



DAYANANDA SAGAR COLLEGE OF ENGINEERING

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Department of Robotics and Artificial Intelligence



DRIVE SYSTEMS FOR ROBOTICS (22RI34)

UNIT 1: NOTES

III SEMESTER, B.E.

**DEPARTMENT OF ROBOTICS AND ARTIFICIAL
INTELLIGENCE**

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Objectives of Drive System:

The objectives of these systems typically include:

1. **Precision and Accuracy:** Ensure that the robot can move with high precision and accuracy. This is crucial for tasks that require exact positioning, such as assembly operations or surgical procedures.
2. **Speed and Efficiency:** Optimize the speed of movement and overall efficiency of the robot. Different applications may demand varying speeds, so the drive system must accommodate these needs while maintaining efficiency.
3. **Stability and Control:** Provide stable and controlled movement to prevent wobbling, tipping, or erratic behavior. This includes maintaining balance and managing dynamic forces, especially in mobile robots.
4. **Load Handling:** Support the robot's ability to carry and manipulate payloads. The drive system must be robust enough to handle the weight of the robot itself plus any additional loads it needs to carry.
5. **Durability and Reliability:** Ensure long-term durability and reliable operation in various conditions. This includes resilience to wear and tear, environmental factors, and potential system.

Salient features of robot drive systems:

- Drive means operate the robot.
- The drive system is to provide a means to control the speed and also torque (or) power.
- Drive system is used for converting hydraulic, pneumatic, and electrical energy into useful mechanical energy. It is used to motion transfer and drive the robot.

Description of Drive systems:

Robotic drive systems consist of numerous intricate subsystems such as electronics, motors, gears, encoders, seals, lubrication etc. Three main types of drives/actuators are currently used in robots: pneumatic, hydraulic and electric, as well as different combinations of these three such as electro pneumatic, non conventional types such as atomic nuclear for high profile

applications space, defense etc. Every robot is fitted with a system of actuators on the arms or in the joints, constituting a drive system. By positioning a drive between the electrical supply and the motor, power is fed into the drive and the drive then controls and regulates the power that is fed into the motor. This allows control of speed, direction, acceleration, deceleration, torque and, in some applications, position of the motor shaft. Drives are widely used in manufacturing industries to regulate and control rotating equipment such as fans, robots, conveyors, machine spindles, and pumps, which are used in production processes.

2-3 ROBOT DRIVE SYSTEMS

The robot's capacity to move its body, arm, and wrist is provided by the drive system used to power the robot. The drive system determines the speed of the arm movements, the strength of the robot, and its dynamic performance. To some extent, the drive system determines the kinds of applications that the robot can accomplish. In this and the following sections, we will discuss some of these technical features.

Functions of drive systems:

- Robotic drive systems use a drive to control and feed power/electricity to a motor, or actuator, that converts power into motion within the robot's joints and its components.
- The actions of the individual joints is controlled in order for the manipulator to perform a desired movements of body, arm, motion and wrist. This is provided by the drive system of robot.
- The joints are moved by actuators powered by a particular form of drive system.
- Common drive systems used in robotics are *electric drive, hydraulic drive, and pneumatic drive*.

Types of Drive Systems

Commercially available industrial robots are powered by one of three types of drive systems. These three systems are:

1. Hydraulic drive
2. Electric drive
3. Pneumatic drive

Hydraulic drive and electric drive are the two main types of drives used on more sophisticated robots.

Hydraulic drive is generally associated with larger robots, such as the Unimate 2000 series (Fig. 2-2). The usual advantages of the hydraulic drive system are that it provides the robot with greater speed and strength. The disadvantages of the hydraulic drive system are that it typically adds to the floor space required by the robot, and that a hydraulic system is inclined to leak oil which is a nuisance. Hydraulic drive systems can be designed to actuate either rotational joints or linear joints. Rotary vane actuators can be utilized to provide rotary motion, and hydraulic pistons can be used to accomplish linear motion.

Electric drive systems do not generally provide as much speed or power as hydraulic systems. However, the accuracy and repeatability of electric drive robots are usually better. Consequently, electric robots tend to be smaller, requiring less floor space, and their applications tend toward more precise work such as assembly. The MAKER 110 (Fig. 2-3) is an example of an electric drive robot that is consistent with these tendencies. Electric drive robots are actuated by dc stepping motors or dc servomotors. These motors are ideally suited to the actuation of rotational joints through appropriate drive train and gear systems. Electric motors can also be used to actuate linear joints (e.g., telescoping arms) by means of pulley systems or other translational mechanisms.

The economics of the two types of drive systems are also a factor in the decision to utilize hydraulic drive on large robots and electric drive on smaller robots. It turns out that the cost of an electric motor is much more proportional to its size, whereas the cost of a hydraulic drive system is somewhat less dependent on its size. These relationships are displayed conceptually in Fig. 2-13. As the illustration suggests, there is a hypothetical break-even point, below which it is advantageous to use electric drive and above which it is appropriate to use hydraulic drive. Having explained these factors, it should be noted that there is a trend in the design of industrial robots toward all electric drives, and away from hydraulic robots because of the disadvantages discussed above.

