Table 10.5 (*b*)

Code No.	*Speed (RPM)*	*Code No.*	*Speed (RPM)*
54	50	71	355
55	56	72	400
56	63	73	450
57	71	74	500
58	80	75	560
59	90	76	630
60	100	77	710
61	112	78	800
62	125	79	900
63	140	80	1000
64	160	81	1120
65	180		:
66	200		:
67	224		:
68	250	:	
69	280	:	:
70	315	99	fast traverse

Every word is composed of an address letter and a number or a symbol. For example No. 4 means sentence No. 4. F18 means tool movement of 0.8 mm/revolution (refer to code number in Table 10.5 (*a*)) and S65 means spindle speed of 180 R.P.M. (Refer to code number in Table 10.5 (*b*)).

Example 10.7. (*a*) *Compare various machine tools for Increasing variety and Increasing Batch, size.*

Solution. General purpose machine tools are used when variety of components to be made is high but batch size is low. Special purpose machine tools are used for lower variety and higher batch size. Typical comparison of various machine tools are shown in Fig. 10.31 (*a*).

In this Fig. 10.31 (*a*)

V = Increasing Variety
S = Increasing Batch size
I.P. = Increasing Productivity
I.F = Increasing Flexibility
GPM = General Purpose machine tools
CNC = Computerised Numerical Control machine tools
FMC = Flexible manufacturing cells
FMS = Flexible manufacturing system
SPM = Special purpose machines
T.L = Transfer Lines.

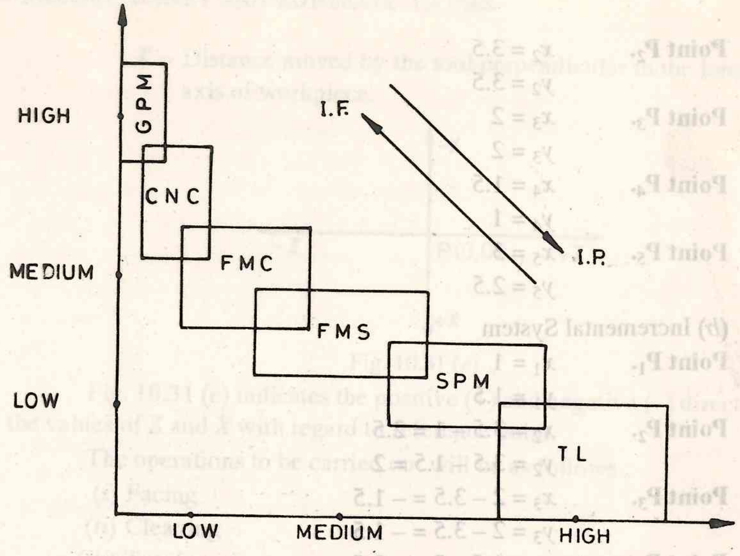


Fig. 10.31 (*a*)

Example 10.7. (*b*) *Write the coordinates of points P_1, P_2, P_3, P_4 and P_5 according to*

(*a*) *Absolute system*
(*b*) *Incremental system.*
Points are shown in Fig. 10.31 (b).

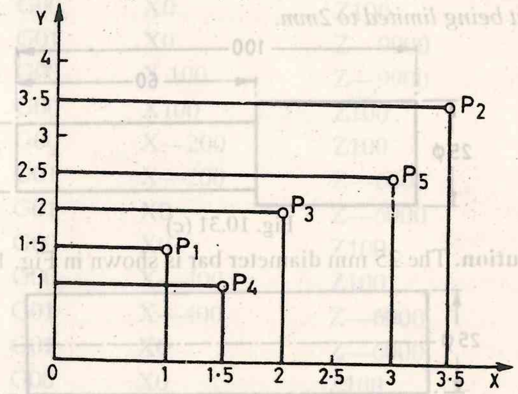


Fig. 10.31 (*b*)

Solution. The coordinates are as follows :

(*a*) Absolute system (Datum O)

Point P_1. $x_1 = 1$
$y_1 = 1.5$

Point P_2. $x_2 = 3.5$
$y_2 = 3.5$

Point P_3. $x_3 = 2$
$y_3 = 2$

Point P_4. $x_4 = 1.5$
$y_4 = 1$

Point P_5. $x_5 = 3$
$y_5 = 2.5$

(*b*) Incremental System

Point P_1. $x_1 = 1$
$y_1 = 1.5$

Point P_2. $x_2 = 3.5 - 1 = 2.5$
$y_2 = 3.5 - 1.5 = 2$

Point P_3. $x_3 = 2 - 3.5 = -1.5$
$y_3 = 2 - 3.5 = -1.5$

Point P_4. $x_4 = 1.5 - 2 = -0.5$
$y_4 = 1 - 2 = -1$

Point P_5. $x_5 = 3 - 1.5 = 1.5$
$y_5 = 2.5 - 1 = 1.5.$

Example 10.7. (*c*) *Write part program for making the component shown in Fig. 10.31 (c) from raw material bar of 25 mm. diameter. Maximum depth of cut being limited to 2mm.*

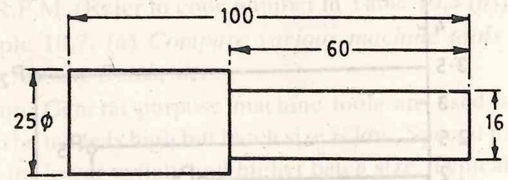


Fig. 10.31 (*c*)

Solution. The 25 mm diameter bar is shown in Fig. 10.31 (*d*)

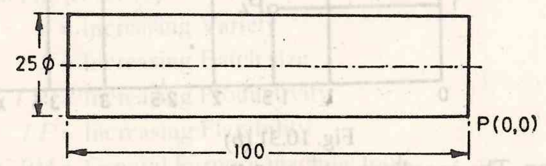


Fig. 10.31 (*d*)

Let us take point *P* (0, 0) as reference point. For point *P*

$$X = 0$$
$$Z = 0$$

where Z = Distance moved parallel to the longitudinal axis of workpiece.

