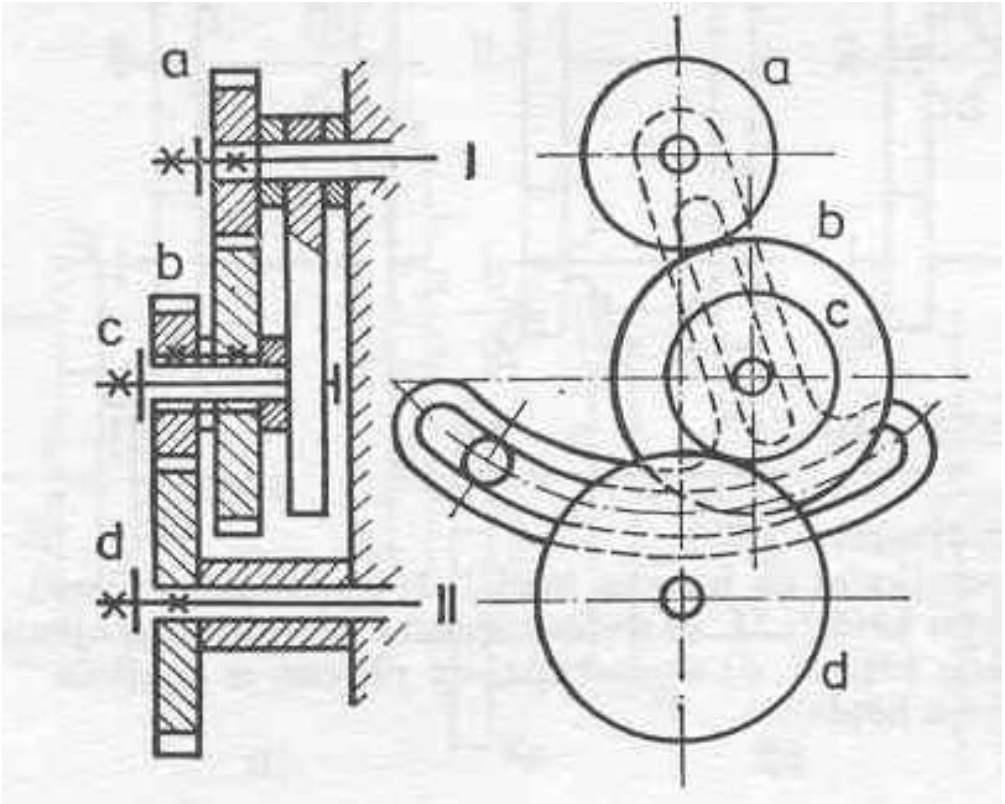
**Gear ratio $i_{total} = i_{12} \cdot i_{34} \cdot \ldots$**



# B1. Gear mechanisms for stepped speed change

- Replaceable wheels.

To change whole speed range.