Pneumatic drive is generally reserved for smaller robots that possess fewer degrees of freedom (two- to four-joint motions). These robots are often limited to simple "pick-and-place" operations with fast cycles. Pneumatic power can

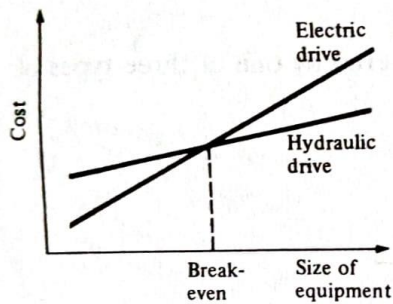


Figure 2-13 Cost vs. size for electric drive and hydraulic drive.

be readily adapted to the actuation of piston devices to provide translational movement of sliding joints. It can also be used to operate rotary actuators for rotational joints.

Applications of Robotic drives.

Robotic drives, also known as robotic actuators or drive systems, are crucial components in robotics that enable movement and control. Here are some key applications and areas where robotic drives play a significant role:

1. Industrial Automation

- **Manufacturing:** Robotic drives are used in assembly lines for tasks like welding, painting, and material handling. They enable precise control of robotic arms and machinery, improving efficiency and consistency.
- **Packaging:** Robots equipped with drive systems are used to automate packaging processes, including sorting, labeling, and palletizing products.

2. Medical Robotics

- **Surgical Robots:** Drive systems in surgical robots provide precise control for minimally invasive procedures, enhancing the surgeon's ability to perform delicate operations.
- **Rehabilitation Robots:** These robots assist in patient rehabilitation through controlled movements, aiding in physical therapy and recovery.
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3. Service Robotics

- **Domestic Robots:** Robotic drives are used in vacuum cleaners, lawn mowers, and other household robots to navigate and perform tasks autonomously.
- **Healthcare Assistants:** Robots that assist with tasks like delivering medications or providing companionship use drives for movement and interaction.

4. Exploration and Surveillance

- **Space Exploration:** Robotic drives are essential for rovers and other spacecraft, allowing them to navigate challenging terrain and conduct scientific experiments.
- **Underwater Exploration:** Submersible robots use drive systems to explore the ocean floor, gather data, and perform maintenance tasks.

5. Defense and Security

- **Bomb Disposal Robots:** These robots use drive systems to move safely and precisely while handling potentially dangerous materials.
- **Surveillance Robots:** In security applications, robotic drives help maintain mobility and stability for surveillance and reconnaissance missions.

6. Agriculture

- **Autonomous Tractors:** Robotic drives enable tractors and harvesters to perform tasks like plowing, planting, and harvesting with high efficiency.
- **Precision Farming:** Robots with drive systems can navigate fields to monitor crops, apply fertilizers, and perform other farming tasks with precision.

7. Entertainment and Education

- **Robotic Toys:** Drive systems in toys allow for interactive and engaging play experiences.
- **Educational Robots:** Used in STEM education, these robots help teach principles of robotics, programming, and engineering.

8. Logistics and Warehousing

- **Automated Guided Vehicles (AGVs):** These robots use drive systems to transport materials and goods within warehouses and distribution centers.
- **Robotic Sorting Systems:** Drive systems are used to sort packages and manage inventory efficiently.

9. Construction

- **Construction Robots:** Robots equipped with drive systems can perform tasks like bricklaying, painting, or demolition, often in hazardous environments.

10. Research and Development

- **Robotic Research:** Researchers use robotic drives to explore new algorithms and technologies, often pushing the boundaries of what robots can achieve.

Robotic drives are integral to the functionality and versatility of robots across these various applications, providing the necessary control and movement to perform complex and specialized tasks.

4.1.3 Control System

The control element of the automated system executes the program of instructions. The control system causes the process to accomplish its defined function, to carry out some manufacturing operation. Let us provide a brief introduction to control systems here. The following chapter describes this important industrial technology in more detail.

The controls in an automated system can be either closed loop or open loop. A *closed loop control system*, also known as a *feedback control system*, is one in which the output variable is compared with an input parameter, and any difference between the two is used to drive the output into agreement with the input. As shown in Figure 4.3, a closed loop

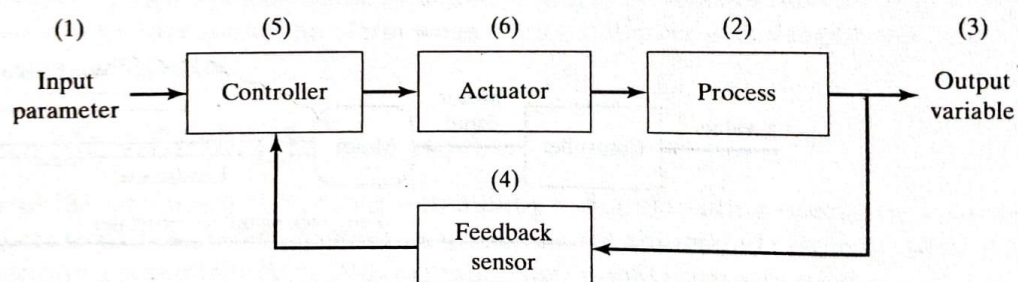


Figure 4.3 A feedback control system.