X = Distance moved by the tool perpendicular to the longitudinal axis of workpiece.

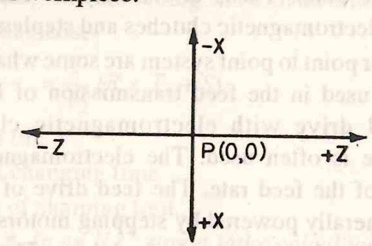


Fig. 10.31 (*e*)

Fig. 10.31 (*e*) indicates the positive (+) and negative (–) directions for the values of *Z* and *X* with regard to reference point.

The operations to be carried out will be as follows :

(*i*) Facing

(*ii*) Cleaning

(*iii*) Turning.

Assuming absolute system of coordinates the program will be as follows :

N1	G90	G71		M03	S1000
N2	G01	X—1250		Z00	F200 M08
N3	G00	X—1250		Z100	
N4	G00	X0		Z100	
N5	G01	X0		Z—9900	
N6	G00	X 100		Z—9900	
N7	G00	X100		Z100	
N8	G00	X—200		Z100	
N9	G01	X—200		Z—6000	
N10	G01	X0		Z—6000	
N11	G00	X0		Z100	
N12	G00	X—400		Z100	
N13	G01	X—400		Z—6000	
N14	G01	X0		Z—6000	
N15	G00	X0		Z100	
N16	G00	X—450		Z100	
N17	G01	X—450		Z—6000	
N18	G01	X100		Z—6000	
N19	G00	X100		Z500	
N20	M02	M05			

Operation N2 indicates facing, operation N5 indicates cleaning and turning operation starts from N9.

10.43. N.C. Machine Tools Drives

In N.C. machine tools the main drives hardly differ from those used on conventional machine tools. These drives may be simple stepped drives, stepped drives with electromagnetic clutches and stepless drives.

Feed drives for point to point system are some what different. A simple stepped drive is not used in the feed transmission of N.C. machine tools. However a stepped drive with electromagnetic clutches also called electromagnetic drive is often used. The electromagnetic clutches permit automatic changing of the feed rate. The feed drive of point to point N.C. machine tools are generally powered by stepping motors. Fig. 10.32 shows a schematic diagram of an electromagnetic feed drive. The drive is powered by a three phase induction motor which may be connected to the bad screw of the machine tool through electromagnetic clutches C_1 and C_2. The clutch C_1 gets engaged during positioning movement and the transducer constantly monitors the displacement of the operative member and sends this information to the comparator. The comparator activates electromagnetic clutch. C_2 resulting in a reduced feed rate.

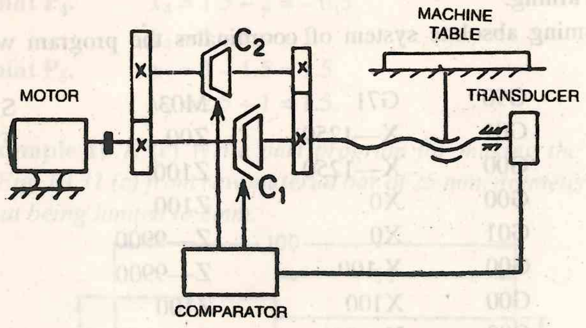


Fig. 10.32

Hydraulic and electrical stepless drives are commonly used in continuous path systems.

10.44. Economics of Numerically Controlled Machines

The cost of manufacturing a component on an N.C. machine tool is made of cost of programming and tape preparation and production cost.

C = Manufacturing cost per component

$= C_1 + C_2$

where C_1 = Cost of part programming and tape preparation per component

C_2 = Production cost = $C_3 + C_4$

C_3 = Machining cost

$= R\,(T + T_1)$

where R = Total machine and operator rate

T = Machining time per component

T_1 = Loading and unloading and tool advance and withdrawl time

C_4 = Tooling cost

$$= \frac{T}{T_2}\,(R \times T_3 + S)$$

where T_2 = Tool life

T_3 = Tool changing time

S = Cost of sharping tool.

Example 10.8. *In an N.C. turret lathe calculate the cost of manufacturing a component when batch size is 20 using following data :*

Initial cost of lathe = *Rs.* 3×10^6

Pay back period = *3 years.*

Operator's wages = *Rs. 8 per hour*

Overheads for machine and operator = *100%*

Tool life = *600 seconds*

Cost of tape preparation per units of machining time = *Rs. 4/sec.*

Total cycle time is 300 seconds out which 5% is spent on actual chip removal.

The lathe tools are fitted with disposable carbide inserts costing Rs. 18 per cutting edge tool resetting time is 80 seconds.

Solution. R = Machine rate + operator rate

$$= \frac{2 \times 3 \times 10^6}{3 \times 50 \times 40 \times 3600} + \frac{2 \times 8}{3600}$$

= Rs. 0.28 per second

C_1 = Cost of part programming and tape preparation

$$= \frac{4 \times 150}{N}$$

where N = Batch size = 20 and machining time is 150 seconds

$$= \frac{4 \times 150}{20} = \text{Rs. } 30$$

C_2 = Production cost = $C_3 + C_4$

C_3 = Machining time cost

$= R\,(T + T_1)$

T_1 = 300 seconds

T = 150 seconds.

