GOVERNMENTPOLYTECHNIC, DHENKANAL

Programme:DiplomainMechanicalEngineering

Course:Mechatronics(Theory)

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Unit1:INTRODUCTIONTOMECHATRONICS

DefinitionofMechatronics

Thesynergisticcombinationofprecisionmechanicalengineering,electroniccontrolandsystemsthinkinginthe design of products and manufacturing processes.

"Mechatronics"involvesanumberoftechnologiessuchas:

- Mechanicalengineering;

- Electronicengineering;

- Electricalengineering;

- Computertechnology;

- Controlengineering

AdvantagesandDisadvantagesofMechatronics

Following are the advantagesanddisadvantagesofmechatronics:

Advantages:

1. Theproductsproducedarecosteffectiveandofverygoodquality.

2. Theperformancecharacteristicsofmechatronicsproductsare suchwhichare otherwiseverydifficultto achieve without the synergistic combination.

3. Highdegreeofflexibility.

4. Amechatronicsproductcanbebetterthanjustsumofitsparts.

5. Greaterextentofmachineutilization.

6. Duetotheintegrationofsensorsandcontrolsystemsinacomplexsystem,capitalexpensesarereduced

7. Owingtotheincorporationofintelligent,self-correctingsensoryandfeedbacksystems,themechatronic approach results in:

- Greaterproductivity;

- Higherquantityandproducingreliability.

Disadvantages:

1. Highinitialcostofthesystem.

2. Imperativetohaveknowledgeofdifferentengineeringfieldsfordesign and implementation.

3. Specificproblemsforvarioussystemswillhavetobeaddressedseparatelyandproperly.

4. Itis expensivetoincorporatemechatronicsapproachtoanexisting/oldsystem.

ApplicationofMechatronics

Followingaretheexamplesofmechatronicssystems:

l.Homeappliances:

- Washing machines

- Breadmachinesetc.

2. Automobile:

- Electricalfuelinjection

- Antilockbrake system.

3. Aircraft:

- Flightcontrol

- Navigationsystem.

1. Automatedmanufacturing:

- Robots

- Numericallycontrolled(NC)machinetools.

ScopeofMechatronicsinIndustrialSector

Mechatronicshelpsin designingandmaintaining automatedequipment.Techniciansandengineersworkin laboratories, offices or on-site manufacturing plants. The goal is to produce safe and efficient automated equipment.Techniciansprimarilymaintainmachinery,whileengineersaremoreconcernedwithdesignand development of components and products.

A Mechatronics engineer unites the principles of engineering disciplines like mechanics, electronics, and computingtogenerateasimpler,moreeconomicalandreliablesystemtheprocessofmechatronicsengineering involves designing, assembling, testing, and evaluating components and products.

Mechatronics technicians apply their knowledge of engineering to solve technical problems and maintain automatedmechanicalequipment.Ajobofamechatronicstechnicianincludesinspecting,troubleshootingand repairing electrical and electronic components.

Componentsofamechatronicsystem:

- Actuators
- Sensors
- Inputsignalconditioning&interfacing
- Digitalcontrolarchitectures
- Outputsignalconditioning&interfacing
- Graphicaldisplays

1. Actuators: Solenoids,voicecoils;D.C. motors;Steppermotors;Servomotor;hydraulics;pneumatics.

2. Sensors:Switches;Potentiometer;Photoelectric;Digitalencoder;Straingauge;Thermocouple;accelerometer etc.

3. lnputsignalconditioningandinterfacing:Discretecircuits;Amplifiers,Filters;A/D, D/D.

4. Digitalcontrolarchitectures:Logiccircuits;Microcontroller;SBC;PLC;Sequencingandtiming;Logicand arithmetic; Control algorithms; Communication.

5. Outputsignalconditioningandinterfacing:Amplifiers;PWM;Powertransistors.

6. Graphicaldisplays:LEDs;Digitaldisplays;LCD;CRT.

- Theactuatorsproducemotionorcausesomeaction;
- Thesensorsdetectthestateofthesystemparameters,inputsandoutputs;
- Digitaldevicescontrolthesystem;
- Conditioningandinterfacingcircuitsprovideconnectionbetweenthecontrolcircuitandtheinput/output devices;
- Graphicaldisplaysprovidevisualfeedbacktousers.

ImportanceofMechatronicsinautomation

Today's customers are demanding more variety and higher levels of flexibility in the products. Due to these demandsandcompetitioninthemarket, manufacturersarethrivingtolaunchnew/modifiedproductstosurvive. Itis reducingtheproductlifeaswellaslead-time tomanufactureaproduct.Itisthereforeessential toautomate the manufacturing and assembly operations of a product.

Mechatronics concurrentlyemploysthedisciplines of mechanical,electrical, control andcomputer engineering at the stage of design itself. Mechanical discipline is employed in terms of various machines and mechanisms, whereas electrical engineering as various electric prime movers viz. AC/DC, servo motors and other systems is used. Control engineering helps in the development of various electronics-based control systems to enhance or replacethemechanicsofthemechanicalsystems. Computersarewidelyusedtowritevarioussoftwarestocontrol the control systems; product design and development activities; materials and manufacturing resource planning, record keeping, market survey, and other sales related activities.

Usingcomputer aideddesign(CAD)/computeraidedanalysis(CAE) tools,three-dimensionalmodelsofproducts can easily be developed. These models can then be analyzed and can be simulated to study their performances using numerical tools. These numerical tools are being continuously updated or enriched with the real-life performancesofthesimilar kindofproducts. Theseexercisesprovideanapproximateideaaboutperformanceof the product/system to the design team at the early stage ofthe product development. Based on the simulation studies, the designs can be modified to achieve better performances.

During the conventional design manufacturing process, the design assessment is generally carried out after the production of first lot of the products. This consumes a lot of time, which leads to longer (inmonths/years) productdevelopmentlead-time.Useof CAD–CAEtoolssavessignificant timeincomparison withthatrequiredin theconventionalsequentialdesignprocess.CAD-CAEgeneratedfinaldesignsarethensenttotheproductionand process planning section.

Mechatronics based systems such as computer aided manufacturing (CAM): automatic process planning, automaticpartprogramming,manufacturingresourceplanning,etc.usesthedesigndataprovidedbythedesign team.Basedtheseinputs,variousactivitieswillthenbeplannedtoachievethemanufacturingtargetsintermsof quality and quantity with in a stipulated time frame.

Mechatronicsbasedautomatedsystemssuchasautomaticinspectionandqualityassurance,automaticpackaging, record making, and automatic dispatch help to expedite the entire manufacturing operation. These systems certainly ensure a supply better quality, well packed and reliable products in the market.

Automation in the machine tools has reduced the human intervention in the machining operation and improved theprocessefficiencyandproductquality.Therefore,itisimportanttostudytheprinciplesofmechatronicsandto learn how to apply them in the automation of a manufacturing system.

Unit2:SENSORSANDTRANSDUCERS

DefinitionofTransducers

Itisdefinedasanelementwhensubjectedtosomephysicalchangeexperiencesarelatedchangeoranelement which converts a specified measure and into a usable output.

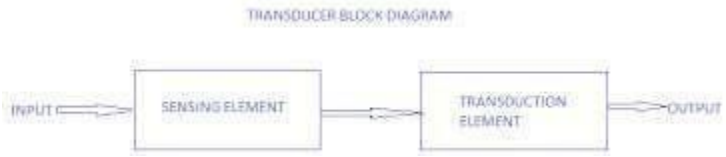
Itcanalsobedefinedasadevicethatconvertsasignalfromoneformofenergytoanotherform.

Most ofthetransducerseitherconvertelectricalenergyintomechanical displacement and/orconvertsomenon-electrical physical quantity (e.g., force, sound, temperature etc.) to an electrical signal.

Atransducerperforms thefollowingfunctions:

1. Detectsorsensesthepresence,magnitudeand changesinphysicalquantity beingmeasured.
2. Providesaproportionalelectricaloutputsignal.

Atransducercanbebroadlydefinedasadevicewhichconvertsanon-electricalquantityintoanelectricalquantity.



ClassificationofTransducers

Inversetransducer

Aninversetransducerisdefinedasadevicewhichconvertsanelectricalquantityintoanon-electricalquantity.

Apiezoelectriccrystalactsasaninversetransducerbecausewhenavoltageisappliedacrossitssurfaces,it changes its dimensions causing a mechanical displacement.

Activetransducers

Theyarealsoknownasself-generatingtypetransducers.Thesetransducersdeveloptheirownvoltageorcurrent. The energy required for production of an output signal is obtained from the physical phenomenon being measured.

Examples:Thermocouplesandthermopiles,piezoelectricpick-up,photovoltaiccell.

Passivetransduces

Theyareknownasexternally-poweredtransducer.Thesetransducersderivethepowerrequiredfortheenergy conversion from an external power source. However, theymay absorb some energy from the physical phenomenon under study.

Examples:Resistancethermometersandthermistors,potentiometricdevices,differentialtransformer, photoemission cell etc.

Analoguetransducers

Thesetransducersconverttheinputphysicalphenomenonintoananalogousoutputwhichisacontinuous function of time.

Examples:Straingauge,a thermocouple,athermistororanLVDT(linearvoltagedifferentialtransformer).

Digitaltransducers

Thesetransducersconverttheinputphysicalphenomenon intoanelectricaloutputwhichmaybeinformofpulse'

Classification based on electrical principle involved:

1. Variable-resistancetype:
    - Strainandpressuregauges.
    - Thermistors,resistancethermometers'
    - Photoconductivecelletc.
2. Variable-inductancetype:
    - Linearvoltagedifferentialtransformer (LVDT).
    - Reluctancepick-up.
    - Eddycurrentgauge.
3. Variable-capacitancetype:
    - Capacitormicrophone.
    - Pressuregauge.
    - Dielectricgauge.
4. Voltage-generatingtype:
    - Thermocouple.
    - Photovoltaiccell.
    - Rotationalmotiontachometer'
    - Piezoelectricpick-up.
5. Voltage-dividertype:
    - Potentiometerpositioncensor'
    - Pressure-actuatedvoltagedivider.

ElectromechanicalTransducers

Anytypeofdevicethateitherconvertsanelectricalsignalintosoundwaves(asinaloudspeaker)orconvertsa sound wave into an electrical signal (as in the microphone).

Advantages:

1. Lesspowerconsumption
2. Frictioneffectisminimum
3. Morecompactinstrumentation
4. Possibilityofnon-contactmeasurements
5. Goodfrequency

Transducersactuatingmechanisms

Actuatingmechanismconvertsasource ofenergy,whichcan bemechanical force,electricalcurrent,hydraulic fluid pressure or pneumatic pressure etc. into motion.

Anactuatingmechanismnotonlychangesthestateoftheobjectbeingcontrolledbutalsomovesthecontrolled member with the minimum possible deviations.

Eg.corrugateddiaphragm,bellows,corrugatedbourdontube(allusedforpressuremeasurement)

DisplacementorPositionsensors

Sensors

Asensorisadevicethatdetectsandrespondstosometypeofinputfromthephysicalenvironment.Thespecific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena.

Adisplacementsensorisadeviceusedformeasuringpositionalmovementordetectingthemovementofagiven object, these movements can be in either a linear or rotary fashion.

Displacementsensors,alsoknownaspositionsensors,areaverycommontypeof sensor.

Someofthemostcommonindustriesfordisplacementsensorsare;Motorsport,automotive,industrial applications, agriculture, aerospace, robotics and many more.

Velocity,Motion,ForceandPressuresenso

rs

Velocitysensor

Avelocitysensorisasensorthatrespondstovelocity

Themagnetofthevelocitysensorissuspendedonamembrane(spring)whichmovesthroughacoilofwire.Due to the vibration, the coil of wire moves through themagnetic field of the permanent magnet and generates (induces) a voltage signal which is proportional to the vibration (velocity).

Eg.tachometers(employedinamotortocalculatetherotationalspeedofashaft),piezoelectricsensor(uses piezoelectric effect to measure changes in velocity)

Motionsensor

Amotionsensorisanelectronicdevicethatusesasensortodetectnearbypeopleorobjects.Motionsensorsare an important component of any security system. When a sensor detects motion, it will send an alert to your security system, and with newer systems, right to your mobile phone.

Activeultrasonicsensorsandpassiveinfraredsensorsarethetwomostcommonmotionsensortechnologies,both of which are known for their accuracy and reliability.

Activeultrasonicsensorsemitultrasonicsoundwavesatafrequencyabovetherangeofhumanhearing.These waves bounce off objects in the immediate vicinity and returnto themotion sensor.