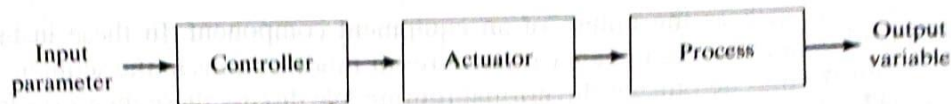


Figure 4.4 An open loop control system.

control system consists of six basic elements: (1) input parameter, (2) process, (3) output variable, (4) feedback sensor, (5) controller, and (6) actuator. The *input parameter*, often referred to as the *set point*, represents the desired value of the output. In a home temperature control system, the set point is the desired thermostat setting. The *process* is the operation or function being controlled. In particular, it is the *output variable* that is being controlled in the loop. In the present discussion, the process of interest is usually a manufacturing operation, and the output variable is some process variable, perhaps a critical performance measure in the process, such as temperature or force or flow rate. A *sensor* is used to measure the output variable and close the loop between input and output. Sensors perform the feedback function in a closed loop control system. The *controller* compares the output with the input and makes the required adjustment in the process to reduce the difference between them. The adjustment is accomplished using one or more *actuators*, which are the hardware devices that physically carry out the control actions, such as electric motors or flow valves. It should be mentioned that our model in Figure 4.3 shows only one loop. Most industrial processes require multiple loops, one for each process variable that must be controlled.

In contrast to the closed loop control system, an *open loop control system* operates without the feedback loop, as in Figure 4.4. In this case, the controls operate without measuring the output variable, so no comparison is made between the actual value of the output and the desired input parameter. The controller relies on an accurate model of the effect of its actuator on the process variable. With an open loop system, there is always the risk that the actuator will not have the intended effect on the process, and that is the disadvantage of an open loop system. Its advantage is that it is generally simpler and less expensive than a closed loop system. Open loop systems are usually appropriate when the following conditions apply: (1) the actions performed by the control system are simple, (2) the actuating function is very reliable, and (3) any reaction forces opposing the actuator are small enough to have no effect on the actuation. If these characteristics are not applicable, then a closed loop control system may be more appropriate.

Closed Loop control system:

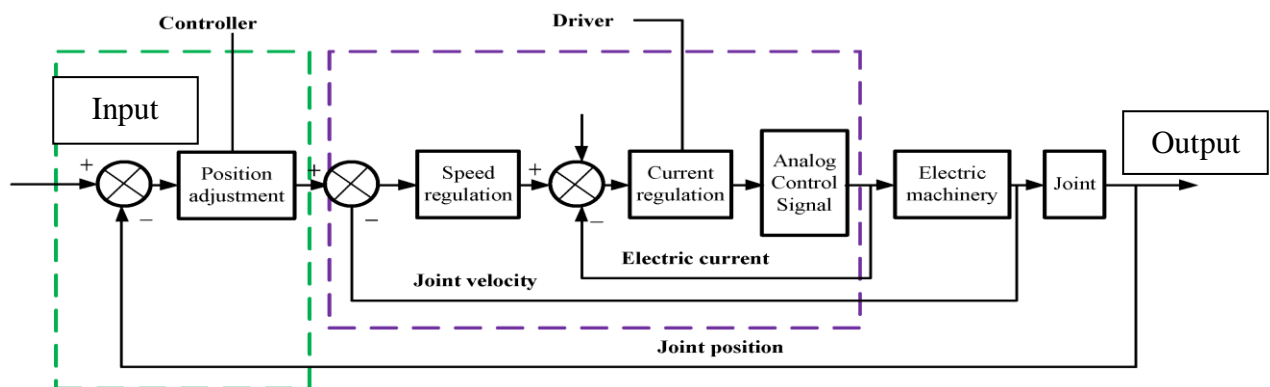


Fig:a (Closed loop Feed back systems)

A closed loop control system is a mechanical or electronic device that automatically regulates a system to maintain a desired state or set point without human interaction. It uses a feedback system or sensor such as joint position sensor, joint velocity sensor.

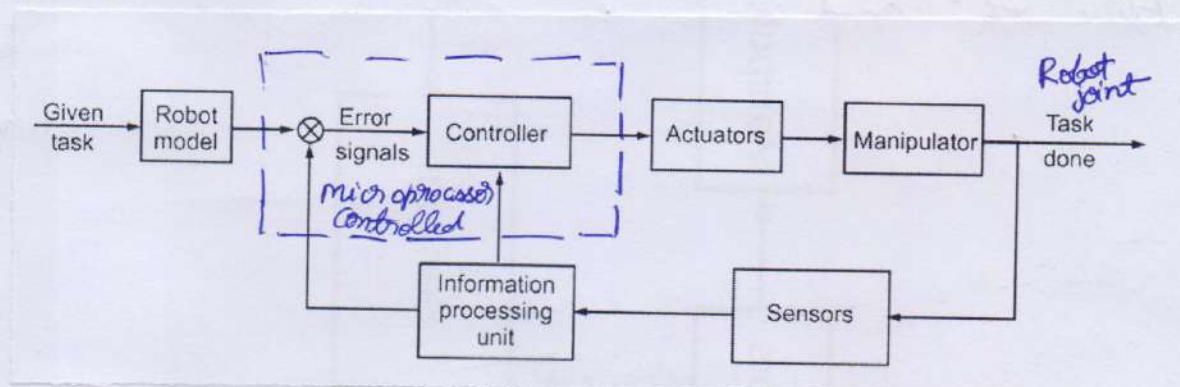
A closed loop system in which the output variable is compared with input parameters, and any differences between the two is used to drive the output. Closed-loop control is a higher level of automation than the envelope protection system. In this control system, the set point/control value is defined and it set by the operator either manually or automatically. If automatically, the operator uses an automated system to find and update the set point.