Assuming loading and unloading time 150 seconds

$C_3 = 0.28\,(150 + 300)$ = Rs. 126

C_4 = Tooling cost

$$= \frac{T}{T_2}(R \times T_3 + S)$$

$$= \frac{150}{600}(0.28 \times 80 + 18) = \text{Rs. } 10.1$$

where T = 150 seconds

T_2 = Tool life = 600 seconds.

T_3 = Tool changing time

= 80 seconds.

S = Cost of sharpening the tool

$C = 30 + 126 + 10.1$

= Rs. 166.1

10.44.1. The coordinate System in N.C. System

The three primary motions for an N.C. machine are given as *X*, *Y* and *Z* axis. The primary *X* motion is normally parallel to the longest dimension of the machine table, *Y* motion is normally parallel to the shortest dimension of the machine table and *Z* motion refers to the axis of the driven spindle. Positive *Z* movement (+ *Z*) is in the direction that increases the distance between the workpiece and the tool. Fig. 10.32 (*a*) shows coordinate convention for single column vertical milling drilling and boring machine.

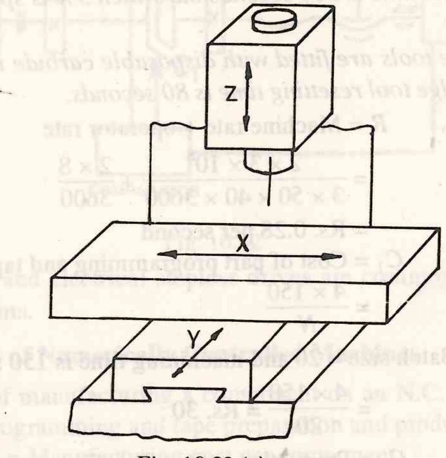


Fig. 10.32 (*a*)

X axis = Table side to side

Y axis = Table front to rear

Z axis = Spindle vertically into workpiece.

Fig. 10.32 (*b*) shows coordinate convention for horizontal milling machine.

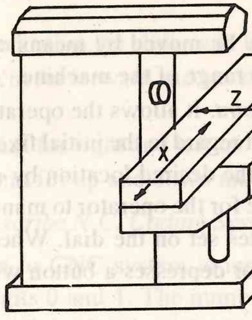


Fig. 10.32 (*b*)

Fig. 10.32 (*c*) shows coordinate convention for turning machine according to V.D.I. 3255.

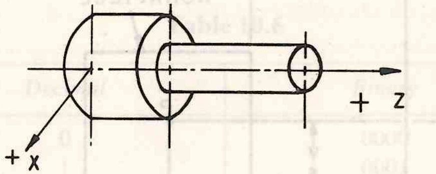


Fig. 10.32 (*c*)

Fig. 10.32 (*d*) shows angular movement directions *A*, *B* and *C* about *X*, *Y* and *Z* axis respectively according to VDI 3255.

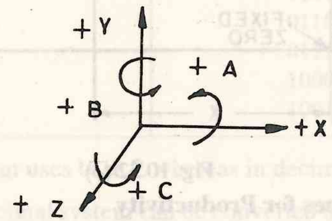


Fig. 10.32 (*d*)

10.44.2. Coordinates and reference points in N.C. Machine Tools

Reference points should be clearly established so that the workpiece and tool can be brought to the correct position.

Machine datum zero point (MP) is the origin of the machine coordinate system. The workpiece datum zero point (WP) is the origin of workpiece coordinate system. The starting point (SP) indicates the starting point of tool or slide.

Zero System. The point where *X*, *Y* and *Z* axes cross is called zero point. A machine tool may have two types of zero point.

(*i*) *Fixed zero point.* The fixed zero point machine is usually made so that the zero location is at the low left hand corner of *X*-*Y* coordinate on some systems the fixed zero may be moved by means of switches or dials to any where within the full travel range of the machine.

(*ii*) *Floating zero point.* It allows the operator to place the zero at any convenient location without regard to the initial fixed zero point. The operator merely moves the table to the desired location by means of jog buttons. The jog buttons make it possible for the operator to manually move the table to the desired location at feed rates set on the dial. When the table is at the exact desired location the operator depresses a button which establishes this point as the zero point.

Fig. 10.32 (*e*) shows a comparison between a fixed zero point and floating zero point.

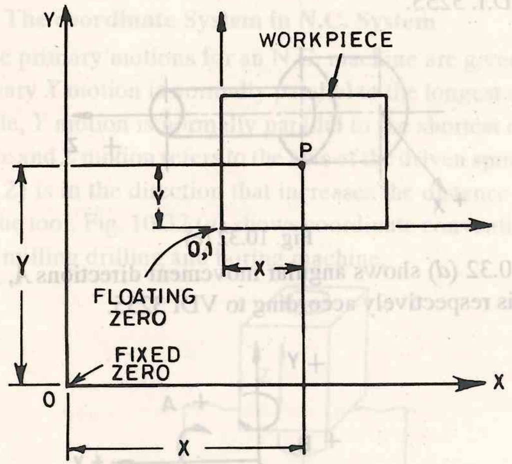


Fig. 10.32 (*e*)

10.45. Laser Machines for Productivity

New concepts in production engineering are required as batch sizes in production are becoming smaller and smaller. Laser machines provide reliability, quality, flexibility, productivity, and above all simplicity in operation particularly for sheet metal processing.