Passiveinfraredsensorsareabitmorecomplexthanactiveultrasonicsensors,buttheresultisthesame.

Infraredmotionsensorsdetectthepresenceofapersonorobjectbydetectingthechangein temperatureofa given area.

Forcesensor

AForceSensorisdefinedasatransducerthatconvertsaninputmechanicalload,weight,tension,compressionor pressure into an electrical output signal.

Force Transducers became an essential element in many industries from Automotive (car sensors or vehicle sensors),Highprecisionmanufacturing,Aerospace&Defense,IndustrialAutomation,Medical&Pharmaceuticals and Robotics

Pressuresensor

Apressuresensorisadeviceorinstrumentwhichisabletomeasurethepressureingasesorliquids.

Pressuresensorscanalsobeusedtoindirectlymeasureothervariablessuchasfluid/gasflow,speed,waterlevel, and altitude.

TemperatureandlightSensors

Temperaturesensor

Atemperaturesensorisadeviceusedtomeasuretemperature.

Thesensorismadeup oftwometals,whichgenerateelectricalvoltageorresistanceonceitnoticesachangein temperature.

Eg.Thermocouple(asensormadeupoftwowireswithtwodifferentmetalsconnectedattwopoints.Thevoltage between the two wires reflects the change in temperature.)

Lightsensor

Thelightsensorisadevicethatconvertsthelightenergyintoanelectricalsignaloutput.Lightsensorsaremore commonly known asPhotoelectric Devices or Photo Sensors because they convert light energy (photons) into electronic signal (electrons).
Photoelectricsensorsuseabeamoflighttodetectthepresenceorabsenceofanobject.

Unit3:ACTUATORS-MECHANICAL,ELECTRICAL

Actuatorsproducephysicalchangessuchaslinearandangulardisplacement.

MechanicalActuators

Mechanicalactuatorsaredevicesthattransformmotionfromoneformtosomeotherrequiredform,

Fore.g.theymighttransform linearmotionintorotationalmotion,orperhapsalinearreciprocatingmotioninto rotarymotion

Machine,KinematicLink,KinematicPair

Machine

Itisanapparatusforapplyingmechanicalpower,consistingofanumberofinterrelatedpartseachhavingadefinite function.

Or

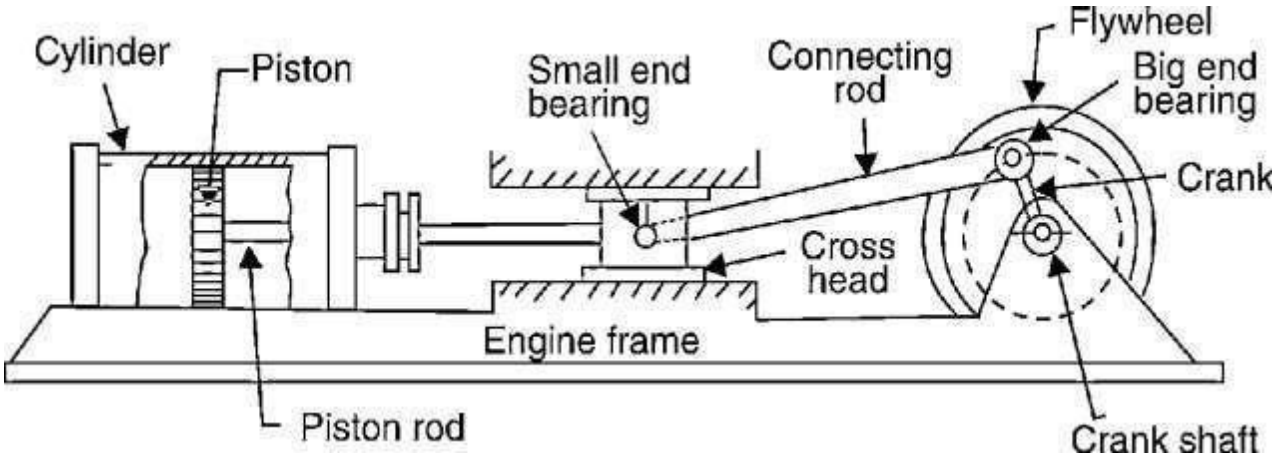
ltisadevicebymeansofwhichavailableenergycanbeconvertedintodesiredformofuseful work.

AMachineistheassemblyofresistantbodieswhoserelativemotionsare successfullyconstrainedsothatavailable energy can be converted into useful work

Kinematiclink

itisaresistantbodyoranassemblyofresistantbodieswhichmakeapartorpartsofamachineto connectwith other parts which have motion 'relative' to it.

Akinematiclinkisassumedtobecompletelyrigid.



ReciprocatingSteamEngine

Piston,pistonrodandcrosshead...onelink.
- Connectingrodwithbigandsmallendbearings...secondlink.
- Crankshaftandflywheel...thirdlink.
- Cylinder,engineframe...fourthlink.

Characteristicsofalink.
Alinkshouldhavetwocharacteristics:

1. Itshouldhaverelativemotion.
2. Itmustbearesistantbody(neednotberigidbody).

Typesoflinks:
Thevarioustypesoflinksare:

1. **Rigid link**-Alinkwhichdoesnotundergoanydeformationwhiletransmittingmotion iscalleda"rigidlink". Strictly speaking, rigid links do not exist

2. **Flexiblelink**-Aflexiblelinkinonewhichispartlydeformedin amannernottothetransmission ofmotion.
Example: Belts, ropes, chains and wires (these link transmit tensile forces only).

3. **Fluid link-**Afluidlinkisonewhichisformedbyhavingafluidinreceptacle&themotionistransmittedthrough the fluid by pressure or compression only
Example:Hydraulicpresses,jacksandbrakes.

KinematicPair

Akinematicpairisajointoftwolinksthatpermitsrelativemotion.
Therelativemotionbetween theelementsorlinksthatformapairisrequiredtobecompletelyconstrainedor successfully constrained.

Completelyconstrainedmotion-Whenthemotionbetweenapairislimitedtoadefinitedirectionirrespectiveofthe direction of force applied, then the motion is said to be a completely constrained motion.

Examples:Themotionofasquarebarinasquareholeandthemotion ofashaftwithcollarsateach endarethe examples of the completely constrained motion.
Themotionofthepistonandcylinder,(formingapair)inasteam engineinwhichthemotionofthepistonislimited to a definite direction (i.e., it will only reciprocate) isalso anexample of completely constrained motion.

Successfullyconstrainedmotion-Themotionissaidtobesuccessfullyconstrainedwhenthemotionbetweenthe elements, forming a pair, ---is such that constrained motion is not completed by itself, but by somemeans.

Fore.g.theloadisplacedontheshafttopreventaxialupwardmovementofthe shaft,thenthemotion ofthepairis said to be successfully constrained.

Classificationof kinematicpairs:

1. Classificationbasedonnatureofrelativemotionbetweentheelements:

(i) **Slidingpair**-Iftwolinkshaveaslidingmotionrelativetoeachother,theyformaslidingpair.
Examples.Pistonandcylinderpair,rectangularrodinrectanglehole

(ii) **Turningpair**.-Whenonelinkhasturningorrevolvingmotionrelativetotheother,theyconstituteaturningor revolving pair.
Examples.Ashaftrotatinginabearing,Rotationofacrankinaslidercrankmechanismisanotherturningpair.

(iii) **Rollingpair-**Whenthelinksofapairhavearollingmotionrelativetoeach other,they form a rolling pair.
Examples.Ballandrollerbearings.Inaballbearing,theballandtheshaftconstituteonerollingpairwhereastheball and the bearing is the second rolling pair.

4. **Screw(orhelical)pair**-Whenthetwoelements of apair areconnectedin such awaythatoneelementcanturn about the other by screw threads, the pair is known as 'screw pair'.
Example.Nutandboltarrangement

5. **Sphericalpair**-Whentwoelementsofapairareconnectedin suchawaythatoneelementwithsphericalshape turns about the other fixed element; the pair formed is called a ‘spherical pair'.
Examples.Theballandsocketjoint,attachmentofacarmirror

2. Classificationbasedonthenatureofcontactbetweenelements:

(I)Lowerpairs(II)Higherpairs.

(i**)Lowerpair**-Ifapairinmotionhasasurfacecontactbetweenitselementsitiscalledalowerpair.
Eg.shaftrotatinginabearing

(II**)Higherpair**-In ahigher pairthereisalineorpointcontact betweentheelementsof apair.Thecontact surfaces of the two elements are not alike or similar.
Examples.toothedgearing,beltandropedrives,camandfollower,ballandrollerbearings

3. Classificationbasedonthenatureofmechanicalconstraint:

(i) Closedpairs(ii)Unclosedpairs.
(i) **Closedpairs**-Iftheelementsofthepair,areheldtogethermechanically,theyconstitutea'closedpair'.
Examples. All lower pairs.

(ii) **Unclosedpairs**-ifthetwoelementsarenotheldtogethermechanically,itformsan‘unclosedpair'.
Example. Cam and follower pair

Mechanism, SlidercrankMechanism

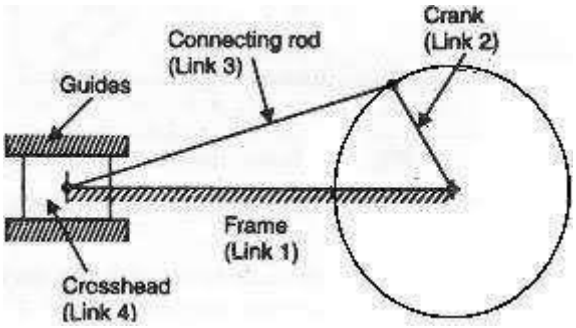
Mechanism
Whenoneofthelinksofakinematicchainisfixed,thechainisknownasmechanism.

Mechanismsareoftwotypes:
Simplemechanism-Amechanismwith/ourlinksisknownassimplemechanism.

Compoundmechanism-Themechanismwithmorethanfourlinksisknownascompoundmechanism.Itmay be made by adding two or more simple mechanisms.

SlidercrankMechanism
Itconsistsofoneslidingpairandthree turningpairs.Itis,usually,foundin reciprocatingsteamenginemechanism. This type of mechanism converts rotary motion into reciprocating motion and vice versa

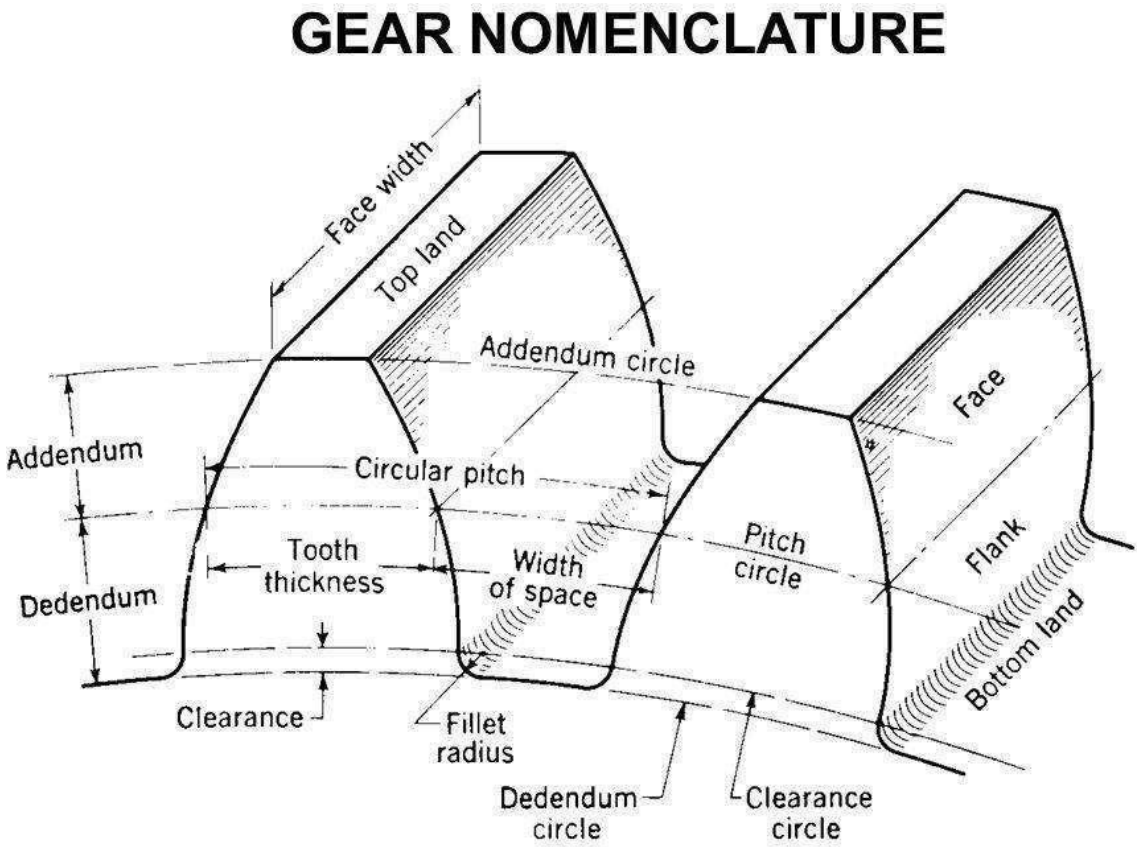
Inasingleslidercrankchain,thelinks1and2,links2and 3and links3and 4formthreeturningpairswhilelinks4 and 1 form a sliding pair'



GearDrive,Spurgear,Bevelgear,Helicalgear,wormgear

Agearisawheelprovidedwithteethwhichmeshwiththeteethon anotherwheel,orontoarack,soas togivea positive transmission of motion from one component to another.