With reference to the closed loop figure above, When the output parameters from the process is obtained, such as joint velocity and position velocity robotic systems, if there are any modifications or variations with respect robot joint **position variations (displacement)** or **robot joint velocity variations** in terms of speed , the error or variations is sensed and measured by joint position sensor and joint velocity sensors. Through the feedback systems. The joint position sensors sends the signals to error compensator , where inturns adjusts and modifies the signals and sends back to position adjustment block which intern sends the corrected and desired signals to robotic driver/actuator which intern actuates the robotic positions where actual manipulator moves.. Similarly the joint velocity sensors sends the signals to error compensator , where in it adjusts and modifies the signals and sends signals to joint velocity adjustment block which intern sends the corrected and desired signals to robotic driver which intern actuates the robotic velocities and controls the speed required for robotic joints.

(Fig a: from above for references)

(1)

Typical block diagram configuration of a control system for a Robot joint.



The above figure illustrates a general block diagram of the control system components for one-joint of the Robot manipulator. The input command is defined position (& possibly speed) to which the joint is directed to move. The output variable is actual position (and speed) of the joint. All the process here is controlled by the microprocessors.

Controllers :-

The purpose of the controller is to compare the actual output of the plant with an input command and to provide control signal which will reduce the error to zero, or close to zero as possible.

The controller generally consists of a summing junction where the input & output signals are compared, it is the control device which determines the control action necessary power amplifications and associated hardware devices to accomplish the control

actions in the robotic plant. The actuators used in the robotics applications is used to convert the control actions into the physical movements in the plant. Here the controller and actuator may be operated by pneumatics, hydraulic, mechanical, or electronic means or it can be combinations of these.

There are four basic control actions which are used singly or in combination to provide six common types of controllers. (1) On-off control, (2) proportional control, (3) integral, (4) proportional-plus-integral (P-I), (5) proportional-plus-derivative (P-D), (6) proportional-plus-integral-plus derivative (P-I-D).

Each of the controller is used in certain typical applications.

① On-off control: - This type of controller, provides only two levels of control, full-on or full-off. An example of a common implementation of this type of controller is the household thermostat. If the error which is present at the controller is $e(t)$ & the control signal which is produced by the controller is $m(t)$ then on-off controller is represented by

$m(t) = M_1, \text{ for } e(t) > 0$
$m(t) = M_2, \text{ for } e(t) < 0$

In most on-off controller either M_1 or M_2 is zero. The practical use of an on-off controller usually requires that the error must move through some range before switching actually takes place. This prevents the controller from oscillating at too high a frequency. This range is referred to as the differential gap.

(2) Proportional control:- In cases where a smoother control action is required a proportional controller may be used. Proportional control provides a control signal that is proportional to the error. Essentially, it acts as an amplifier with a gain K_p . Its action is represented by

$$m(t) = K_p e(t)$$

using the differential operator notation introduced earlier the transfer function would

$$\frac{M(s)}{E(s)} = K_p$$

(3) Integral Control:- In a controller which is employing an integral control action the control signal is changed at a rate proportional to the error signal. That is, if the error signal is large, the control signal increases rapidly, if it is small, the control signal increases slowly. This may be represented by

$$m(t) = K_i \int e(t) \cdot dt$$

where K_i is the integrator gain. The corresponding transfer

$$\frac{M(s)}{E(s)} = K_i / s$$

using $1/s$ as the operator for integration. If the error were to go to zero, the output of the controller would remain constant. This feature allows integral controllers to be used when there is some type of constant load on the system. Even, if there is no error the controller would still maintain an output signal to counteract the load.

④ Proportional-plus-Integral control:-

Sometimes it is necessary to combine control actions. A proportional controller is incapable of counteracting a load on the system without an error. An integral controller can provide zero error but usually provides slow response.

One way to overcome this is with is the P-I controller. This is represented by.

$$m(t) = K_p e(t) + \frac{K_p}{T_i} \int e(t) dt$$

where T_i adjusts the integrator gain & K_p or K_p adjusts both the integrator & the proportional gain. The transfer function is

$$\frac{M(s)}{E(s)} = K_p \left(1 + \frac{1}{T_i s} \right)$$

⑤ Proportional-plus-Derivative Control:-

Derivative control action provides a control signal proportional to the rate of change of the error signal. Since this would generate no output unless the error is changing, it is rarely used alone. The P-D controller is represented by.

$$m(t) = K_p e(t) + K_p T_d \frac{de(t)}{dt}$$

and the transfer function is

$$\frac{M(s)}{E(s)} = K_p (1 + T_d s)$$

The effect of derivative control action is to anticipate changes in the error & provide a faster response to changes.

Features:-

- * Decreases the type of the system by one.
- * Reduces the rise time & settling time.
- * It has high sensitivity.
- * Rise time & settling time decreases & bandwidth increases
- * The speed of response is increased i.e. the transient response is improved.