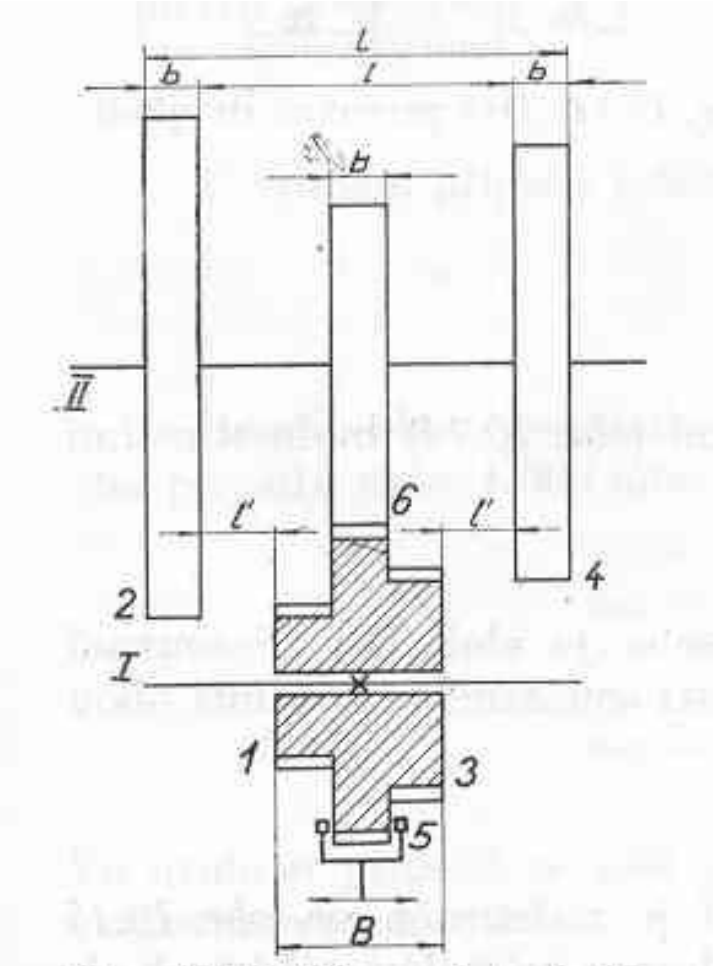


# B1. Gear mechanisms for stepped speed change

- Sliding cluster.

Sliding wheels into engagement with fixed counter gears.

Splined shafts.

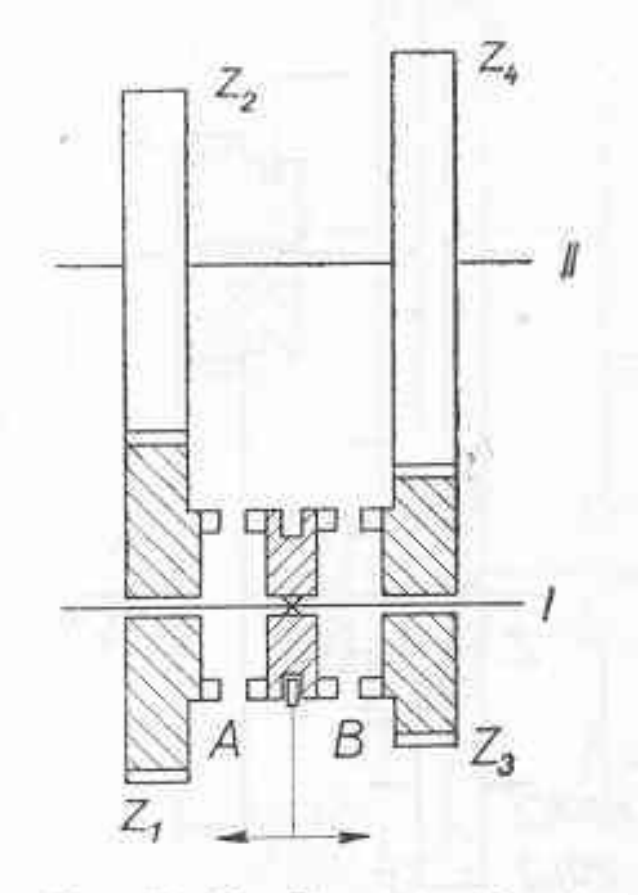


# B1. Gear mechanisms for stepped speed change

- Wheels with couplings.

Wheels on one shaft are fit with clearance.

The wheels are connected with the shaft by coupling.