Gears constitute the most commonly used device for power transmission or for changing power-speed ratios in a powersystem.Theyareusedfortransmittingmotionandpowerfromoneshafttoanotherwhentheyarenottoofor apart and when a constant velocity ratio is desired.



1. **Pitchcircle**-Itisanimaginarycirclewhichwouldtransmitthesamemotionastheactualgear,bypurerolling action. Thediameterofthepitchcircleisknownaspitchcirclediameter.

2. **Addendumcircle**-Acircleconcentricwiththepitchcircleand boundingtheouterendstotheteethiscalledan addendum circle.
Thediameteroftheaddendumcircleisknownasaddendumcirclediameter.

3. **Addendum**-Itistheradialdistancebetweenthepitchcircleandaddendumcircle.

4. **Dedendum(Orroot)circle**-Itisacircleconcentricwiththepitchcircleandboundingthebottomofthetooth.

5. **Dedendum**.-Itistheradialdistancebetweenthepitchcircleandthededendumcircle.

6. **Clearance**.Thedifferencebetweenthededendum(ofonegear)andaddendum(ofthematinggear)iscalledas clearance.

7. **Workingdepth**-Itisthesumoftheaddendaofthetwomatinggears.

8. **Circularthickness(orThicknessoftooth**)-Thelengthofarcbetweenthesidesofageartooth,measuredonthe pitch circle is known as circular thickness (or thickness of tooth).

9. **Toothspace**-Itisthewidthofthespacebetweentwoadjacentteethmeasuredalongpitchcircle.

10. **Backlash**-Itisthedifferencebetweenthetoothspaceandthetooththickness.

11. **Face**-Itistheactionorworkingsurfaceoftheaddendum.

12. **Flank**-Theworkingfaceofthededendumiscalledtheflank.

13. **Topland**-Itisthesurfaceofthetopofthetooth.

14. **Bottomland**-Itisthesurfaceofthebottomofthetoothspace.

15. **Wholedepth**-Itisthetotaldepthofthetoothspace,equaltoaddendumplusdedendum;alsoitisequal tothe working depth plus clearance

16. **Toothfillet**-Itistheradiuswhichconnectstherootcircletothetoothprofile.

17. **Circularpitch**.Thedistancemeasuredalongthepitchcirclefromapointononetoothtothecorrespondingpoint on an adjacent tooth is called circular-pitch.

$p=\pi d/z$

Thatis,thecircularpitchiscalculatedbydividingthepitchcirclecircumferencebythenumberofteeth.

18. **Pitchdiameter**-Itisthediameterofapitchcircle.

19. **Diametralpitch**.Numberofteeth onawheelperunitofitspitchdiameteris called
the diametral pitch.

diametral_pitch**=**Numberofteethonthewheel**/**Diameterofthepitchcircle

20. **Module-**Itisthereverseofthediametralpitch.Ratiobetweenthepitchdiameter and
the number of teeth is known as module

Typesofgears:
Thetypesofgeararediscussedbelow:

1. Spurgear-Aspurgearisagearwheelorpinionfortransmittingmotionbetweentwoparallel shafts.
It is the simplest form of geared drive.

Theteetharecastormachinedparallelwiththeaxisofrotation ofthegear. The
efficiency of power transmission by these gears is very high

Thedisadvantagesarethattheyareliabletobemorenoisyinoperationandmaywearout

2. Helicalgear-helicalgearisoneinwhichteethinstead,ofbeingparallelwith shaftasinordinaryspurgears,are inclined.
This ensures smooth action.

3. Bevelgear-Abevelgeartransmitsmotionbetweentwoshaftswhichintersect.

Iftheshaftsareatrightanglesandwheelsequalinsize, theyarecalledmitregears; If the

shaftsare not at right angles, they are sometimes called angle bevel gears.

Spiraltoothedbevelgearsarepreferredtostraight-toothedbevelsincertainapplications, becausetheywillrunmore smoothly and make less noise at high speeds.

4. Wormgear-Wormgearsconnecttwonon-parallel,non-intersectingshaftswhichareusuallyatrightangles.Oneof the gears is called worm .it is essentially part of a screw meshing with the teeth on a gear wheel, called "worm wheel".
Wormgearingissmoothandquiet.

Belt&Beltdrive

Abeltisacontinuousbandofflexiblematerialpassingoverpulleystotransmitmotionfromoneshafttoanother.

Beltsareavailable:
1. withanarrowrectangularcross-section-Flatbelts
2. withatrapezoidalcross-section-V-belts
3. Roundcross-section-Roundbelts

Flatbelts:
Flatbeltsareusedfortheirsimplicityandbecausetheyaresubjectedtominimum bendingstressonthepulleys.The load capacity of flat beltsis varied by varying their width, and only one is used in each drive.

Theyaremadeofleather,rubber,textile,balataandsteel.

V-belts:
AV-beltisabeltoftrapezoidalsectionrunningonpulleyswithgroovescuttomatchthebelt.Thenormalangle between the sides of the groove is 40 deg.
V-beltsareusuallymadeoffabriccoatedwithrubber
Theyareusedwhenthedistancebetweentheshaftsistooshortforflat-beltdrives;
TheV-beltislesslikelytoslip,hencemorepowercanbetransmittedforthesamebelttension.

Roundbelts
Theseareemployedtotransmitlowpower,mainlyininstruments,machineryoftheclothingindustryandhousehold appliances.
Theymaybemadeofleatherandrubber.Thediameterrangeisfrom3to12mm,usually from4to8mm.

Beltdrive:
Abeltdriveconsistsofthedrivinganddrivenpulleysandthebeltwhichismounted onthepulleyswith acertain amount of tension

Beltdrivesmaybe:

(I)Openbeltdrive
(II)Crossedbeltdrive.

Openbeltdrives-areapplied,betweenparallelshaftswhichrotateinthesamedirection.Herethebeltissubjectto tension ‘and bending.

Crossedbeltdrives- the power istransmitted between small shaftsrotating opposite direction. Since the angle of contactinthistypeofdriveismore,itcantransmitmorepowerthanopenbeltdrive.Howeverthereismorewear and tear of the belt in this drive.

Applicationsof beltdrives:
Themainapplicationsofbeltdrivesare:
(I)Totransmitpowerfromlowormediumcapacityelectricmotorstooperativemachines.
(ii) Totransmitpowerfromsmallprimemovers(internalcombustionengines)toelectricgenerators,agriculturaland other machinery.

Bearings

Abearingisadevicewhichsupports,guidesandrestrainsmovingelements.
Thematerialusedforbearingiscommonlycast-ironforslowspeeds,bronzeorbrassliningbeingfittedforhigher steels.
Whitemetalorantifrictionmetalis usedasalining forthebronze,oritmay be helddirectlyinthecast-ironorinthe steel of a connecting rod.

ClassificationofBearings
Bearingsmaybeclassifiedasfollows

1. Plainbearings:
(a) Journalbearing.
(b) Pivotbearing
(c) Collarorthrustbearing.

2. Ballandrollerbearings.

Plainbearings

Ajournalbearingisonein whichthebearingpressureisperpendiculartotheaxisoftheshaft.Theportionofthe rotating element which is in contact with the bearing is called journal.

Apivot bearingisoneinwhichthepressureisparallel totheaxisoftheshaftandtheendoftheshaftrestsonthe bearing surface.

In**collarbearing** thepressureisparalleltotheaxisoftheshaft,whichispassed andextendedthroughthebearings. These bearings are employed to take up unbalanced axial loads on the horizontal Shaft

Ballandrollerbearings
arealsoknownasrollingcontact bearingsorrollingelementbearingsbecausethebearingelementsespecially arein a rolling contact.
Sometimestheseareal soreferredtoas“antifrictionbearings”,throughsomefrictionisalwayspresentowingto rolling resistance between the balls/rollers and contacting parts etc.
Thestartingfrictioninballandrollerbearingsislowerthan thatinanequivalentjournalbearingin which metal-to-metal rubbing takes place at the time of starting.
Theballandrollerbearingsarealsoquitesuitableatmoderatespeedsbutathighspeedsitisfoundthataproperly designed and lubricated journal bearing has less friction.

Electricalactuator

Anactuatorreceivingelectricalenergyformotioniscalledanelectricalactuator.

Designsforelectricactuatorsarebasedonthespecifictaskstheyaccomplishandtheycanvaryinbothdimension and size.

Most electricactuatorsoperate through theinteraction ofmagneticfieldsandcurrent-carryingconductorsto generate force.

Electricactuatorsarefoundinapplicationsasdiverseasindustrialfans,blowersandpumps,machinetools, household appliances.

Switchesandrelay

Switches

Aswitchisanelectromechanicaldeviceusedtomakeorbreakthecircuits.

Switches can be controlled mechanically.

It controls the flow of current by opening or closing of circuits.

Theyareoperatedmanuallybyaleverorbypushingthebuttons.

Itoperatesslowlywhencomparedtorelaybecauseitrequiresaphysicalobjecttomakethechanges.

Example: Manual control of switch (Physical control of fans & lights at Home)

An electric switchisadevicethatinterruptstheelectronflowinacircuit.Circuitsconsist ofasourceofpowerand load. Aload is a power-powered device. The function of an electric switch istoregulate the current between the load and source of power. The power source is the electrons that push through the circuits. The voltage is the quantity of force or pressure applied by the power source. Power sources must have a negative and positive endpoint. The negative terminal connects to the charge, and the electrons drive through the circuit. The load receivesthecurrentandreturnsitviathepositiveterminaltothepowersource.Theelectricalswitchisinsertedin thisloop.

Relay

Arelayisbasicallyjustaswitch,butit'saswitchoperatedviaremotecontrol. Relays

can be controlled electronically.

Itcontrolshighpowercircuitswithlowpower signalsby openingorclosingthecontacts. It is

used to protect the system from damage.

Itoperatesfasterthantheswitches. It

is a remote control switch.

Example:ToturnON/OFFanAirConditioner

Relayworksontheprincipleofelectromagneticinduction.When theelectromagnetisappliedwithsomecurrentit inducesamagnetic field around it. In the relay, Copper coil and the iron core actsas an electromagnet.

Whenthecoilisappliedwith DCcurrentitstartsattractingthecontactasshown.Thisiscalledenergizingofrelay. When

the supply isremoved it retrievesback to the original position. Thisiscalled De energizing of relay.

Solenoid

A "solenoid" consistsof a coil and a movable iron core called the armature. When the current is passed through the coilitgetsenergizedandconsequentlythecoremovestoincreasethefluxlinkagebyclosingtheairgapbetweenthe cores. The movable core is usually spring-loaded to allow the core to retract when the current is switched off. The forcegeneratedisapproximatelyproportionalto the squareofthecurrentandinverselyproportiontothesquareof the width of the air gap.

Theyarefrequentlyusedin:
- Homeappliances
- Automobiles
- Factoryautomation.

D.CMotors

Adirectcurrent(DC)motorisatypeofelectricmachinethatconvertselectricalenergyintomechanicalenergy.Dc motors take electrical power through direct current, and convert this energy into mechanical rotation.

DCmotorsusemagneticfieldsthatoccurfromtheelectricalcurrentsgenerated,whichpowersthemovementofa rotor fixed within the output shaft. The output torque and speed depends upon both the electrical input and the design of the motor.