⑥ Proportional-plus-Integral-plus-Derivative control:-

Three of the control actions can be combined to form P-I-D Controller. The P-I-D Controller can be represented by.

$$m(t) = K_p e(t) + \frac{K_p}{T_i} \int e(t) dt + K_p T_d \frac{de(t)}{dt}$$

and the transfer function is

$$\frac{M(s)}{E(s)} = K_p \left(1 + \frac{1}{T_i s} + T_d s \right)$$

P-I-D Control is the most general control type & probably the most commonly used type of Controller. It provides quick response, good control of system stability & low steady-state error. The computations associated with any of the above controllers are typically performed by microcomputers in modern robot controller.

Features:-

- (*) It includes quicker response time, because P only control along with the decreased / zero offset from the combined derivative & integral controller.
- (*) Easy to implement
- (*) Easy to stabilize, faster response
- (*) uses low resources.
- (*) Easier to tune by simple trial and error.
- (*) Better response to unmeasured disturbances.
- (*) PID hardware is not heavy, does not require skilled labour.

Power Transmission systems:

Gears



- They are used to transmit power to a driven piece of machinery and to change or modify the power that is transmitted.
- Gears are used to transmit rotary motion from one shaft to another shaft., this transfer is between parallel shafts.
- Gears are used basically for reducing speed and increasing output torque, increasing speed, changing the direction of shaft rotation, or changing the angle of shaft operation
- The simplest type of gears used to transmit power between parallel shafts are spur gears.
- The driving gears is referred as pinion gears.
- The gear trains are referred as series of gears arrangement act as speed reducers.
- Gears come in various configuration for parallel shafts(i.e spur gears), orthogonal intersecting shafts (i.e bevel gears), skew shafts (i.e worm gears or cross helical gears).
- Different types of gears have different load bearing capacities , wear characteristics and frictional properties.
- The major disadvantage of using gears are backlash and friction.
- Backlash arises from imperfect meshing of gears, it has maximum angular motion
- The ratio η describes the speed reducing and torque increasing effects of gear drives.

Gears

- The Pinion size is one-fourth size of gear.
- As a pinion makes one revolution correspondingly the driven gear turns only one-fourth of a revolution.
- The torque applied by pinion is multiplied **four times** at the gear shaft.
- Since speed is quartered and the torque is quadrupled the power output equals the power in the gear train.

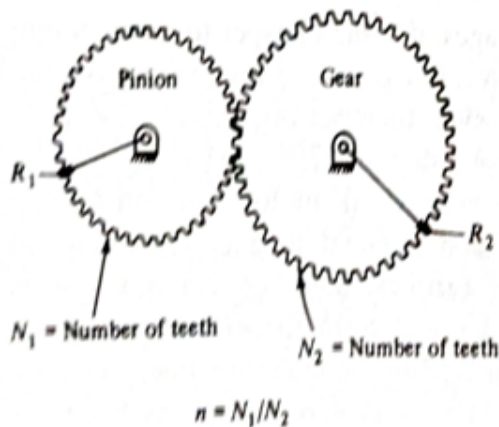


Figure 3.23 Spur gear train.

$$n = \frac{N_1}{N_2} \quad (3-43)$$

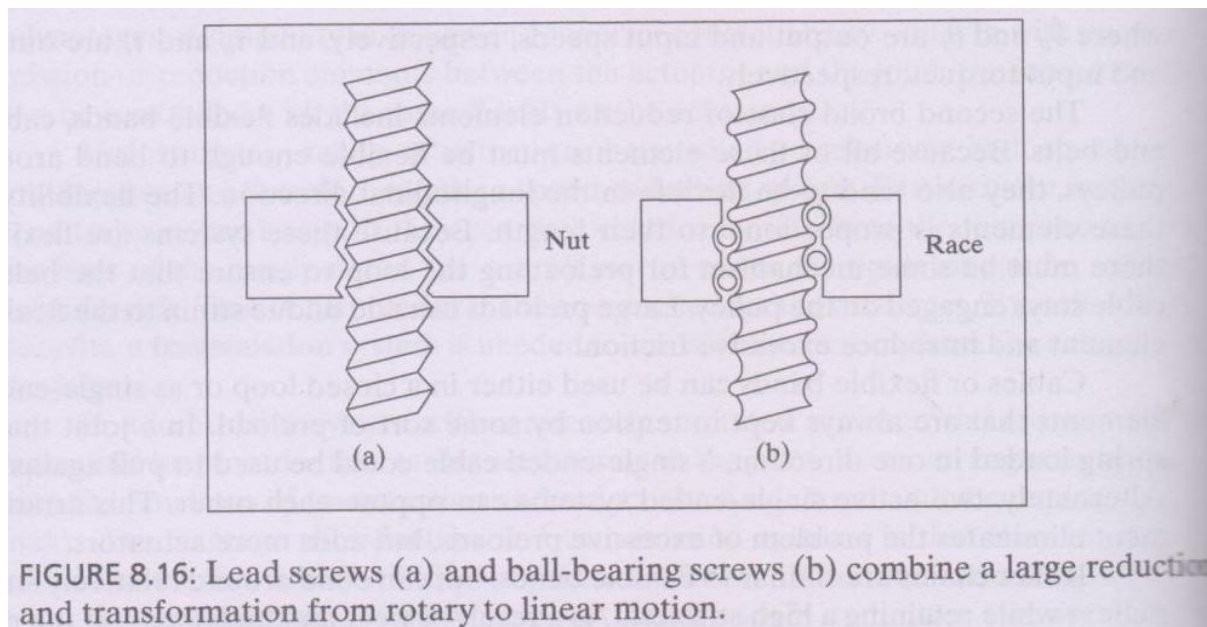
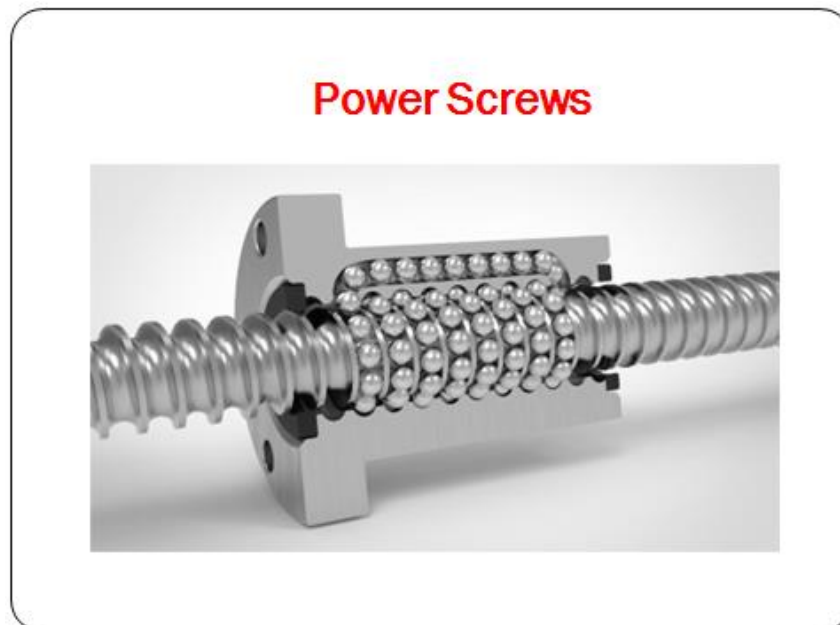
and the speed of the output with respect to the input is