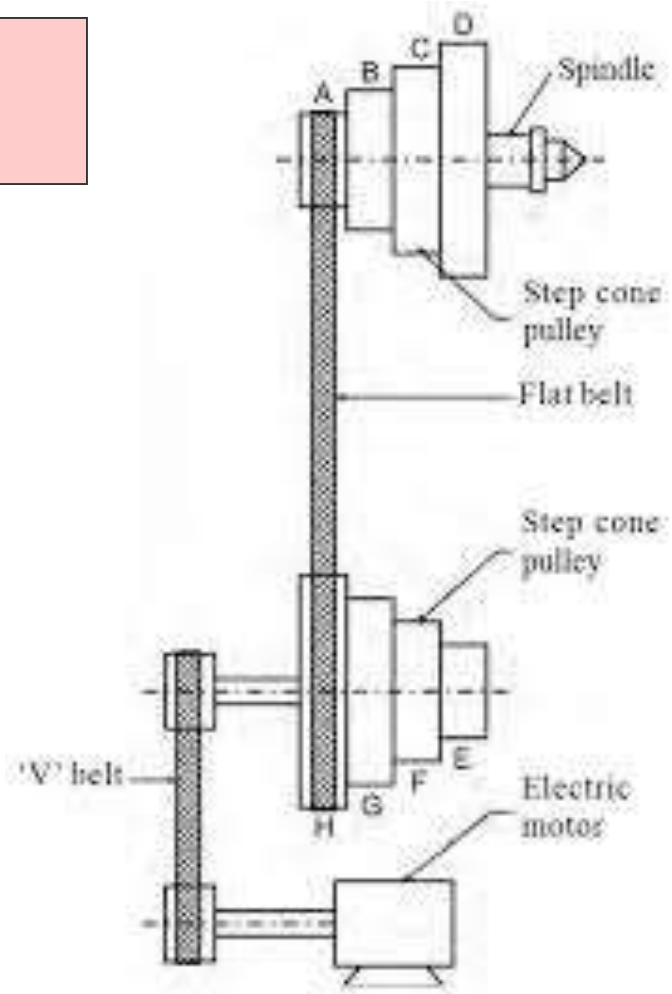
# B1. Gear mechanisms for stepped speed change