DCmotorscanvaryin sizeandpowerfromsmallmotorsin toysand appliancestolargemechanismsthatpower vehicles, pull elevators and hoists, and drive steel rolling mills.

DCmotorsincludetwokeycomponents:a**stator**andan**armature**.Thestatoristhestationarypartofamotor,while thearmaturerotates.InaDCmotor,thestator providesarotatingmagneticfieldthatdrivesthearmaturetorotate.

WORKING

AsimpleDCmotor usesa stationaryset ofmagnetsinthestator, and acoil ofwirewitha currentrunningthroughit to generate an electromagnetic field aligned with thecentre of the coil. One or more windings of insulated wire are wrapped around the core of the motor to concentrate the magnetic field.

Thewindingsofinsulatedwireareconnectedtoacommutator(arotaryelectricalswitch),thatappliesanelectrical current to the windings. The commutator allows each armature coil to be energized in turn, creating a steady rotating force (known as torque).

Whenthecoilsareturnedonandoffinsequence,arotatingmagneticfieldiscreatedthatinteractswiththediffering fields of the stationary magnets in the stator to create torque, which causes it to rotate. These key operating principles of DC motors allow them to convert the electrical energy from direct current into mechanical energy through the rotating movement, which can then be used for the propulsion of objects.

TypesofDCMotors

- **BrushlessDCmotors**arealsoknown aselectronicallycommutated motors,orsynchronousDCmotors.

ThekeydifferencesbetweenbrushlessDCmotorsandothervarietiesisthattheydonothaveacommutator,which is replaced by an electronic servomechanism that is able todetect and adjust the angle of therotor.

The**brushlessDCmotor**hasseveraladvantages.Commutatorsusesoftcontactscalled‘brushes’whichweardown over time. A brushlessDC motor istherefore more durable, and also safer than themore classical design.

- The**brushedDCmotor** istheoriginalDCmotor.Theclassicbrushedmotorfeaturesacommutator,to reverse the current every half cycle and create single direction torque.

WhilebrushedDCmotorsremainpopularforelectricalpropulsion,cranes,papermachines,andsteelrollingmills, many have been phased out for the more efficient brushless model in recent years.

- A**DCshuntmotor**isavariety ofbrushedmotorthathasthefieldwindingsconnectedinparallelwiththe armature. Shunt wound DC motors have a lower current because of the parallel windings.

Ashuntmotorisusedforapplicationsthat requireaconstant torque,wheretheloadisnotsignificantlyalteredby speed, such as conveyor belts, mixers and hoists.

Thespecificfieldwindingsprovideuniqueshuntmotorcharacteristicsthatmakeit suchaneffectivechoicefor constant torque applications.

ApplicationsofDCmotors

At home, small DC motors are used in tools, toys and various household appliances. In retail, the applications of DC motorsincludeconveyors andturntables,whileinanindustrialsetting,largeDCmotoruses alsoincludebrakingand reversingapplications.

A.CMotors

An AC motor is an electric motor that uses alternating current to produce mechanical energy using magnetism blendedwithalternatingcurrent.ThestructureofanACmotorincludescoilsthatproducearotatingmagneticfield inside a rotor attached to an output shaft, which produces a second magnetic field.

WORKING

The main componentsof an ACmotor arethe stator,stationary outer drum,and the rotor,therotatinginner portion attachedto themotor shaft. Thestatorandtherotor producerotatingmagneticfields.Thewinding ofthestatorthat creates the rotating field is created by alternating current.

InanACmotorthewindingservesasthearmatureandfieldwinding.Whenthestatorisconnected toan ACsupply flux an air gapisformed rotating the fluxat a fixed synchronous speed, which producesvoltagesin the stator and rotor winding.

The term AC motor describes several versions of the motor, which include single phase, three phase, brake, synchronous, asynchronous, customized, two speed, and three speed single phase. The difference between the variousversionsrelatestothetypeofworkthatisrequiredwheresomeformsofACmotorsaresimpleandusedfor small jobswhile other versionsare designed for biggermore demanding work. Akey difference is the phase of the electrical feed, which is different for residential use compared to industrial use.

Residentialelectricityissingleordoublephasedwhileelectricityforindustrialuseisthreephased.Thisdistinctionis the reason for the difference between industrial AC motors and residential ones.

ACmotorsarereferred toasinductionmotorssincetheyuse electriccurrenttoproduce torque,whichiscreated by electromagnetic induction from the magnetic field of the stator

The stator produces a rotating magnetic field. It has a solid metal axle, a loop of wire, coils, squirrel cage, and interconnections.ThoughasquirrelcageisnotfoundinallACmotors,itisthemostcommontype.InACmotors, electricity issent directly to the outer coils of the stator. The stator hasmultiple plates that extend out from its center with copper magnetic wire.

ForathreephaseACmotor,ithasthreephasewindingswith acoreandhousing.Thewindingsare120oapart,which can be six or twelve windings. The windings are placed on a laminated iron core.

Unlike aDC motor, therotoron anAC motor does not haveany connectionwith theexternal powersource. It receivesitspowerfromthe stator.Inathreephaseinductionmotor,therotorcan beasquirrelcageorwound version.

In the squirrelcageversion, therotorconsists ofrotorbarswithendrings atbothends.In themajorityofcases, the squirrelcageismadeofaluminumorcopper.Intheoperation ofasquirrelcagemotor, thebarsoftherotorinteract with the stator'selectromagneticfield(EMF). Asthecurrentfluctuates,theEMFdoesthe samecausingtherotor to rotateproducingrotationalmotion.Akeyfactorinthemotion isthat therotordoesnot turnat the samefrequency as the ACcurrentandisconstantly trying tocatchup, whichis howtherotationis produced. If it didhave thesame frequency, the rotor would freeze, and there would not be any motion.

A wound or slip ring AC motor is a special type of AC motor. It containsthe exact same parts asall AC motors but is always threephase. Thecylindricallaminatedcore of therotoris woundexactlylikethewindingsonthestatorwith wire. Theterminalendsofthewiresareconnectedtoslipringsontheoutputshaft.Theslipringsconnecttobrushes and avariablespeedresistor. Thesliprings providecontrolof thespeedandtorque of themotor, whichis themain positive feature of a wound rotor.

Types of AC Motors

SinglePhaseACMotor

SinglephaseACmotorsareusedwherethereisasinglephasesupply.ThistypeofACmotorissmallerandless expensive. They areconstructed usingfractional kilowattcapacity. The stator isactivated by asingle phaseAC electricalsupply. Unlike athree phase ACmotor,asinglephase motor hasonemain winding and one auxiliary winding, which is perpendicular to the main winding.

Therotorrotatesaccordingtothesumoftwooppositelyrotatingfields,whichisthedoublerevolvingfieldtheory. The torque that is produced is equal and opposite.

PolyphaseACMotor

PolyphaseMotors, ormanyphasemotors, area typeofACmotorthatcanbetwoorthreephaseandaresimilarto single phase motors in how they operate. The stator poles in a polyphasemotor are not aligned with each other, whichmeans that the rotor passes by the stator poles at different times. Apolyphase system hasa group of equal voltages at the same frequency that are placed to have an equal phase difference between the adjacent electromagnetic fields (EMF). A polyphase system can be two, three, or six phase with the majority being three phase.

SynchronousACMotor

A synchronous AC motor is where the rotation of the shaft is at the same frequency as the current supply with the rotationperiodbeingequaltotheintegralnumberofACcycles. Thesynchronousspeedisconstantandatwhichthe motor generates electromotive force.

Thespeed ofasynchronousmotor isindependentoftheload wherevariationsintheload doesnot affectthespeed of themotor. Synchronousmotorsare notself-starting,which isunlike self-startingmotorswhere the power supply is connected directly to the stator.

AsynchronousMotor

An asynchronousmotoruses aninducedcurrentinitsrotorto producerotatorymotion. Thisis themostcommonof theACmotorssinceitreliesonACcurrentthatisconnectedtothestatorforitspowersupply. Allofthepowerforan asynchronous motor is connected to the stator, none of which is connected to the rotor. The power for the rotor comes from induction.

Theinductionfortherotorisduetoitscloseproximitytothestatorselectromagneticfield,whichcausestherotorto generate its own electromagnetic field that causes it to spin. Since there aren't any brushes or slip rings, an asynchronous motor is the most efficient and reliable of all of the AC motors. It is used for heavy duty applications because of its simplicity of design and ruggedness.

StepperMotors

Asteppermotorisanelectromechanicaldeviceitconvertselectricalpowerintomechanicalpower.

Thesteppermotorusesthetheoryofoperationformagnetstomake themotorshaft turnaprecisedistancewhena pulse of electricity is provided.

The**construction ofasteppermotor**isfairlyrelatedtoaDCmotor.Itincludesapermanentmagnetlike Rotorwhich is in themiddle & it will turn once force acts on it. Thisrotor isenclosed through a no. of the stator which iswound throughamagneticcoil alloverit.Thestatoris arrangednear torotor sothatmagneticfieldswithin the stators can control the movement of the rotor.

Thesteppermotorcan becontrolledbyenergizingeverystator onebyone.Sothestatorwillmagnetize&workslike an electromagnetic pole which uses repulsive energy on therotor to move forward. The stator's alternative magnetizing as well asdemagnetizing will shift the rotor gradually &allowsit to turn through great control.

The **stepper motor working principle** is Electro-Magnetism. It includes a rotor which is made with a permanent magnetwhereasastatoriswithelectromagnets. Oncethesupplyisprovidedtothewindingofthestatorthenthe magnetic field will be developed within the stator. Now rotor in the motor will start to move with the rotating magnetic field of the stator.
Inthismotor, thereisasoftiron thatisenclosedthroughtheelectromagneticstators.Thepolesofthestatoraswell as the rotor don't depend on the kind of stepper. Once the stators of this motor are energized then the rotor will rotate to line up itself with the stator otherwise turns to have the least gap through the stator. In this way, the stators are activated in a series to revolve the stepper motor.

TypesofStepperMotor

Therearethreemaintypesofsteppermotors,theyare:

- Permanentmagnetstepper
- Hybridsynchronousstepper
- Variablereluctancestepper

PermanentMagnet StepperMotor

Permanent magnet motors use a permanent magnet (PM) inthe rotor and operate onthe attractionor repulsion between the rotor PM and the stator electromagnets.

Thisisthemostcommontypeofsteppermotor. Thismotorincludespermanentmagnetsintheconstructionofthe motor. The main benefit of this stepper motor is less manufacturing cost.

VariableReluctanceStepperMotor

Variablereluctance (VR) motorshave a plain iron rotor andoperate based on theprinciple that minimumreluctance occurswith minimum gap, hence the rotor points are attracted toward the stator magnet poles.

Thesteppermotorlikevariablereluctanceisthebasictypeofmotor

HybridSynchronousStepper Motor

Hybrid stepper motors are named because they use a combination of permanent magnet (PM) and variable reluctance (VR) techniques to achieve maximum power in small package sizes.

Themostpopulartypeofmotoristhehybridsteppermotorbecauseitgivesagoodperformance.But,thistypeof stepper motor is expensive as compared with permanent magnet stepper motors.

Specificationandcontrolofsteppermotors

- Size:42.3mmsquare×48mm
- Weight:350g
- Shaftdiameter:5mm
- Stepsperrevolution:200
- Currentrating:1.2Aper coil
- Voltagerating:4V
- Resistance:3.3Ωper coil
- Holdingtorque:3.2kg-cm
- Inductance:2.8mHper coil
- Leadlength:30cm
- Outputshaftsupportedbytwoballbearings

Steppermotorcontrolprovidesthisinputtrainofpulsestocommandthemotortomovetothedesiredpositionorat the desired speed.

Steppermotorcontrolconstantvoltagedrivesareusedtoapplyaconstantpositiveornegativevoltagetoeach winding to drive motion.

ServoMotorsD.C&A.C

A **servo motor** is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motorstorotatewithgreatprecision.Ifyouwanttorotateanobjectatsomespecificanglesordistance,thenyou use a servo motor. It is just made up of a simplemotor which runs through a **servo mechanism**.

Ifmotoris poweredbyaDC powersupply thenitis calledDC servomotor, andifitis AC-poweredmotorthenitis called AC servo motor.

ServoMotorWorkingMechanism

Itconsistsofthreeparts:

1. Controlleddevice
2. Outputsensor
3. Feedbacksystem

It is a closed-loop system where it uses a positive feedback system to control motion and the final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output signal and reference input signal.