$$\omega_o = n\omega_{in} \quad (3-44)$$

where ω_o is the output speed and ω_{in} is the input speed. The output torque is

$$T_o = \frac{T_{in}}{n}$$

Power screws: Lead Screws/Ball Screws:



In robotics and many applications, power screws are often used to convert rotary motion to linear motions. Lead screw or ball-bearing screws provide another popular method of getting a large reduction in a compact package. Lead screws are very stiff. It provides supports to large loads. It has the property to transform the rotary motion to linear motion. Ball bearing screws are very similar to lead screws. But ball bearing instead of having nut riding directly on the screws, a recirculating circuit of ball bearing rolls between the sets of threads.

Ball bearing screws have very low friction and usually back drivable(Lead Screws that have an efficiency of 50% or greater will back drive, The efficiency of ball screws is relatively constant and is typically better than 90% .

Salient features of Power screws:

- In robotics and many applications, power screws are often used to convert rotary motion to linear motions.
- Lead screws are very stiff.
- It provides supports to large loads.
- It has the property to transform the rotary motion to linear motion.
- Ball bearing screws are very similar to lead screws in its functions.
- But ball bearing instead of having nut riding directly on the screws, a recirculating circuit of ball bearing rolls between the sets of threads.
- Ball bearing screws have very low friction and usually backdrivable(Lead Screws that have an efficiency of 50% or greater)
- The important parameter with power screw is screw pitch “p”, often called as lead.
- Pitch defines the distance that a screw travels in single rotation.

for the screw's angular rotation to linear motion is given by

$$v(t) = p\omega(t) \quad (3-45)$$

where $v(t)$ is the linear velocity in inches per minute, $\omega(t)$ is the angular velocity in rotations per minute, and p is the screw pitch expressed in inches per rotation. In most cases the screw is rotating and a nut is moving along the length of the screw. The conversion from torque, T , applied to the screw to force, F , on the nut is obtained by the following Eq. (3-46)

$$F = \frac{2T \pi d_m - \mu p \sec \beta}{d_m p + \mu \pi d_m \sec \beta} \quad (3-46)$$

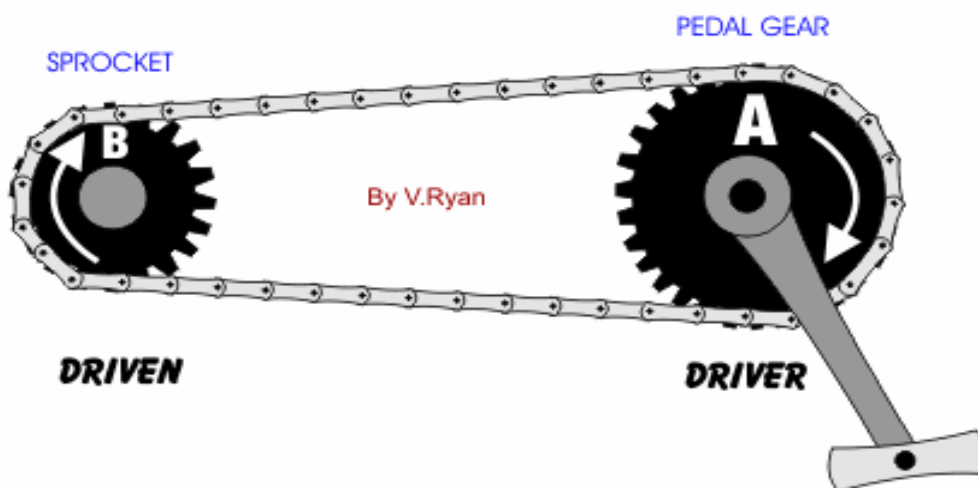
where μ = the coefficient of friction between the screw threads

β = the thread angle on an Acme or Unified thread

d_m = the mean diameter of the screw

This equation applies for Acme and Unified threads, in which there is a thread angle, β . For square threads, the value of β is 0, and the secant terms = 1.0 in Eq. (3-46).