Belts drive

- Flat belt
- V-belt
- Cogged belt

- Textile belt
- Leather belt
- Rubber belt

Minimum pulley diameter:
D1, D2=i.D1

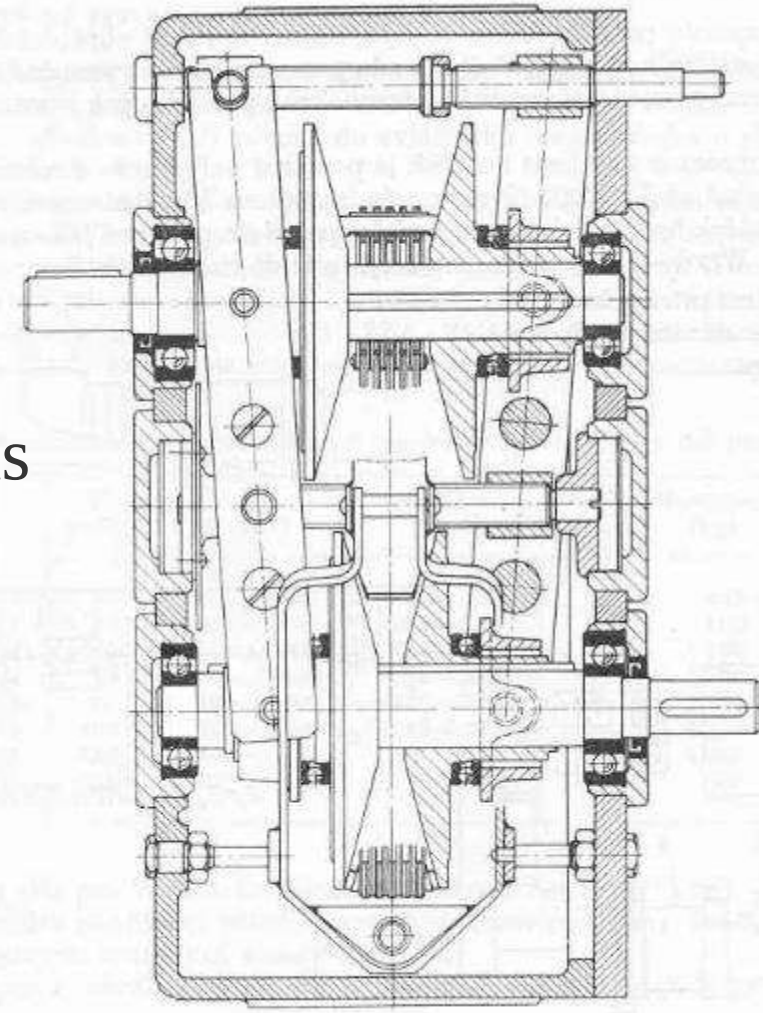


Step cone pulley drive

# B1. Gear mechanisms for continuous revs regulation

- A variator

- Belts
- Lamellar chains



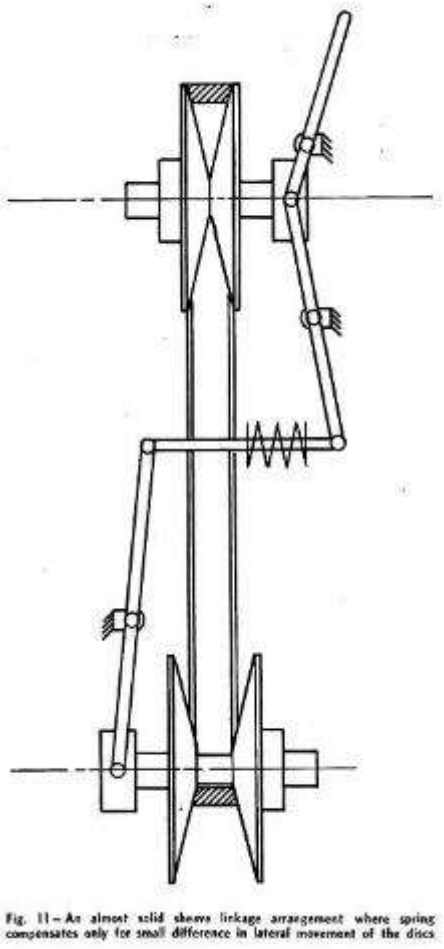
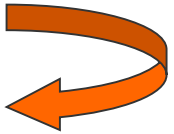


Fig. 11 – An almost solid sheave linkage arrangement where spring compensates only for small difference in lateral movement of the discs

# 2. Main drive system

- **Rotational**



**Requirements:**

- ensure the possibility of setting the cutting speed to a sufficient extent and with the necessary accuracy
- secure for cutting motion power requirement
- enable a rapid reversal of the cutting motion
- for machines with high automation ensure accurate positioning of the output member (spindle)
- reliability, durability, dynamics, rigidity, thermal stability, noise ...

# 2. Main drive system

- Parameters of main drive system

| | |
|---|---|
| Power | Up to 100 kW |
| Revolutions | Up to 80 000 rpm |
| Torque | Up to 1000 Nm |

# 2. Main drive system

- **A significant development of motors with high control.**

- **⇒ This leads to simplification or complete elimination of subsequent gear mechanisms:**
- direct drives

# 2. Main drive system

- induction motor with a lot of speed gearbox - older and inexpensive machines
- **control motor (induction with frequency converter) with two or three speed gearbox**
- **direct drive (electrospindle)**

# 2. Design of main drive system

Motor parameters:

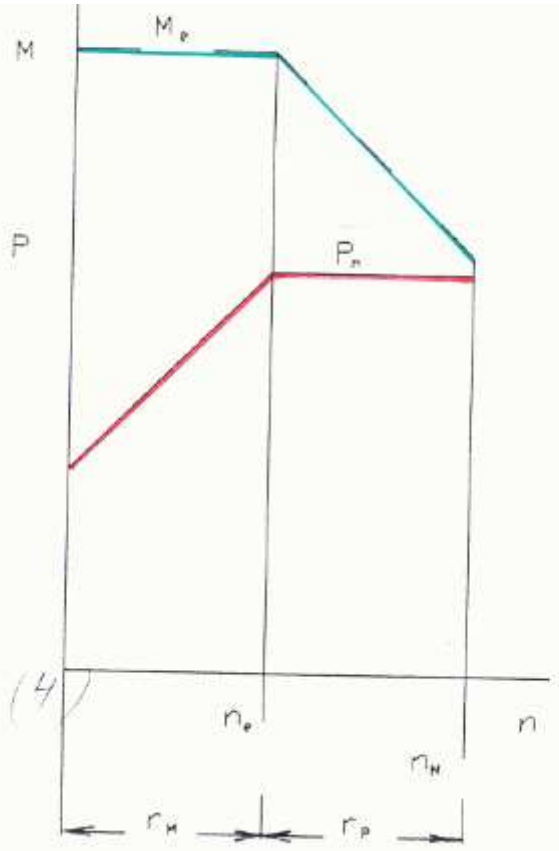
- motor power P
- motor nominal speed $n_e$
- maximum motor speed $n_M$