Here reference input signal is compared to the reference output signal and the third signal is produced by the feedback system.And thisthirdsignal actsasaninput signalto thecontrolthedevice.Thissignalispresentaslong as the feedback signal is generated or there is a difference between the reference input signal and reference output signal. So the main task of servomechanism is to maintain the output of a system at the desired value at presence of noises.

A servo consists of a Motor (DCor AC), a potentiometer,gear assembly, and a controlling circuit. First of all, we use gear assembly to reduce RPM and to increase torque of themotor. Say at initial position of servomotor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Now the difference between these two signals, one comes from thepotentiometer and another comes from other sources, will be processedinafeedbackmechanismandoutputwillbe providedin termsof error signal.Thiserror signal acts as the input for motor andmotor starts rotating. Nowmotor shaft is connected with the potentiometer and as the motorrotatessothepotentiometeranditwillgenerateasignal.Soasthepotentiometer'sangularpositionchanges, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the outputofpotentiometerissameasexternalsignalprovided.Atthiscondition,therewillbenooutputsignalfromthe amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer, and in this situation motor stops rotating.

DifferencebetweenACServoMotorandDCServoMotor

Characteristics	ACServoMotor	DCServoMotor
Efficiency	Low(about5-20%)	High
Speed&Torque	Adaptabletostrongtorqueandhigh-sped working condition.	Adaptabletoalimitedtorqueandspeed.
Stability	Lessstabilityissues	Moreproblemsofstability
Noise	Noradiofrequencynoise	Brushescauseradiofrequencynoise
Operation	Havestableandsmoothoperation	Noisyoperation
Weight&Size	Lighterweightandsmallinsize	Heavyweightandlargeinsize
Repair &Maintenance	Sincenocommutators,Lessmaintenanceis required	Becauseofcommutationprocess,regular maintenance is needed.
OutputPower	Deliverlowpowernormallybetween0.5Wand 100W	Providehighpower

Unit4:PROGRAMMABLELOGICCONTROLLERS(PLC)

Introduction

A PLC is an industrial computer that has been adapted for the control of manufacturing processes, such as assemblylines,machines,roboticdevices,oranyactivitythatrequireshighreliability,easeofprogramming,and process fault diagnosis.

Advantages

PLCincreasesthereliability,flexibility,andaccuracyoftheautomationsystem.

PLChasalowercostassociatedwithitascomparedtotheotherautomationtechnology.

PLChasgoodcapabilitiesandflexibilityforprogramming.Even,youcaneasilymakethemodificationinthe existing program at any time.

ProgrammingusedforPLCiseasytowriteandunderstand.

PLCdoesnottakemuchspace.Itoccurssmallerinsize,especiallycompactPLC. Fast

operation

PLChaslowmaintenanceassociatedwithit.

InthePLCsystem,werequirelessandsimplewiringascomparetotheothersystems. One can

easily make the changes in an already implemented design.

InthecaseofPLCdesign,ifanythinggoeswrong,onecaneasilytroubleshoottheproblem. It can

sustain in a robust environment with less maintenance.

SelectionandusesofPLC

Uses

1. IndustrialApplicationsof PLC-

TransportationSystemlikesConveyorBeltSystem.

Packing and Labeling System in Food & Beverage.

Automatic Bottle or Liquid Filling System.

PackagingandLabellingSysteminPharmaIndustries.

IndustrialCraneControlSystemforOperationofOverheadTravelingCrane. Glass

Industries for glass production and recording data.

PaperIndustriesfortheproductionofPages,BooksorNewspapers,etc.

CementIndustriesformanufacturingormixingtherightqualityandquantitiesofrawmaterials,andaccuracyof data regarding.

FaultDetectionandProtectionofIndustrialMachines

2. PowerStationApplicationsof PLC-

PLCisusedtoMonitorandDetectfaultconditions.

It is used in the Power Generation, Transmission, and Distribution System.

PLCusedinUndergroundCoalMineorWaterLevelSensingandDataSurvey.

3. Commercial Applications of PLC-

SmartTrafficControlSignalSystem.

Fire Detection and Alarm System.

Luggage Handling System.

SequenceorNumericalCountingandPackingSystem.

Mining Equipment Line Detection

SelectionofaPLC

ForselectionofaPLC,thefollowingcriterianeedtobeconsidered:

1. Typesofinputs/outputsrequired

2. lnput/Outputcapacityrequired.

3. Sizeofmemoryrequired.

4. SpeedandpowerrequiredforCPU

BasicInternalStructures

ThemaincomponentsofaPLCconsistofacentralprocessingunit(CPU),powersupply,programmingdevice,and input and output (I/O) modules.

CPU
TheCPUisthebrainofthePLCandcarriesout programmedoperations.Theseoperationsoroutputsareexecuted based on signals and data provided from connected inputs.

I/OModules
PLCinputmodulesconnectvariousexternaldevices, suchassensors,switches,andpushbuttonstothePLCto read various digital and analog parameters, such as temperature, pressure, flow, speed, etc.

OutputmodulesconvertsignalsfromtheCPUintodigitaloranalogvaluestocontroloutputdevices.

PLCProgrammingLanguage

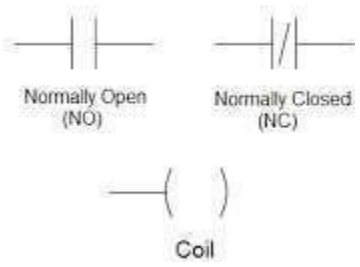
ThemostcommonmethodsofPLCprogrammingincludeLadderLogic,FunctionBlock,andstructuredtext.

LadderLogic

LadderLogicisagraphical PLCprogramminglanguageandisthemostcommonmethodofprogramming.Ladder Logic can be used to execute tasks such as sequencing, counting, timing, data manipulation, and more.

FortheLadderDiagram(LD)programminglanguage,normally openandnormallyclosedcontactisusedinthe form of input. And the coil or lamp is used in the form of output.

ThesymbolicrepresentationofIandOmodulesintheLDprogram.



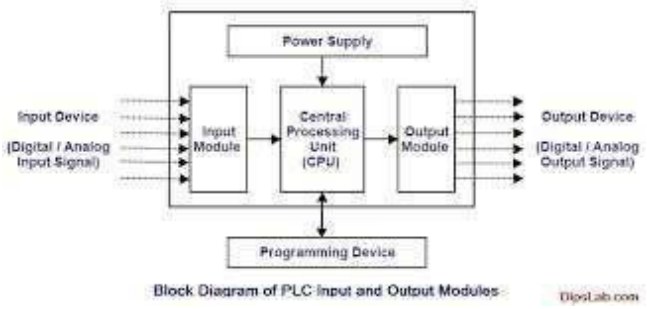
StructuredText

Structuredtextisatext-basedPLCprogramming.Programmingwithstructuredtexthasmultipleadvantages,such as the program requiring less space due to being text based instead of graphic based.

FunctionBlock

FunctionblockPLCprogramsarerepresentedintheformofgraphicalblocks.Functionblockscanhavestandard functions such as timers, counters, calculating min and max values, obtaining averages, and more.

Input/OutputProcessing&Programming



Block Diagram of PLC Input and Output Modules

Theinputdeviceprovidesasignaltoaninputmodule.Thisinputmoduleisconnectedwiththe CPUfortheinitial automated processes. CPU processes all the input data.

AfterprocessingbyCPU,itgivesoutputdatatotheoutputmodule.Theoutputmoduleprovidesasignaltothe outputdevice.

Andthemainfunctionoftheprogrammingdeviceistochangeormonitorthe PLCprogramming.

ClassificationofPLCInputandOutputModules

Theclassificationofinputandoutput(I/O)modulesofPLCisbasedonthetypesofsignals.

1. DigitalI/OModule

ThedigitalmoduleisalsocalledDiscreteModule.
Inthismodule,theI/Osignalworkonthebinarysystemi.e.only0or1value. It is

useful in the ON or OFF condition.

2. AnalogI/OModule

TheanalogmoduleiscalledaContinuousModule.
Thisanalogsignalprovidesanyintermittentvaluebetweenthetwoextremelimits(initialtofinalrange)forthe analog input module.

Mnemonics

Mnemonicsarememorydevicesthat helplearnersrecalllargerpiecesofinformation, especiallyintheformoflists like characteristics, steps, stages, parts, etc.

Mnemoniccodeprovidesthesameinformation asladderdiagramandcanbetypeddirectlyonProgramming Console.

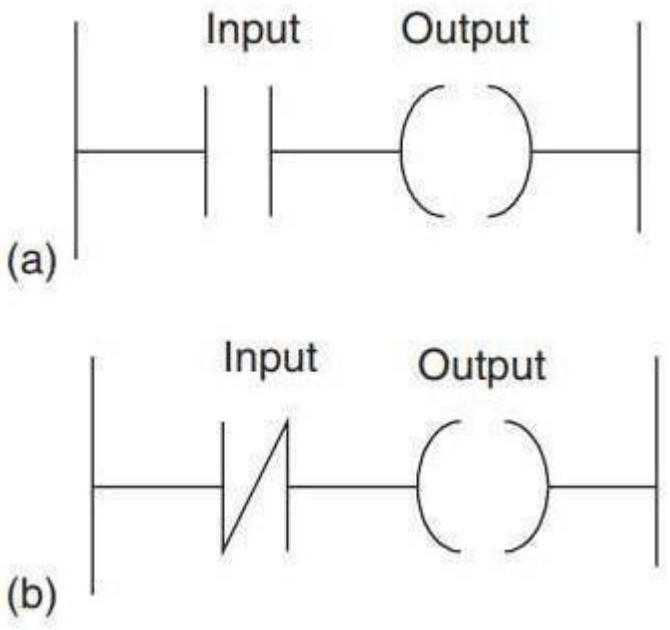
Therearealotofinstructionsusedtodevelop thePLCprogram.Eachinstructionhasa respectivefunction.

LD-LOADInstruction

Theseinstructionsareusedtostartalineoftheprogram.
Itisusedinthefirstcontactsinthenormallyopencondition(NO).

LDNOT-LOADNOTInstruction

Theseinstructionsareusedtostartalineoftheprogram.
Itisusedinthefirstcontactsinthenormallyclosedcondition(NC).

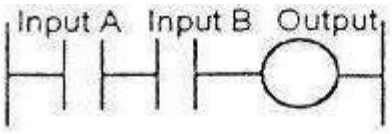


AND-ANDInstruction
Theseinstructionsareusedinthesecondcontactinanormallyopen(NO)anda series with previous contacts

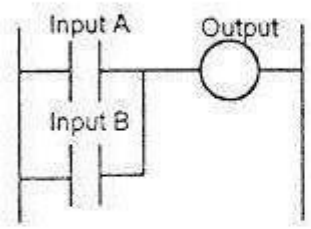
ANDNOT-ANDNOT Instruction
Theseinstructionsareusedinthesecondcontactinanormallyclosed(NC)andin series with previous contacts

OR-ORInstruction
Theseinstructionsareusedinthesecondcontactinanormallyopen(NO)andin line (parallel) with previous contacts**.**

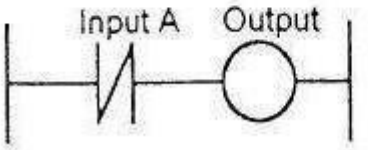
ORNOT-ORNOTInstruction
Theseinstructionsareusedinthesecondcontactinanormallyclosed(NC)andin line (parallel) with previous contacts



AND



OR



NOT

OUT-OUTPUTInstruction
Theseinstructionsareusedforthecoiloutput.

END
- ENDinstructionhas nophysicalcontactdevice.
- Itisthelastinstructionrequiredforcompletionofaprogram. If no
- END instruction, the program cannot be implemented

MasterandJumpControllers

Mastercontrolscanbethoughtofas"emergencystopswitches".

PLC manufacturers offer a form of amaster control relay as part of their instruction set. These instructions functioninasimilarmannertothehardwiredmastercontrolrelay;thatis,whentheinstructionistrue,thecircuit functions normally, and when the instruction is false, non-retentive outputs are switched off.

Jumpinstructioninladderlogicisusedtoskipsomeprocessorrungsaccordingtotherequirement

Whenthejumpinstructionisused,thePLCwillnotexecutetheinstructionsofarungthatisjumped

TheMCRinstructionsetsallnon-retentiveoutputstothefalse stateandkeepstheretentive outputs in their last state. The JMP instruction leaves all outputs in their last state.