CNC laser processing machines is quite suitable for processing metallic and non-metallic materials such as steel, high temperature resistant materials super alloys, tungsten, molybdenum titanium, ceramic, plastic, wood etc. The machine consists of a rigid welded and stress relieved structure with a table designed specially for the laser processing of sheet metal. The portal carbon-dioxide laser cutting machine can control the laser beam. Salient features of laser machine are as follows :

(*i*) Slides driven by precision linear motion guides and ball-screws.

(*ii*) Motorisation by A.C. servo drives.

(*iii*) Centralised lubrication for slides and ball screws.

(*iv*) *X*-axis movement for forward and backward movement of the work table.

(*v*) *Y*-axis movement for right and left movement of focussing unit.

(*vi*) *Z*-axis movement for up and down motion of the focussing unit.

Example 10.9. *Describe N.C. Coding Systems.*

Solution. The data to CNC system is input in the coded form. The coding is based on two digits 0 and 1. The number system which uses these two digits is called binary. All the data input to the control system is converted into a binary equivalent. A minimum of four digits are required in the binary system to represent any single digit number in the decimal system as indicated in Table 10.6.

Table 10.6

Decimal	*Binary*
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

The binary system uses base 2 whereas in decimal system base is 10.

The values in decimal system can be converted into binary system and vice versa.

10.46. Decimal to binary Conversion

In order to convert decimal number into binary equivalent the decimal number is divided by 2 and remainder is written on side. This forms the right most digit of binary number. The quotients are progressively divided by 2 and remainder is written on the side till the remainder is 1 or 0. The last remainder forms the left most digit of the binary number.

Example 10.10. *To write binary equivalent number of decimal numbers 9 and 5.*

Solution. (*a*) $9 = 8 + 1$

$= 1000 + 0001$

$= 1001$

(*b*) $5 = 4 + 1$

$= 0100 + 0001$

$= 0101.$

Example 10.11. *To convert decimal number, 57 to binary number.*

Solution. Divide 57 by 2 till remainder is 1 or 0.

2	57
2	28 – 1
2	14 – 0
2	7 – 0
2	3 – 1
	1 – 1

Hence Binary number is 111001.

Example 10.12. *Write the two instructions blocks when two holes are to be drilled in the job shown in Fig. 10.33. Using C.N.C. machine.*

The holes are to be drilled using a 10 mm drill rotating at 400 RPM when feed rate is 150 mm/min. The G, M and T codes are not to be specified.

Solution. (*a*) In fixed block format the two instruction blocks will be as follows :

N	*X*	*Y*	*F*	*S*	
001	15.00	20.00	150	400	E0B
002	75.00	20.00	150	400	E0B

(*b*) In TAB sequential format the two instructions blocks will be as follows :

001 TAB 15.00 TAB 20.00 TAB 150 TAB 400 E0B

002 TAB 75.00 E0B

(*c*) In word address format the two instructions blocks will be as follows :

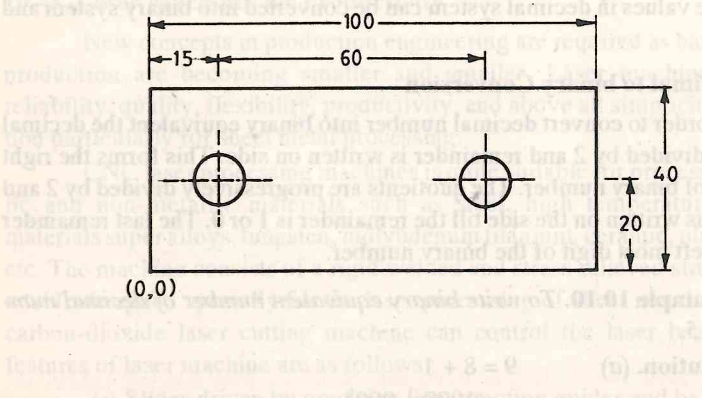


Fig. 10.33

N001	X15.00	Y20.00	F150	S400	E0B
N002	X75.00	E0B			

Example 10.13. *Describe Basic components of an N.C. system.*

Solution. Numerical control (NC) can be defined as a form of programmable automation. In N.C. the numbers form a program of instructions designed for a particular component. When component changes the program of instructions also changes. The capability to change the program for each new component is what gives N.C. flexibility.

Not only has N.C. replaced human skills and intuition but it has made it possible to generate complex machine motions with a degree of precision that is far beyond any human capability.

Three basic components of an N.C. system are as follows :

(*i*) Program of instructions

(*ii*) Controller unit also called a machine control unit (M.C.U.)

(*iii*) Machine tool or other controlled process.

The program of instruction serves as the input to the controller unit which in turn commands the machine tool or other processes to be controlled.

The program of instructions is the detailed step-by-step set of directions which tell the machine tool what to do. It is coded in numerical or symbolic form on some type of input medium that can be interpreted by the controller unit. The program of instructions is prepared by some one called a part programmer. For a machining operation the processing steps involve the relative movement between the cutting tool and the workpiece Fig. 10.34 shows three basic components of a numerical controlled system.