other parameters are derived:

- control range $r_p$ during a constant power

$$r_p = n_M / n_e$$

Power, torque – motor speed



# 2. Design of main drive system

Requirements for the output member:

- P on the spindle,
- $n_{max}$ of spindle,
- $n_{min}$ of spindle,
- maximum permissible torque $M_L$ - limited,
- limited speed – compute from P and $M_L$ $\omega_L = \frac{P}{M_L}$
- $n_L = \frac{30 * \omega_L}{\pi}$

- permissible drop in performance between grades or overlap

  ( a = $P/P_{min}$ = 1,26 given by standard.)

- life of the machine approx. 14 000 hours

# 2. Design of main drive system

The number of required steps of gear mechanism:

given $n_{max}$, $n_L$, $r_p$

the number of necessary steps p

$$r_p{}^p = n_{max}/n_L \Rightarrow p$$

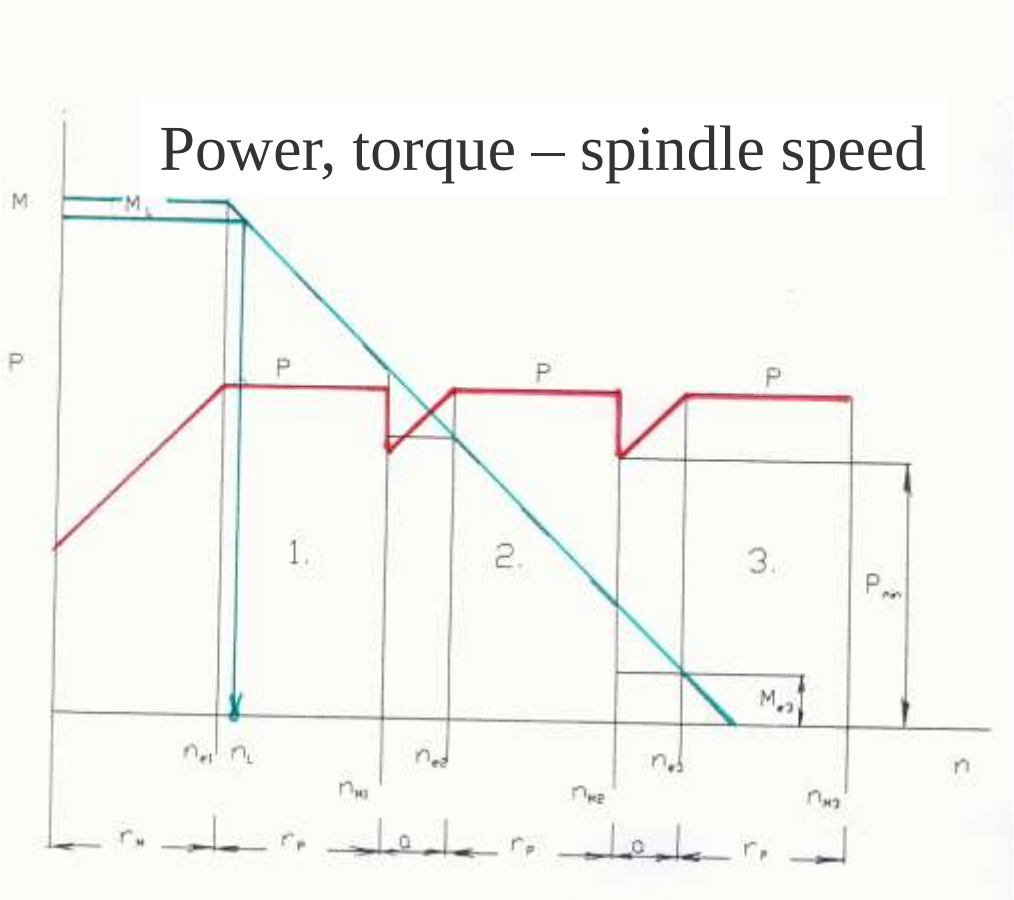
- If it exact number does not overlap nor between-degree drop in performance.
- If not, rounded up to an integer.