Chain Drives:



- They operate with constant ratio.
- Due to positive interaction between chains and sprockets there is low possibilities of slipping.
- The pitch of the chain drive is the distance between rollers centers.
- The driving sprockets and driven sprockets each have equal number of teeth designed to match size and pitch of the chain.
- The power transmission is similar to that of gear drives.
- Lubrication is an importance factor in chain drive maintenance.

Chain and Belt Drives:

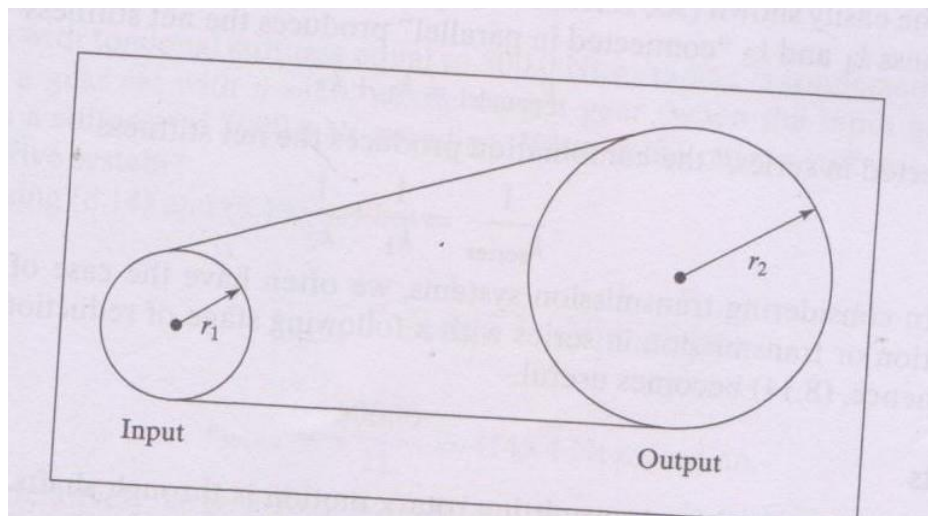
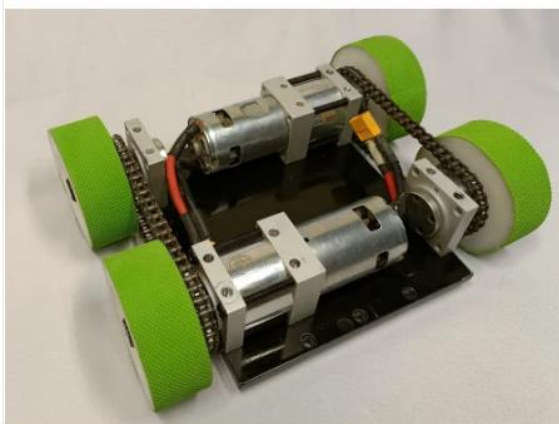


Figure common reference both belt and chain drives



Applications of Chain drive(1) and Belt drive(2) in Robots

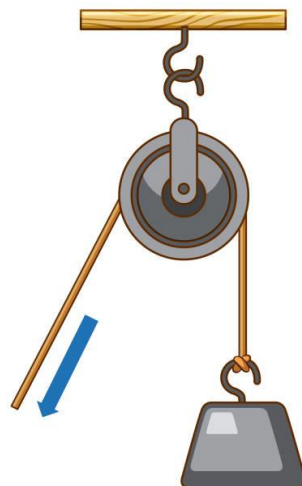
Cables or flexible bands can be used either in closed loop or as a single ended elements. It is always kept in tension by preload condition. A joint is spring loaded in one direction. A single ended cable could be used to pull against it. Alternately two single ended cable could oppose each other. This eliminates the problems of excessive preloads, but adds more actuators. Roller chains are similar to the flexible bands but can bend around relative small pulleys. The chains systems maintain high stiffness. As a result , wear and high loads on the pins connecting links, toothed belt drive are more compact than the roller chains for certain applications. Band, cable, belt and chain drives have ability to combine the transmission with reduction. Cables or flexible bands can be used either in closed loop or as an single ended elements. Roller chains are similar to the flexible bands but can bend around relative small pulleys.

- **Belt drives:** A belt drive is a frictional drive that transmits power between two or more shafts using pulleys and an elastic belt. .
- Band, cable, belt and chain drives have ability to combine the transmission with reduction.
- It can operate at wide ranges of speed and power requirements. It is also highly efficient.