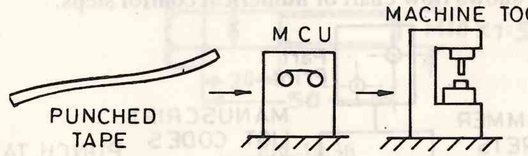


Fig. 10.34

M.C.U. consists of the electronics and hardware that read and interpret the program of instructions and convert it into mechanical actions of the machine tool. The typical elements of M.C.U. are as follows :

(*i*) Tape reader

(*ii*) A data buffer

(*ii*) Signal output channels to the machine tool

(*iv*) Feed back channels from the machine tool

(*v*) Sequence controls

(*vi*) Control panel.

The function of tape reader is to wind and read the punched tape containing the program instructions. The data buffer stores the input instructions in logical blocks of information. A block of information usually represents one complete step in the sequence of processing elements.

The signal output channels are connected to the servo motors and other controls in the machine tool. The machine control unit (MCU) sends the instructions to the machine tool through these channels. The return loop sends back the feed back data to the controller. This will help to check that :

(*i*) Instructions have been properly executed by the machine.

(*ii*) The table and workpiece have been properly located with respect to the tool.

The sequence controls coordinate the activities of various elements of the MCU. The control panel or control console contains the dials and switches by which the machine operator runs the NC system. It may also contain data displays to provide information to the operator.

The duties of the operator are as follows :

(*i*) To start and stop and machine

(*ii*) To load and unload the machine

(*iii*) To change tool. In some machines automatic tool changers are provided. In such machines tools are automatically changed under tape command.

(*iv*) To control the coolant supply.

Modern N.C. machines are generally provided with a micro computer as the controller unit. Such machines are called computer numerical control (CNC) machines.

Fig. 10.35 shows flow chart of numerical control steps.

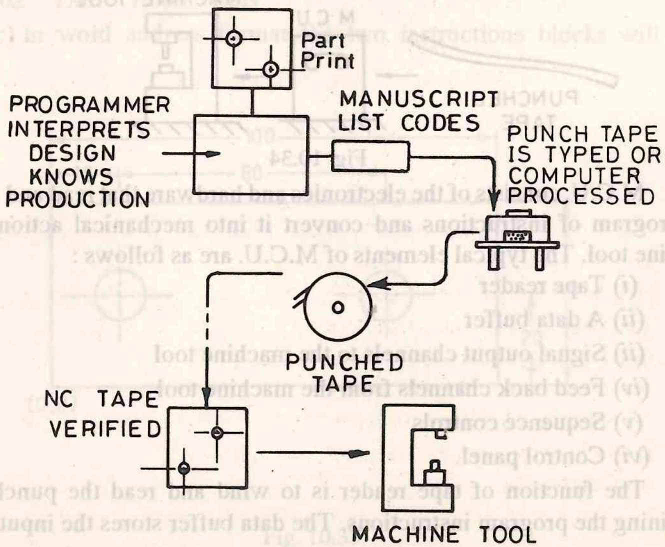


Fig. 10.35

The positional control function implies that the hand wheel has been replaced by a button which makes it possible to move the table very fast, very slow or by a desired increment as small as a fraction of a thousand of a millimeter.

In N.C. machine tools all the movements of the tool and machine table are automatically controlled by electric motors. The motors used for controlling the speed, feed and depth of cut are either servomotor or stepper motor which enable the user to select any desired speeds and feeds.

The machine may have a tool magazine so that the tool changing is done automatically. Other functions like machine ON/OFF, coolant on/off etc. are controlled through part programming.

PROBLEMS

10.1. Compare an engine lathe with capstan and turret lathes.

10.2. What is the difference between capstan and turret lathe ?

10.3. Make a neat sketch of a turret lathe, name its parts and describe its operation.

10.4. Make a neat sketch of capstan lathe, name its parts and describe its operation.

10.5. Write short notes on the following :

(*a*) Turret indexing mechanism.

(*b*) Work holding devices for a turret lathe.

(*c*) Bar feeding mechanism of turret lathe.

(*d*) Vertical turret lathe.

10.6. Describe the tooling set up on a turret lathe required to produce the bolt shown in Fig. 10.36.

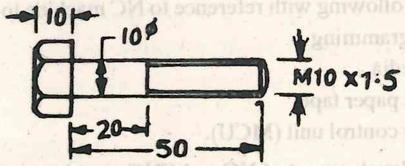


Fig. 10.36

10.7. (*a*) What is an automatic machine ? State the factors which affect the classification of automatic machines ?

(*b*) What are the different types of automatic machines ?

10.8. Describe the following automatic machines :

(*i*) Automatic cutting off machine.

(*ii*) Swiss type automatic screw machine.

(*iii*) Turret type automatic screw machine.

10.9. Write short notes on the following :

(*a*) Multi-spindle screw machine

(*b*) Type of cams used in automatic machine

(*c*) Cam lay-out.

10.10. What is numerical control of machine tools ?

10.11. Explain open loop system and closed loop system of numerical control.

10.12. Write short notes on the following :

(*a*) Digital and analogue control for N.C. machine tools.

(*b*) Point to point numerical control system.

(*c*) Continuous path numerical control. System of NC machine tools.

(*d*) Type of tapes used in numerical control.

(*e*) Codes used in numerical control.

10.13. State the advantages and disadvantages of numerical control machine tools.

10.14. (*a*) What is a transfer machine ?

(*b*) Describe the following types of transfer machines.

(*c*) Rotary transfer machines.

(*d*) In line transfer machines.

10.15. State the advantages and disadvantages of transfer machines.

10.16. Discuss the features of NC machines.

10.17. (*a*) What is automation.