Unit5:ELEMENTSOFCNCMACHINES

NC machines

Numericalcontrol,popularlyknownastheNCisverycommonlyusedinthemachinetools.

The numerical control machine is defined as the machine that is controlled by the set of instructions called as the program.

In numerical control method the numbers form the basic program instructions for different types of jobs; hence the name numerical control is given to this type of programming.

Whenthetypeofjobchanges,theprograminstructionsofthejobalsochange.

Itiseasiertowritethenewinstructionsforeachjob,henceNCprovideslotsofflexibilityinits use.

The NC technology can be applied to wide variety of operations like drafting, assembly, inspection, sheet metal working, etc. But it is more prominently used for various metal machining processes like turning, drilling, milling, shapingetc.

Due to NC all themachining operations can be performed at the fast rateresulting in bulk manufacturing becoming quite cheaper.

Thereare3typesofNCmachinesandareasfollows.

- **TraditionalNumericalControl(NCMachine)**
  Theycan run with the help of a tape reader system i.e. whatever the operation you want to perform,you can punch it on the tape, and therebythe NC machine can performthat operation.

- **ComputerNumericalControl(CNCMachine)**
  TheEvolutionoftheCNCmachinetakesplaceaftertheevolutionofNCmachines.Toovercomethe limitation of the NC machine, the CNC machine has come into the picture.

In the case of NC machines, the Tape Reader system is used, which after several usages,the wear and tearof the tape take place and the operator has to punch again on the newtape to carryout the operation.

In order to avoid this limitation of NC Machine, the CNC machine uses a computer-generated file to store the program which was written bythe usage of G-Codes and M-Codes.

Whatever operation you need to change like speed, feed, depth of cut, etc. can be changed in the program instantly and there is no damage to the file as of tape reader. This is the reason, CNC machines are used which are highly accurate compared to NC Machines.

- **DistributedNumericalControl(DNCMachine)**
  TheDNC Machineissimilar toCNCMachine, exceptaremotecomputer isused tocontrolno. ofmachines that can perform no. of operations at a time

ANCMachineisconsistbyfollowingparts:

1. MCUorCPU
2. DriveUnit
3. FeedbackDevices
4. TapeReadersystem
5. VeryFewManual Controls

MCU(MemoryControlledUnit):
MCU is the MemoryControl Unit that is taking the information fromthe input devices via the keyboard or mouse and analyze the data, and send the data to the output devices available in the NC machine.

DriveUnit:
Driveunitisa devicethatisused for convertingElectrical energyintoMechanical energywhich isrequired for traveling the axis.

FeedbackDevices:
Feedback deviceisaDisplacement MeasuringEquipment.MCUwill comparethedistancetraveled bytheaxiswith the distance to be traveled and determines the difference in distance.
TheMCUwillcalculatetheno.ofpulsesandsendittothedriveunit.Thisprocesscontinuesintheformofacycle. Feedback Device→MCU→Drive Unit.

TapeReaderSystem:
Theinstructionsfordoingoperationwaspunchedonthepapertape. Forreadingtheinstruction giveninthepunched paper tape, a **tape reader system** will be used.

Lightisprovidedononesideofthetapeandlightreceivingsensorsareplacedontheother side.
When the tape is moving and stopping at some location where the holes are present, the light is passing and is incident on lightreceiving sensors. Thesensors which arereceiving the light generatethe electrical pulseand that is to be sent to the MemoryControl Unit (MCU) to drive the motor ofa machine to dothe operation precisely.

VeryFewManualControls:
Even though the above parts are present in the NC machine, still the manual interventions are required for loading and unloading of the work piece, switching ON and OFF, etc. called manual controls.

CNCmachines

Computer Numerical Control (CNC) machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills

With a numerical control machine, programs are inputted via punch cards. By contrast, the programs for CNC machines are fed to computers through small keyboards. CNC programming is retained in a computer's memory. The code itself is written and edited by programmers.

The language behind CNC machining is alternately referred to as G-code, and it's written to control the various behaviors of a corresponding machine, such as the speed, feed rate and coordination.

FunctionsofCNC:
TheprincipalfunctionsofCNCare:
1. Machinetoolcontrol.
2. In-processcompensation.
3. Improvedprogrammingandoperatingfeatures.
4. Diagnostics.

AdvantagesofCNCmachines:
CNCmachinesofferthefollowingadvantagesin manufacturing:
1. Greaterflexibility.
2. Reduceddatareadingerror.
3. Increasedproductivity.

4. Consistentquality.
5. Automaticmaterialhandling.
6. Eliminationofoperatorerrors.
7. Reducedoperatoractivity.
8. Lowerlabourcost.
9. Smallerbatches.
10. Longertoollife.
11. Just-in-timemanufacture.
12. Reliableoperation.
13. Eliminationofspecialjigsandfixtures.
14. Reducedinspection.
15. Lessscrap.
16. Accuratecostingandscheduling.
17. CNCmachinecandiagnoseprogramandcandetectthemachiningmalfunctioning even before the part is produced.
18. Conversionofunits-possiblewithincomputermemory.

Disadvantages ofCNC machines:
1. Higherinvestmentcost.
2. Highermaintenancecost.
3. CostlierCNCpersonnel.
4. Air-conditionedplaces arerequiredfortheinstallationofthemachines.
5. Unsuitableforlongrunapplications.
6. Plannedsupportfacilities.

Applications ofCNC:
CNCisbeingusedinthefollowingmachines/areas:
Drilling machines.
Turningmachines.
Boringmachines. Milling machines.
Grindingmachines. Pipe bendingmachines. Coil winding machines.
Flamecuttingmachines.
Welding,wirecutEDMandseveralotherareas.

CAD/CAM

CAD/CAM(Computer-AidedDesign/Computer-AidedManufacture)technologywasinitiatedintheaerospace industry but presently it is spreading at a rapid pace in all industries.
Itcanbedefinedmost simply astheuseofcomputerstotranslateaproduct'sspecificrequirementsintothefinal physical product.

Withthissystem,aproductisdesigned,producedandinspectedinoneautomaticprocess.
Itplaysakeyroleinareassuchasdesign analysis,production planning,detailing,documentation,N/Cpart programming, tooling fabrication, assembly, jig and fixture design, quality control, and testing.

Wheneveranydeviationisnoted,aprogrammablecontrollertakesautomaticcorrectiveactiontocompensatefor the deviation. Thus a closed loop system is formed which produces consistent quality products, reduces wastes and increases productivity.

CAD/CAMsystemisideallysuitedfordesigningandmanufacturingmechanicalcomponentsoffreeformcomplex with three dimensional shapes

CAD

CAD(ComputerAidedDesign)isdefinedas:
Adesignprocessusingsophisticatedcomputergraphicstechniques,backedupwithcomputersoftwarepackages to aid in the analytical, development, costing and ergonomic problems associated with design work

Advantages:
ThefollowingareadvantagesofCAD:
1. Drawingscanbeproducedatafasterrate.
2. DrawingsproducedbyCADsystemsaremoreaccurateandneat.
3. Inthissystemthereisnorepetitionofthedrawings.
4. CADsystemsassimilateseveralspecialdraughtingtechniqueswhichare notavailablewithconventionalmeans.
5. Designcalculationsandanalysiscanbecarriedoutquickly.
6. WithCADsystemssuperiordesignformscanbeproduced.
7. CAD simulation and analysistechniquescandrasticallycutthe timeandmoneyspenton prototype testingand development - often the costliest stage in the design process.
8. UsingCADsystemsdesigncanbeintegratedwithotherdisciplines.

CAM

CAM(Computer-AidedManufacture)concernsanyautomaticmanufacturingprocesswhich controlled by computers.

ThemostimportantelementsofCAMare:
1. CNC manufacturingandprogrammingtechniques.
2. Computercontrolledroboticsmanufactureandassembly.
3. FlexibleManufacturingSystems
4. ComputerAidedInspection(CAI)
5. Computer AidedTesting(CAT)

Advantages:
CAMentailsthefollowing,advantages'.
1. Productobtainedissuperiorinquality.
2. Themanufacturedformhasagreaterversatility.
3. Higherproductionrateswithlowerwork-forces.
4. Thereislesslikelihoodofhumanerror.
5. Increasedmanufacturingefficiency
6. Theproductionprocessescanberepeatedviastorageofdata.

SoftwareandhardwareforCAD/CAM

Softwareusuallyconsistsofanumberofseparateapplication packagestoperformthedesiredfunction.Thesizeof computer depends on the number and sizesof packages and number of work stations

Hardwareisresponsiblefortherelibilityandspeedofresponseofthesystem.

CADDHardware

- SystemUnit
- CentralProcessingUnit(CPU)
- Memory
- HardDisk,FloppyDisk,CD-ROM

- ExternalStorageDevices
- TheMonitor
- PrintersandPlotters
- Digitizer, PuckandMouse

CADDSoftware

- Draw
- Edit
- Dataoutput
- Systemcontrol
- Datastorageandmanagement

Functioningofcadcamsystems

In order togenerate the actualmodel, **CAM works alongsideCAD**—using CAD designs,CAM usesnumericalcoding to runthemachine thatcreatestheproduct.A CAD/CAMpackageallowscompaniestodevelopand save theirown product designs, and program machines to create the actual component.

Computer-aided design & computer-aidedmanufacturing (CAD/CAM) softwareis **used to design and manufacture prototypes, finished products, and production runs of products**.

FeaturesandcharacteristicsofCAD/CAMsystem

1. AmajorportionoftheoutputoftheengineeringsectorinvolvesbatchproductionandCAD/CAMoffers immense cost and quality benefits for such requirements.

2. Thework-in-progress,inbatch production,isreducedconsiderably.

3. Itispossibletoproduceatrandomallthevariantsandseriesofaproductplanned tobemanufacturedbya firm.

4. Suchasystemhasinherentflexibilitytocatertonewmodelsoftheproductinpipelinewithoutmajor modification.

5. Insuchasystem,severalmachiningcentresarearrangedoneaftertheotherwithrobotsandproperautomatic materials handling equipment. Software is developed to integrate the machine CNC control and the handling system. Each machining centre is equipped with several tool magazines. All the tools required to complete each operation on each model of the product can be stored in the magazine.

6. AllthepartProgramsfor thedifferentmodelsare storedin thememory.System hasonly toidentify themodel of the productpresented to amachine inorder tocompletethe machining operations. Thusitispossible tohave totally random mixes of models of a product proceeding down the line at any one time.

7. System can be conceived in multiplies of 15-20 minutes operations. If certain operations take longer, then multiplesofsimilarmachinescanbeinstalledintheline.Sometimesidenticalmachinesareintroducedforeach operation so that production can continue even if one machine goes down.

5.1.3.5ApplicationareasforCAD/CAM

1. Designanddesignanalysis:

CADsystemwouldbebestsuitedfordrawingofficeswherefrequentmodificationsarerequiredondrawingand several parts repeat.
Itmustberemembered thatitisveryeasywithcomputertomakemodificationsandveryfasttodrawpartprofile once its details are fed into computer.
OnceadrawingisenteredintheCADsystem,latermodificationscanbedonequickly,anddetaildrawingscanbe prepared quickly from a general arrangement drawing.
Storingofthedrawingisveryconvenient,easy,occupiesverylessspaceandsymbolsforelectrical,hydraulic, control and instrumentation circuitscan be called up quickly and positioned on the schematic drawing.

Standard componentscan be stored permanentlyin the data base andcalled up and positioned on the drawing, resultinginsaving oftimeandenforcement of standards.Itispossibletoassociatenongraphicalinformationlike past number, supplier, material etc., for any component assembly.
It isveryconvenienttocalculatepropertieslike weight,centre of gravity,moment ofinertia,etc.,because3-D models can be easily produced.
Itisalsopossibletocarryoutfiniteelementanalysisbyproducingmeshingforanalysis.

2. Manufacture:
WithcAD/cAMsystemthecompleteNCpartprogrammingprocesscanbecarriedoutinteractively,

ElementsofCNCmachines

1. Machinestructure.
2. Guideways/Slideways.
3. Drives.
4. Spindleandspindlebearings.
5. Measuringsystems.
6. Controls.
7. Gauging
8. Toolmonitoring.
9. Swarfremoval.
10. Safety.

MeasuringSystems-
MeasuringsystemsareusedonalltheCNCmachinestoperformthefollowingfunctions:
1. Tomonitorthepositionofaslideonaslideway.
2. Toorientthespindle/table.
3. Tomeasurethespindlespeed.