# 2. Design of main drive system

Diagram the output member - speed, torque, power

Limited torque.

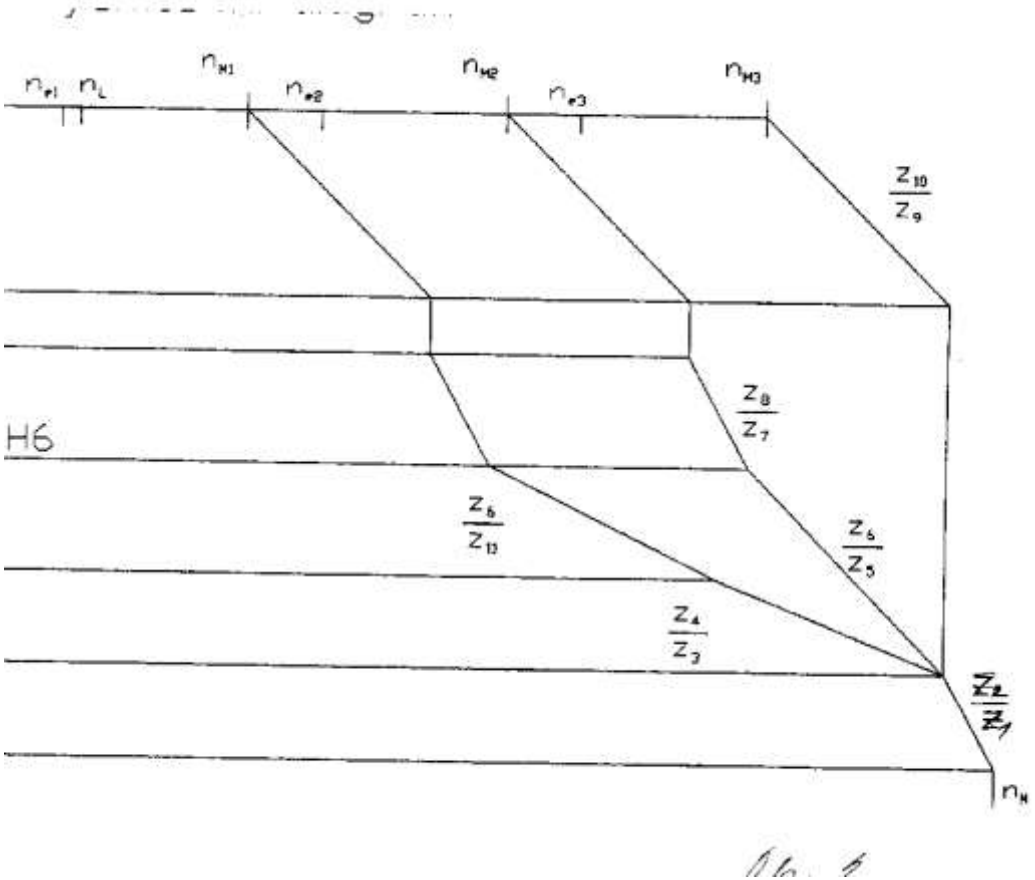
Permissible drop in performance between grades or degrees of overlap.