(*b*) Describe the economics of automatic machines.

(*c*) State advantages and disadvantages of automation.

10.18. Write short notes on the following :

(*a*) Tool slides of automatic machine tools.

(*b*) Methods of increasing production capacity of automatic machine tools.

(*c*) Operating cycle of automatic machine tools.

10.19. Explain the following with reference to NC machine tools :

(*i*) Part programming

(*ii*) Input media

(*iii*) Punched paper tape

(*iv*) Machine control unit (MCU).

10.20. Discuss the development of NC and CNC machine tools.

10.21. Describe CNC machine tools.

10.22. Discuss the various features of CNC that make it more useful.

10.23. Describe :

(*a*) Absolute system

(*b*) Incremental system of dimensioning used in NC.

10.24. Describe DNC system.

10.25. With the help of schematic diagram explain a numerical control system for simple turning operation.

10.26. Write short note on the following :

(*i*) Computer application in production

(*ii*) B.C.D. system for N.C.

10.27. Discuss the cost of manufacturing a component on N.C. machine tool.

10.28. Describe basic components of an N.C. system.

10.29. Write short notes on the following :

(*i*) Functions of CNC system of machine tools

(*ii*) Advantages of CNC system

(*iii*) Data required for part programming

(*iv*) Machining centre N.C. machine tool

(*v*) Computer aided manufacturing (CAM)

(*vi*) Laser machines for productivity.

10.30. Sketch and describe N.C. system for simple turning on lathe.

10.31. Write short notes on the following :

(*i*) Automatic tool changer (A.T.C.) for C.N.C. machines

(*ii*) N.C. procedure

(*iii*) Process planning sheet.

10.32. Discuss the following :

(*i*) Block and words in N.C. system

(*ii*) Function words in N.C. system of machines

(*iii*) Programming Formats.

11

Testing, Maintenance and Erection of Machine Tools

11.1. Testing of Machine Tools

Machine tools are subjected to various tests before they are sent for sales. Since machine tool consists of various parts assembled together such as motor shafts, couplings, gear, clutches, bearings, coolant pumps, and other structures such as columns, beds, gear boxes, tail stock, head stock etc. Certain basic tests are essential for smooth operation of machine tool. Tests also deal with temperature increase in certain parts such as bearings. The rise in temperature in bearings should be within permissible limits. The entire structure of machine tool should be stiff and rigid. The bed of the machine tool is normally made of cast iron to have more vibration proof characteristics. The amplitude of vibrations should be within the desired range.

The accuracy and surface finish of the parts produced by a machine tool depends upon many factors. One of these factors is the accuracy of the machine tools. Therefore, to produce parts economically and accurately it is essential that the machine tool on which the parts are produced is accurate. An inaccurate machine tool cannot produce accurate parts. To check how accurate a machine tool is it very important to test the machine tool to certain accepted standards.

Testing of a machine tool has the following advantages :

(*i*) By testing of a machine tool it can be put in a proper grade or precision class, thereby helping a purchaser to know what he can expect from the machine tool.

(*ii*) Testing helps in preventive maintenance of a machine tool.

(*iii*) Testing helps in determining the condition of the machine tool and hence its useful life.

There are two types of tests :

(*i*) Geometrical tests or Alignment tests.

(*ii*) Practical tests or Performance tests.

Geometrical tests cover the manufactured accuracy of machine tools. They are checks on the relationship of the various elements of the machine

tool when it idle and unloaded. Such tests include checking the parallelism of the spindle and of a lathe, squareness of the table movement to the spindle of a milling machine and that the taper hole of a drilling machine is running true. Practical tests are used to check the working accuracy of a machine tool. Both these tests are collectively known as Acceptance Tests.

Testing of a machine tool may be carried out in the following cases :

(*i*) Before a machine is despatched from the manufacturer to the customer.

(*ii*) After a new machine has been installed and levelled.

(*iii*) When a machine has been overhauled.

(*iv*) When a machine is not giving satisfactory performance.

Standards for testing of different machine tools were first published by a German called Dr. Georg Schlesinger in 1927. In our country the various tests have been prescribed by Indian Standard Institute, based on the tests formulated by Dr. Schlesinger. In order to ascertain the condition or performance of a machine tool inspection charts are available which enable the manufacture or inspector to check the various alignments against prescribed limits.

The degree of working accuracy of a machine tool, beside, depending on machine tool itself, is also influenced by the following factors :

(*i*) Type of cutting tool and its condition.

(*ii*) Tool material.

(*iii*) Cutting speed, feed and depth of cut.

(*iv*) Material to be machined.

(*v*) Clamping equipment.

(*vi*) Skill of the operator.

11.1.1. Procedure for acceptance test

Acceptance tests cover the grade of accuracy of the machine tool and also its working accuracy.

The following procedure is followed while carrying out acceptance tests :

(*i*) The machine tool is set up and the principal horizontal and vertical planes and axes are checked with a spirit level.

(*ii*) Guiding and bearing surfaces of bends are checked for the following :

(*a*) Parallelism

(*b*) Flatness

(*c*) Straightness.

(*iii*) The various components of the machine tool are checked for movements in different directions.

(*iv*) The main spindle is tested for :

(*a*) Concentricity

(*b*) Axial slip

(*c*) Accuracy of axis.

(*v*) Working tests are carried out on the machine tool to check whether the machine tool produce finished components within the specified limits of accuracy.

Acceptance tests include primary trials and idle run, test, performance test under load, checking whether the machine tool complies with the accuracy standards, and tests to determine the rigidity and vibration proof properties in metal cutting.