Controls
For CNC machines, CNC controls are of significant importance. Earlier, CNC controls were developed for simple applications in turning, machining centres and grinding, butthese days CNC systems have been developed tomeet with the increased machine tools requirements of higher spindle speeds, higher rapid traverses and more number of axes. The new generation computer numerical controls allow simultaneous control of more axes, interpolate positions faster, and use more data points for precise control.

Thenewcontrollersofferthe following:
- Advancedgraphicinterfaces;
- Programsimulation;
- Somecutterselectingcapabilities.

Gauging

The quality can be maintained by eliminating the effect of parameter like tool wear and thermal growth, with the use of automatic gauging system.

Thegauging onamachine toolmaybeusedforthefollowing purposes- To
inspect workpiece.
Todetecttool breakage.
Todefinetooloffsets.
Toautomaticallyaligntheworkpiece. To
detect the stock variation

ToolMonitoringSystem
The tools wear out or even break during machining. If tool n ear and breakage is not properly monitored, the productivity of the machine and the quality of the component produced are affected. Now-a-days established monitoring sensors and systems are available commercially which can be integrated with CNC machines.

Followingarethetwowaysofmonitoringtoolwearandbreakage:
1. Directmonitoring:Inthistypeofmonitoringa touchprobeis directlyusedto monitorthetoolconditionby checking the tool edge position and checking for the existence of a tool edge.

2. lndirectmonitoring:Here,thetoolconditionischeckedindirectlybymonitoringthechangeincertainparameter whose value when affected reflects the tool condition.

Followingparametersareusedtomonitortoolcondition:

(l)Cuttingforces.
(ii) Toollife.
(iii) Workpiecedimensions.
(iv) Emissionofnoiseduringcutting
(v) Powerofthespindleorafeeddriveoradriven tool.

SwarfRemoval
InCNCmachinesthecuttingtimeismuchmoreandassuchthevolumeofswarfgeneratedisalsomore.
- Unless the swarf is quickly and efficiently removed from the cutting zone, it can affect the cutting process andquality of the finished product.
- Alsothe swarf cannot be allowed to accumulate at the machine toolbecause it may hamperthe accessto themachinetool.
- In addition some auxiliary functions like automatic component loading or automatic tool change may also be affected by accumulation of swarf.
To overcome all above problems it is necessary to provide an efficient swarf control system with the CNCmachine tools with some mechanism to remove the swarf from the cutter and cutting zone and for the disposal of swarf from the machine tool area itself.

Safety
Asthe CNCmachinesare undercontinuousautomaticoperation,thereisaneed toprotectthemachineguideways and to ensure operatorssafety since the machinesrun at high speeds with automatic auxiliary operations.
- In order to have efficient working and long life of the machine it isessential to protect machine guideways, drive screws and transducers etc. These elements are protected by the use of various types of collapsible guards and covers.

All the sliding elements are fitted with wipers and drive screws are normally protected by using telescopic covers. Jets of cutting fluidsare used to wash away swarf and clear the tool work area.
- Operator's safety is very important aspect which cannot be overlooked. To ensure safe working conditions the CNC machine tools are provided with metallic or plastic guards.

Introduction

MachineStructure

The"machinestructure"istheloadcarryingandsupportingmemberofthemachinetool.
ThedesignandconstructionofCNCmachineshouldbesuchthatitmeetsthemain“objectives"

(i) Highprecisionandrepeatability
(ii) reliability;
(iii) Efficiency.

Inordertomeettheserequirements,thenumericallycontrolledmachinetoolsshouldhaveastructure with the following characteristics:

1. Itdoesnotdeformorvibrate beyondthepermissiblelimitsundertheactionofstaticanddynamicforces, to which it is subjected.
Static load of a machine tool results from the weights of slides and the workpiece, and the forces due to cutting.
Dynamicloadsatermusedfortheconstantlychangingforcesactingonthestructure whilethemovementistaking place.
Theseforcescausethe wholemachinetovibrateandtheoriginofthesevibrationsmaybeduetounbalanced rotating parts, improper meshing of gears, bearings irregularities

2. Itsdesign should be suchthatthethermal distortion isminimum.Themachinetoolshouldbeprotectedfrom external andinternalheatsources;someoftheseheatsourcesare:Electricmotor; frictioninmechanicaldrives, gear boxes, bearings and guideways; machinery Process; temperature of surrounding objects.

3. Themachinestructuredesignshouldbesuchthattheremovalofswarfiseasyandthechipsetc.,donotfall on the slideways.

Guideways/Slideways

IntroductionandTypesofGuideways

Introduction
Inmachinetoolstheguidewaysareusedtoservethefollowing purposes;
(i) Tocontrol thedirectionorlineofactionofthecarriageorthetableonwhichatooloraworkpieceisheld.
(ii) Toabsorballstaticanddynamicloads.

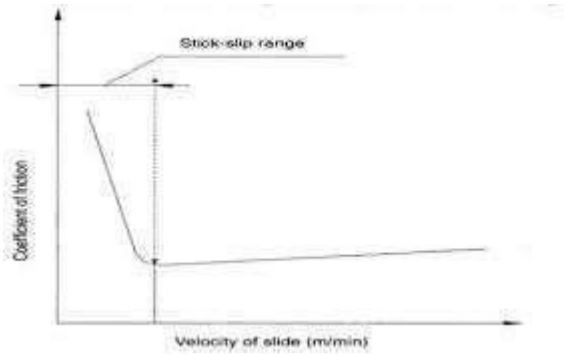
Theguidewaysmaybeanintegralpartofthemachinestructureormay bemounted separatelyonthestructure. These guideways may be horizontal, vertical or inclined.
Howeververticalandinclinedguidewaysarepreferredsothatchipsproducedduringthecuttingoperationdonot get collected on the quickways.
Theshapeandsizeoftheworkproduceddependsontheaccuracyofthemovement

Guidewaysarebroadlyclassifiedasfollows:
1. Frictionguideways.
(i) Veeguideways.
(ii) Flatguideways
(iii) Dovetailguideways.
(iv) Cylindricalguideways

2. Antifrictionlinearmotion(LM)guideways.

3. Frictionlessguideways:
(l)Hydrostaticguideways.
(ii)Aerostaticguideways.

Frictionguideways
Theseguidewaysfindwideapplicationinconventionalmachinetoolsduetotheirlowmanufacturingcostand good damping properties.
Itoperateunderconditionsofslidingfrictionanddonothaveaconstantcoefficientoffriction.Thefrictional coefficient varies with the sliding velocity



Atthecommencementofthemovement,thecoefficientoffrictionisveryhigh,butasthevelocityincreasesitfalls rapidly and beyond a certain critical velocity it remains almost constant. Thus, to start motion/movement, the forceto overcomefriction has tobecorrespondingly high. This phenomenon isknownas, stick-slip phenomenon.

Veeguideways:
TheVeeguidewaysarewidelyusedonmachinetools,especially'onlathebeds.

Theseguidewayswearawayrapidlyduetolackofbearingsurface.Thesearedifficulttomanufacture.

Flatguideways
Theseguidewayshavebetterloadbearingcapabilitiesthanotherguideways.
- Theseareeasiertomanufacture.
- Insuchguidewaysthechipaccumulationandlubricationproblemsareserious.
- Thesedonotwearuniformly.
- Jibsareusedtoensureaccuratefittingoftheslideontheflatsurface.

Dovetailguideways
Theseguidewayshavelargeloadcarryingcapacityandtendtochecktheoverturningtendency undereccentric loading.
- Theyarepreferredwhenbothhorizontalandverticallocationsofmovingpartsareconsideredessential.
- Jibsareusedtoensureaccuratefittingoftheslide on thedovetailsurface.Thejibsaretaperedandcanbe adjusted to reduce excessive clearance caused by wear.

Cylindricalguideways
Theseguidewaysareaeryefficientforrelativelyshorttraversesandlightloads.

- Theiruseforlongtraversesandheavyloadsisnot suitable becausetheguidewaysmay sagorbendinthecentre of the span under a load.

Antifrictionlinearmotion(LM)guideways

Theseguidewaysareusedon CNC machine tool storeduceamountofwear,friction,heatgenerationandimprove smoothness of the movement,

The antifriction guidewaysareemployed toovercometherelativelyhighcoefficientoffrictioninmetal-to-metal contacts..

Theyuserollingelementsinbetweenthemovingandstationaryelementsofthemachine.

Advantages:Theantifrictionguidewaysclaimthe followingadvantages overthefrictionguides:

1. Highloadcarryingcapacity.
2. Heavierpreloadingpossibility.
3. Hightraversespeeds.
4. Lowfrictionalresistance.
5. Nostick-slip.
6. Easeofassembly.
7. Commerciallyavailable inready-to-fitcondition.

Theirmaindisadvantageis'lowerdampingcapacity'. Types

of antifriction guideways

1. Linearbearingwithballsusesrecirculatingballswithinabushtypeofbearing.

Thesearedesignedtorunalongprecisiongroundshaftsandofferfrictionlessmovementmakingstrokesoflength with high linear precision.

2. Linearbearingwithrollers:

Therecirculatinglinearrollerbearingsareusedformovementalongaflatplane.Theirmaincharacteristicfeature is that there is continuous roller circulation which allows unlimited linear movement.

Frictionless guideways

Hydrostaticguideways:

- Intheseguidewaysthesurfaceoftheslideisseparated fromtheguidewaybyaverythinfilmoffluidsuppliedat pressures as high as 300 bar.
- Inhydrostaticguidewaysfrictionalwearandstickslipareentirelyeliminated.
- Insuchguidewaysahighdegreeofdynamic stiffnessanddampingisobtained,boththecharacteristics contributing to good machining capabilities.
- Owingtohighcostanddifficultyinassembly,theirapplicationislimited.

Aerostaticguideways:

Intheseguideways,theslideisraisedinacushionofcompressed airwhichentirelyseparates theslideand guidewaysurfaces.

Advantagesoffrictionlessguideways:

1. Longerlife.
2. Largedampingcapability.
3. Frictionless.
4. Highstiffness.
5. Nostick-slip.
6. Lessthermaldistortionduetobetterheatdissipation.

Disadvantages:

1. Difficultyinassemblingtheguideways.
2. Highcost.

3. Leakageproblems.

Factorsofdesignofguideways

(i) Reducefriction;
(ii) Reducewear;
(iii) Satisfytherequirementsofmovementoftheslides;
(iv) Improve smoothnessofthe drive

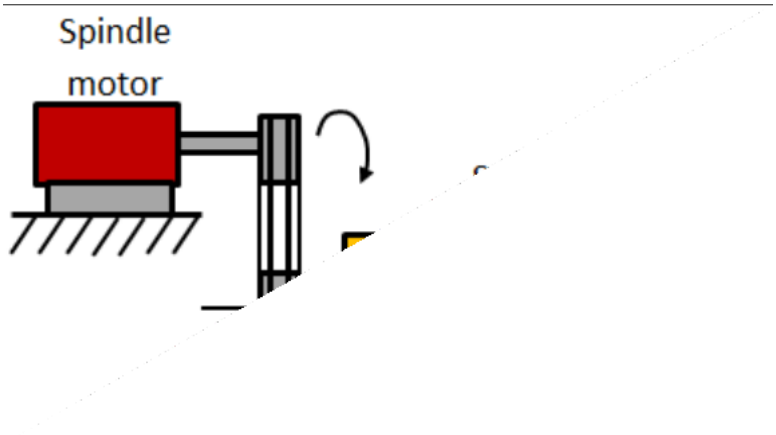
Thefollowingfactorsshouldbeconsideredwhile designingguideways:
1. Geometricandkinematicaccuracy.
2. Positioninrelationtoworkarea.
3. Provisionforadjustmentofplay.
4. Rigidity.
5. Dampingcapability.
6. Velocityslide.
7. Frictioncharacteristics.
8. Wearresistance.
9. Protectionagainstswarfanddamage.
10. Protective guardstosafeguardtheguidewaysagainstaccidentaldamages.
11. Freedomfromunnecessaryrestraints.
12. Effectivelubricationandefficientlubricationsvstems.

Drives

Deviceswhichimpartmotiontomechanicalcomponents

Theprimaryfunctionofthedriveistocausemotionofthecontrolledmachinetoolmembertoconformasclosely as possible to the motion commands issued by the CNC system.