# 2. Design of main drive system

Speed diagram

- Input gear
- Gear paths of the individual steps
- Final gear



# 2. Design of main drive system

**Kinematic scheme**:

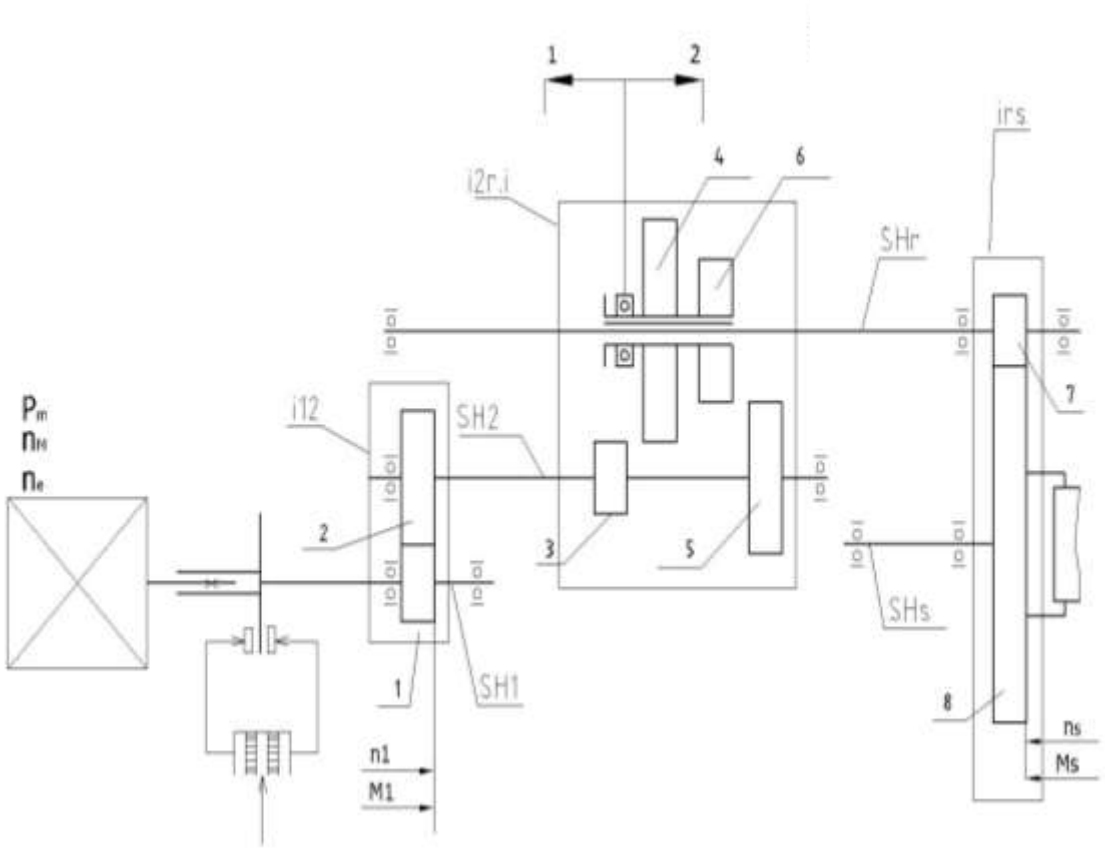
Input gear $i_{12} = \frac{z_2}{z_1}$

Speed gears

2. gear: sliding double gear (6) interlock with (5) $i_{2r.2} = \frac{z_6}{z_5}$

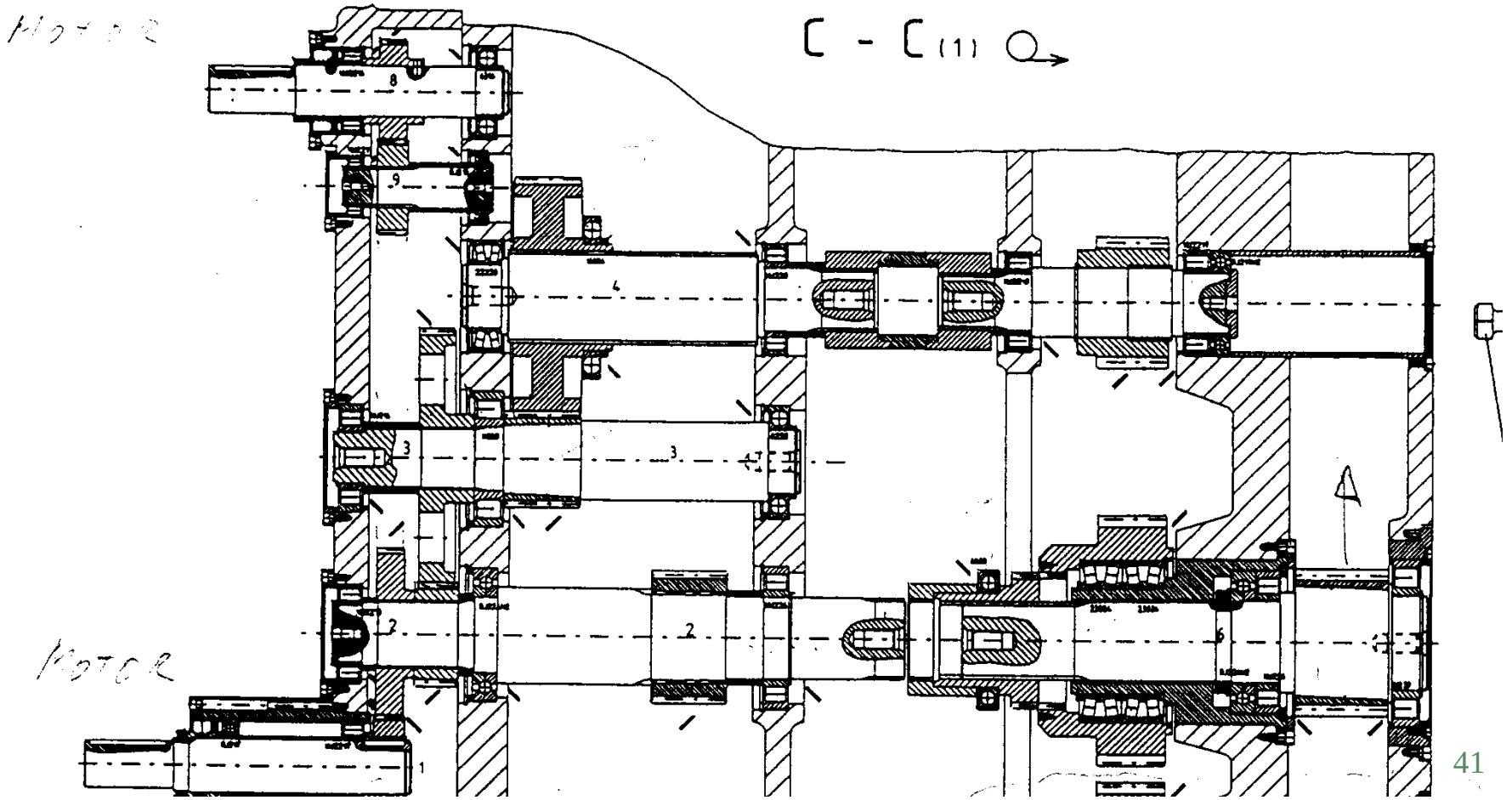
1. gear: (4) interlock with (3) $i_{2r.1} = \frac{z_4}{z_3}$

Final gear $i_{rs} = \frac{z_8}{z_7}$



# 2. Design of main drive system

## Construction design



# 2. Design of main drive system

Checking of motor

Check the total speed gear, achieving the limit torque, achieving the required speed range

Dimensioning:

- gearing (strength, surface speed, strength and dimensional calculation)
- shafts
- bearings
- backlash
- connecting elements, …..