The following points are considered in the acceptance test :

(*i*) The levelling test to ascertain the straightness and parallelism of the slide ways is to be done. Dial indicators, test mandrels straight edges, gauge blocks, spirit levels are used for this test. The allowable tolerance is 0.02 mm for a length of 1000 mm.

(*ii*) When the cutting operation is taking place on the machine, certain amount of vibrations are noted. Therefore, machine is to be tested properly whether the amplitude of vibration is within the desired range. Vibration test can be conducted by using transducer which senses the mechanical vibrations and converts into electrical signal which is fed into amplifier which amplifiers the signal.

(*iii*) The operating temperature of bearings should be limited to 80 to 90°C. If the temperature is increased then artificial cooling is to be provided.

Acceptance charts are prepared for the machine tool tests which specify the type of tests and the range of allowable or permissible limits of deformation, deflection, amplitude of vibrations etc.

11.2. Testing Equipment

The various tools and equipment used for carrying out the acceptance tests are as follows :

(*i*) *Dial gauge.* The dial gauge should have clearly readable graduations on sufficiently large dial. It need not be finer than 0.001 mm.

(*ii*) *Spirit level.* Both horizontal and frame type spirit levels are used. It should have a sensitivity varying from 0.03 to 0.05 mm per metre for each division.

(*iii*) *Straight edge and squares.* They are used to check straightness or flatness. They are made up of cast iron or steel. They should have a strong ribbed construction with wide bearing surfaces.

(*iv*) *Test mandrels.* They are used to check the true running of the spindle of the machine tools. They are accurately turned hardened and ground. A test mandrel is so chosen in length and diameter that the deflection due to its weight is negligible.

The test mandrels may have either a taper shank for being fitted in the nose of the machine spindle or a round shank for being held between the centres.

(*v*) Autocollimeter.

(*vi*) Micrometer.

Test charts are compiled for each type of machine tool giving details of tests to be carried out and permissible errors. They are extensively used as guide lines for conducting tests.

11.3. Order of Test

The test is carried in the following order :

(*i*) Accuracy of the machine tool itself.

(*a*) Levelling.

(*b*) Erecting and setting up.

(*c*) Testing the guiding and bearing surfaces.

(*d*) Testing the axes and surfaces in relation to other important units and components.

(*ii*) Accuracy of finished workpiece.

(*iii*) Power consumption.

11.4. Test Chart for General Purpose Parallel Lathes

As per IS 1878 (Part 1) 1971 some of the tests carried out to check the accuracy of general purpose lathes with swing over bed up to 800 mm are as follows :

[For complete details refer IS : 1878 (Part 1) 1971]

(See Table on next page)

11.5. Maintenance of Machine Tools

The machine tool users expect a machine tool to produce accurate workpiece within specified limits not only when it is new but throughout its working life. For this reason the wear of the machine tool must not exceed certain limits and parts which become fault due to wear or other damages must be replaced or repaired without delay.

The direct object of machine tool maintenance is to delay the deterioration which takes place and to avoid disruption to the production programme. Improved maintenance would reduce machine tool down time and lead to higher productivity and subsequent lower the production cost. Good maintenance is in fact good management.

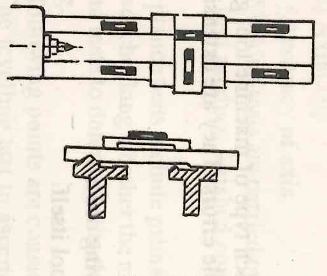
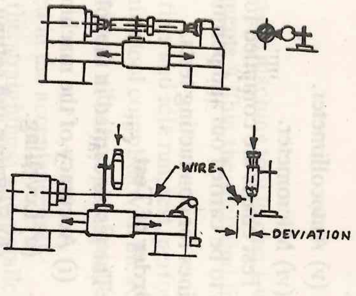
Maintenance can be defined under three main headings as follows :

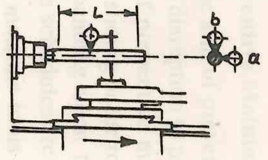
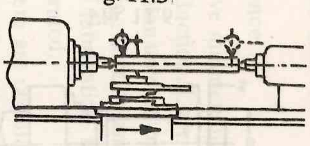
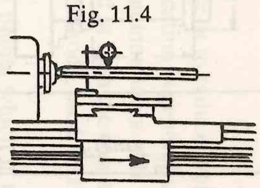
(*i*) Preventive maintenance.

(*ii*) Corrective maintenance.

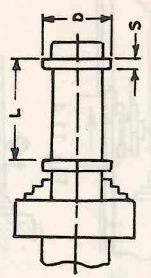
(*iii*) Reconditioning.