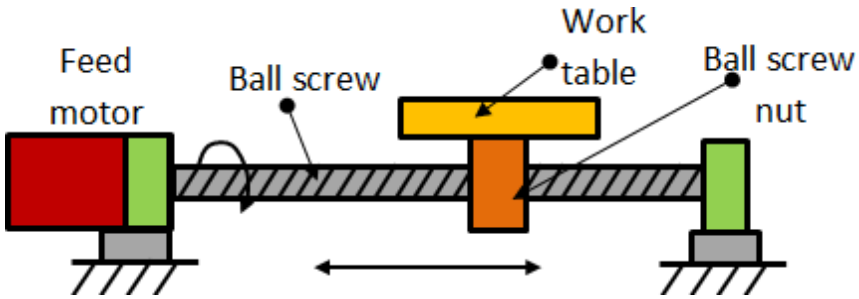
Spindledrives



Thespindledrivesareusedtoprovideangularmotiontotheworkpieceoracuttingtool.
These drives are essentially required to maintain the speed accurately within a power band which will enable machining of a variety of materialswith variations in material hardness. The speed ranges can be from 10 to 20,000rpm.

The machine tools mostly employ DC spindle drives. High overload capacity is also needed for unintended overloads on the spindle due to an inappropriate feed. It is desirous to have a compact drive with highly smooth operation.

Feeddrive



Theseareusedtodrivetheslideoratable
Therequirementsofanidealfeeddriveareasfollows.
• Thefeedmotorneedstooperatewithconstanttorquecharacteristicstoovercomefrictionandworkingforces.
• Thedrivespeedshouldbeextremelyvariablewithaspeedrangeofabout1:20000,whichmeansitshouldhave a maximum speed of around 2000 rpm and at a minimum speed of 0.1 rpm.
• Thefeedmotormustrunsmoothly.
• The driveshouldhaveextremelysmallpositioningresolution.

SpindleandSpindleBearings

Spindle
Thespindlecarryingtheworkpieceortoolwhensubjected tohighcuttingspeedsandhighmaterialremovalrates, experiences deflectionandthrustforces.Toensureincreased stabilityandminimizetorsionalstrain, themachine spindle is designed to be short and stiff & the final drive to the spindles is located near to the front bearing as possible. Therotationalaccuracyofthespindleisdependentonthequalityanddesignofbearings used.Theballorroller are suitable for high speeds and high loads because of low friction, low wear rate&lesser liability to incorrect adjustment and ease of replacement when necessary.

Spindlebearings
Inmodernmachinetools,whichemployhighperformancecuttingtoolmaterials,thedesignedcharacteristicsof spindles used are:
(l)Minimumdeflectionundervaryingloads. (il)
Long service life.
(lli)Stiffness.
(lv)Thermalstability'.
(v) Goodrunningaccuracybothinradialandaxialdirections.
(vi) Axialloadcarryingcapacity'.
(vii) Highspeedofoperation,

Thevarioustypesofspindlebearingsusedinthedesignofaspindleformachinetoolsare:
1. Antifrictionbearings.
2. Hydrostaticbearings.
3. Hydrodynamicbearings

1. Antifrictionbearings

Theantifrictionbearingsaresuitable.forhighspeedsandhighloads.
Theseareoftenpreferredtohydrodynamicbearingsbecausethefollowingreasons-.
Highreliability.
Ease ofreplacement.
Lowfriction.
Moderatedimensions.
Lesserliabilitytosufferfromwearorincorrectadjustment.

2. Hydrostaticbearings

Herethespindleissupported byarelativelythickfilmofoil(calledhydrostaticpockets)suppliedunderpressure; the oil in the pockets being stationary. The oil is supplied to the bearing through a throttling system to control pressure and volume. Lubricating seals are usedto prevent the leakage of oil. There isno mechanical contact.
-Theloadcarryingcapacityofthistypeofbearingisindependentofthespeedofrotation.

Theyhavethefollowingmerits'.
(i) Highwear resistance.
(li)Highdampingproperties.
(ili) High running accuracy.

Thesebearingsareusedingrindingandboringmachinesetc.

3. Hydrodynamicbearings

ThePressureofoilwithinthebearingiscreatedbytherotation ofthespindle.Asthespindlerotates,theoilin contact with the spindle is carried into wedge shaped cavities between the spindle and the bearing due to centrifugal action. As the oil is forced through the small clearances between the bearing and spindle, the oil Pressure is increased. Inthistypeofbearingthereisaconstantflowofoilroundthespindle,maintaining athickoilfilm.

Theessentialfeaturesofthesebearingsare:
(i) Goodrunningaccuracy.
(il)Simplicity.
(lli)GooddampingProperties.

(lli)GooddampingProperties.

Themainlimitationofthistype ofbearingisthat adefiniteclearancemustbeprovidedfor theoilfilmtobe maintainedbetween bearing and thespindle; theclearancesnormallyprovidedvary from50 pmto 200 pm depending upon the journal diameter'
These bearingsareusedwhere theloadcarryingcapacitiesarelow-andfrequent startingandstopping ofthe spindle is not required as in the case of grinding machines

Unit6:ROBOTICS

Definition,Functionandlawsofrobotics

DEFINITION

Robotics is an interdisciplinary branch of computer science and engineering. Robotics involves design, construction,operation,anduseofrobots.Thegoalofroboticsistodesignmachinesthatcanhelp andassist humans.

FUNCTION

LAWSOFROBOTICS

IsaacAsimov's"ThreeLawsofRobotics"

1. Arobotmaynotinjureahumanbeingor,throughinaction,allowahumanbeingtocometoharm.
2. ArobotmustobeyordersgivenitbyhumanbeingsexceptwheresuchorderswouldconflictwiththeFirstLaw.
3. ArobotmustprotectitsownexistenceaslongassuchprotectiondoesnotconflictwiththeFirstorSecondLaw.

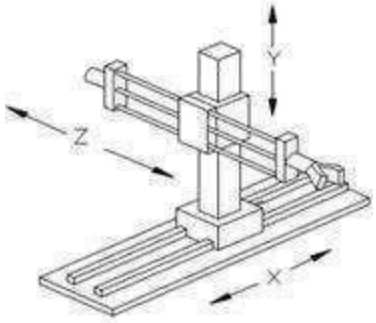
TYPESOFINDUSTRIALROBOTS

1. CartesianRobots

Cartesian robots, which are also called linear robots or gantry robots, are industrial robots that work on threelinear axesthatuse the CartesianCoordinatesystem(X,Y,and Z),meaningthey moveinstraightlineson3-axis(up and down, in and out, and side to side).

Cartesianrobotsareapopularchoiceduetobeinghighlyflexibleintheirconfigurations,givinguserstheabilityto adjust the robot's speed, precision, stroke length, and size.

CartesianRobotsareoneofthemostcommonlyusedrobottypesforindustrialapplicationsandareoftenusedfor CNC machines and 3D printing.



2. SCARA Robots

SCARAstandsforSelectiveComplianceAssemblyRobotArmorSelectiveComplianceArticulatedRobotArm. SCARA

Robots function on 3-axis(X, Y, and Z), and have a rotary motion as well.

SCARARobotsexcelinlateralmovementsandarecommonly fastermovingandhaveeasierintegrationthan CartesianRobots.

Typically,SCARArobotsareusedforassemblyaswellasbio-medapplication.

3. ArticulatedRobots

ArticulatedRobotsmechanicalmovementandconfigurationcloselyresemblesahumanarm. The

arm is mounted to a base with a twisting joint.

Thearmitselfcanfeatureanywherefromtworotaryjointsup totenrotaryjointswhichactasaxes,witheach additional joint or axis allowing for a greater degree of motion.

MostArticulatedRobotsutilizefourorsix-axis.

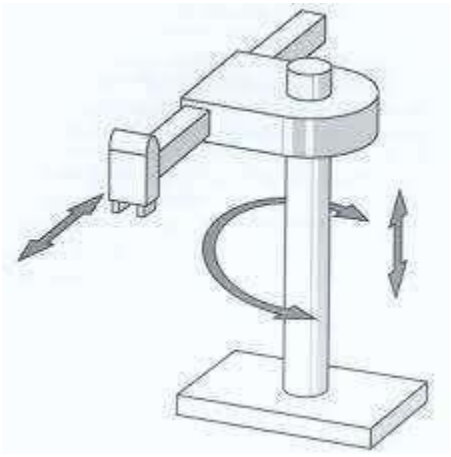
TypicalapplicationsforArticulatedRobotsareassembly,arcwelding,materialhandlingandpackaging.

4. CylindricalRobots

CylindricalRobotshavearotaryjointatthebaseandaprismaticjointtoconnectthelinks.

Therobotshaveacylindrical-shapedworkenvelop,whichisachievedwithrotatingshaftand anextendablearm that moves in a vertical and sliding motion.

CylindricalRobotsareoftenusedintightworkspacesforsimpleassembly,coatingapplicationsduetotheir compact design.



5. DeltaRobots

DeltaRobots,orparallelrobots,possessthreearmsconnectedtoasinglebase,whichismountedabovethe workspace.

DeltaRobotsworkinadome-shapeandcanmovebothdelicatelyandpreciselyathigh speedsduetoeachjointof the end effector being directly controlled by all three arms.

DeltaRobotsareoftenusedforfastpickandplaceapplicationsinthefood,pharmaceutical,andelectronic industries.

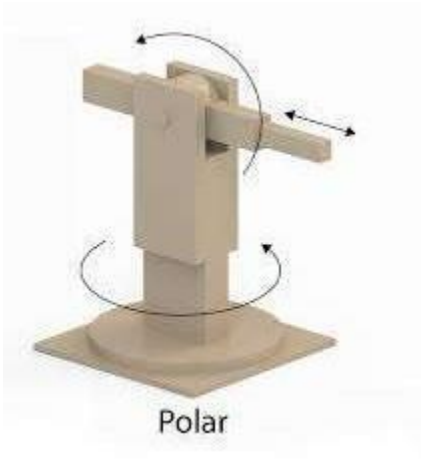
6. PolarRobots

PolarRobots,orsphericalrobots,haveanarmwith tworotary jointsandonelinearjointconnectedtoabasewith a twisting joint.

Theaxesoftherobotworktogethertoformapolarcoordinate,whichallowstherobottohaveasphericalwork envelope.

PolarRobotsarecreditedasoneofthefirsttypesofindustrialrobotstoeverbedeveloped. Polar

robots are commonly used for die casting, welding, and material handling.



7. CollaborativeRobots

CollaborativeRobotsorCobotsarerobotsthatcandirectlyandsafelyinteractwithhumansinasharedworkspace. Cobots

are typically used for pick and place, quality inspection, etc.

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ROBOTICSYSTEMS

Therearethreetypesofroboticsystems–

1. Manipulationroboticsystem

Themanipulationrobotsystemisthemostcommonlyusedinthemanufacturingindustry.

Thesesystemsaremadeupofmanyoftherobotarmswith4-6axesandvaryingdegreesoffreedom.

Theycanperformseveraldifferentfunctions,includingwelding,materialhandlingandmaterialremoval applications.

2. Mobileroboticsystem

Themobileroboticsystemisabitdifferent.

Thissystemconsistsofanautomatedplatformthatmovesitemsfromoneplacetoanother.

Whiletheserobotsystemsareusedheavilyinmanufacturingforcarryingtoolsandspareparts,theyarealsoused in the agricultural industry for transporting products.

3. Dataacquisitionandcontrolroboticsystem

Dataacquisitionandcontrolroboticsystemsareusedtogather,processandtransmitdataforavarietyofsignals. They are also used in software for engineering and business.

Manyofthemobileroboticsystemscanusesignalsfromthesesystems.

ADVANTAGESANDDISADVANTAGESOFROBOTS

Advantages

- Robotscanincreaseproductivity,efficiency,qualityandconsistencyofproducts.
- Unlikehumans,robotsdon'tgetbored
- Untiltheywearout,theycandothesamethingagainandagain
- Theycanbeveryaccurate
- Robotscanworkinenvironmentswhichareunsafeforhumans
- Robotsdon'thavethesameenvironmentalrequirements thathumans do
- Robotshavesomesensors/actuatorswhicharemorecapablethanhumans

Disadvantages

- Theuseofrobotscancreateeconomicproblemsiftheyreplacehumanjobs
- Robotscanonlydowhattheyaretoldtodo–theycan'timprovise
- Safetyproceduresareneededtoprotecthumansandotherrobots
- Althoughrobotscanbesuperiortohumansinsomewaysbuttheydon'thavesuchpowerfulbrains,and cannot compete with a human's ability to understand.
- Oftenrobotsareverycostly–intermsoftheinitialcost,maintenance,theneedforextracomponents and the need to be programmed to do the task.

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