Salient features of belt drives:

- i) They can be used for power transmission between the axes of driving and driven shafts having considerable distances between them.
- (ii) The belt drive operation is smooth and silent.
- (iii) Simple design and low initial cost.
- **Simplicity:** Fewer components compared to gear drives, which makes them easier to maintain and replace.
- **Flexibility:** Can handle varying distances between shafts and can accommodate some misalignment.
- **Noise and Vibration Reduction:** Typically quieter and produce less vibration than gear drives.

Rope Drives:



- Rope drives are used to activate linear joints.
- Ropes undergoes continuous flexing during operations
- If the ropes stretches, it results in degrading the accuracy of the robotic systems.

- **Salient features of rope drives:**
- **Flexibility:** Rope drives can handle a range of distances between pulleys and can be used in configurations where space is limited.
- **Low Noise:** They are often quieter than gear drives because they absorb some of the vibrations and shocks.
- **Reduced Wear:** Ropes can be less prone to wear and tear compared to gears, especially in high-torque application

Precision Gear Boxes :



In robotics, a gearbox is a crucial component that plays a significant role in controlling the speed, torque, and direction of the motors that drive the robot's movements. Gearboxes are integral to achieving the desired performance in robotic systems, making them a key consideration in the design and development of robots. Gearboxes are used to adapt the speed and torque of motors so that they are suitable for the specific requirements of machines and processes.

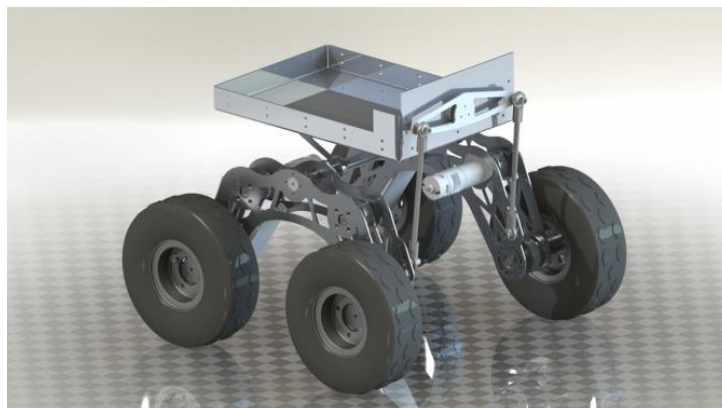
Types of Gear Boxes in robotics:

- 2 Wheel Drive
- 4 Wheel Drive with 2 Gearboxes
- 4 Wheel Drive with 4 Gearboxes
- 6 Wheel Drive with 2 Gearboxes
- Tank Drive and Treads
- Omni-directional Drive Systems
 - Mecanum
 - Holonomic / Killough
 - Crab/Swerve
- Other

Examples for 2 Wheeled Robot



Examples for four wheeled robots



Harmonic Gears:

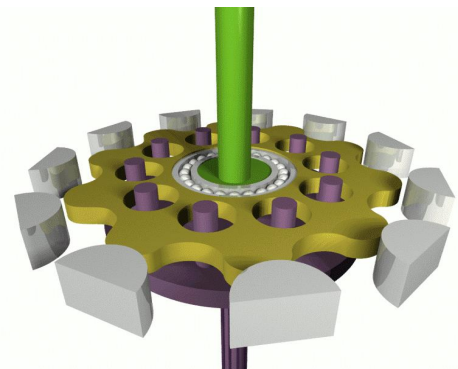


- Harmonic drives are proprietary products of USM to improve gear characteristics when compared to traditional gears.
- It can be used as speed reducers or increasers.
- The input and output shafts lie along the same axis, so that harmonic drives can be mounted to the face of the motor with the output shafts coming out of the same end.
- Harmonic drives can provide the reduction ratios from 1:1 to infinity:1, although they are typically used in the range of 100:1.
- Harmonic drives require very little maintenance.
- They can operate with no noticeable wear over their lifetime.
- They are less efficient when compared with well designed gear trains.
- Harmonic drive robot arms utilize these drives for their compact size, high precision, and efficient power transmission.
- By incorporating harmonic robotic gearbox drives into robot arm gearboxes, precise and smooth motion control can be achieved, allowing for accurate positioning and manipulation of objects.
- Harmonic Gear Manufacturer — Application in robots, medical, energy, space machines.
- The Operating principle which is based upon the elastic mechanics of metals.
- The greatest benefits are the zero-backlash characteristics and the weight and space savings compared to other gears because our gear mechanism consists of only three basic parts.

Applications:

- *Industrial Robots*
- *Aerospace*
- *Medical Equipment*
- *Machine Tools*
- *Measuring and Testing*
- *Printing Machines*
- *Semiconductor Equipment*
- *Woodworking Machine*

Cyclo or Cycloid gears speed reducers:



- It is high precision gear box that uses unique cycloidal design to provide extremely smooth and efficient power transmission.
- A cycloidal drive or cycloidal speed reducer is a mechanism for reducing the speed of an input shaft by a certain ratio.
- Cycloidal speed reducers are capable of relatively high ratios in compact sizes with very low backlash.
- The input shaft drives an eccentric bearing that in turn drives the cycloidal disc in an eccentric, leading to cycloidal motion.
- The perimeter of this disc is geared to a stationary ring gear and has a series of output shaft pins or rollers placed through the face of the disc.
- These output shaft pins directly drive the output shaft as the cycloidal disc rotates.
- The radial motion of the disc is not translated to the output shaft.
- These are more suited for speed reduction systems in high speeds and low torques.