Geometrical Tests

Part Name	*Object*	*Measuring Instrument*	*Permissible deviation*	*Figure*
1. Bed	Straightness of carriage slide ways (*a*) In longitudinal direction	Spirit level	0.02 mm per 1000 mm	
	(*b*) In transverse direction	Spirit level	0.04 mm per 1000 mm	Fig. 11.1
2. Carriage	Straightness of carriage in a horizontal plane	(*a*) Dial gauge and test mandrel	0.02 to 0.03 mm per 1000 mm	
		(*b*) Taut wire and microscope		Fig. 11.2

Part Name	*Object*	*Measuring Instrument*	*Permissible deviation*	*Figure*
3. Head stock spindle	Parallelism of spindle axis to the carriage movement (*a*) In horizontal plane (*b*) In vertical plane when maximum value of L is 300 mm	Dial gauge and mandrel	(*a*) 0.015 per 300 mm free and end of mandrel inclined towards tool only (*b*) 0.02 per 300 mm free end of the mandrel inclined upward only	 Fig. 11.3
4. Centres	Difference in height between head stock and stock centres	Dial gauge and test mandrel	0.06 mm per 1000 mm. Tail Stock centre higher than head stock centre.	 Fig. 11.4
5. Tool slide	Parallelism of the longitudinal movement of the tool slide to the spindle axis	Dial gauge and test mandrel	0.04 mm per 300 mm free end of the mandrel inclined upward only.	 Fig. 11.5

Practical Test

Nature of test	*Cutting condition*	*Check to be applied*	*Measuring intrument*	*Observations*	*Permissible deviation*	*Figure*
Turning of cylindrical test piece held in chuck	Machining of two diameters and cylinder over a maximum length of S = 20 mm	(*a*) Roundness (*b*) Cylindricity	Micrometer	Test pieces to be finish machined on the two collars in one pass of the tool	(*a*) 0.01 mm (*b*) 0.04 for *L* = 300 mm	 Fig. 11.6

11.6. Preventive Maintenance

The aim of preventive maintenance is to reduce wear and tear and to prevent to disruption to production. Lubrication is generally considered to be the heat of preventive maintenance of machine tools. All moving parts are subject to sliding or the rolling friction and in both the cases the lubrication is must. Depending upon the lubrication methods used in the machine tool, lubrication schedules are formed.

In machine tools there are certain points which if not checked periodically not only reduce the efficiency of the machine but tool also may lead to major break-down. Therefore, regular inspection of such points is quite essential. All wearing parts in the machine tool or the parts subjected to fatigue are replaced normally before failing in a preventive maintenance system.

Preventive maintenance is the planned maintenance of machine tools and equipment. A regular planned preventive maintenance consists of a minor and medium repairs and major overhauls. Preventive maintenance plays an important role in achieving reliability in the use of the system. The preventive maintenance programme can account for the most efficient operation of machines which can result in high productivity. Adequate number of the personnel should be used for preventive maintenance. If there are too many maintenance people the cost of keeping them is excessive and if too less the cost of idle time equipment looms large. Fig. 11.7 is between cost (*O*) and number of maintenance personnel (*N*). The total cost is indicated by curve *A* whereas cost of idle personnel is indicated by curve *B* and cost of idle equipment is indicated by curve. *E*. To minimise cost the optimum number of personnel (*P*) should be used.

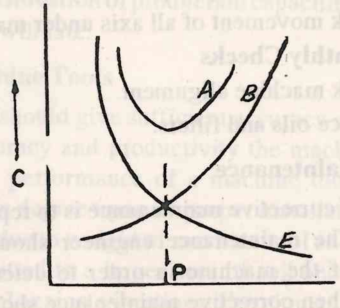


Fig. 11.7

A well conceived preventive maintenance programme should contain the following features :

(*i*) Adequate records covering volume of cost and work.

(*ii*) Inspection frequency schedule.

(*iii*) Proper identification of all items to be included in preventive maintenance programme.

(*iv*) Well qualified personnels for maintenance.

Preventive maintenance is essential to keep the machine in order for production and safety. Reliability safety and above all availability of right machine at right point of time are the other advantages of preventive maintenance.

A proper preventive maintenance schedule should be followed such as under :

(*i*) **Daily Checks**

The following duties should be performed by the operator.

(*i*) To clean the machine.

(*ii*) To check lubricating oil levels and oil flow in sight glasses.

(*iii*) To check coolant level.

(*iv*) To keep the maintenance department informed of even the minor defects noted in the performance of the machine.

(*ii*) **Weekly Checks**

The following checks should be carried out by the maintenance department :

(*i*) To check all lubrication levels

(*ii*) To check coolant.

(*iii*)To check all filters.

(*iv*) To check hydraulic and pneumatic lines.

(*iii*) **Monthly Checks**

(To be carried out by the maintenance department).

(*i*) To check spindle drive belts for wear.

(*ii*) To check hydraulic pumps and hydraulic oil.

(*iii*) To check movement of all axis under manual dial in control.

(*iv*) **Six Monthly Checks**

(*i*) To check machine alignment.

(*ii*) To replace oils and filters.

11.7. Corrective Maintenance

To object of corrective maintenance is to replace the worn part and to carry out repair. The maintenance engineer should regularly inspect the specific elements of the machine in order to determine whether wear has reached the stage when corrective maintenance should be carried out before failure occurs. When inspection shows that corrective action is necessary the machine tool should be withdrawn from production. It is essential to maintain a record of the nature and cost of all repairs carried out. This will help to bring to light those elements of machines which need improved servicing, more frequent inspection or modification to the machine design. Such records also help in taking the decisions regarding the need for reconditioning and replacement.

11.8. Reconditioning

It is the rebuilding of the machine so that it gives the required production. The need to recondition the machine can be determined by the frequency of the corrective maintenance. There is certain life span of every machine tool and component after which it becomes unserviceable inspite the best possible planned and preventive maintenance carried out during its useful life. This is the stage when major overhaul or reconditioning is called for. Thorough inspection of machine tool should be made. The inspection report should indicate the details of the components required to be replaced during reconditioning and the skilled labour required to accomplish the task. A rough estimate of the cost is prepared and generally it is undesirable to recondition the machine tool if the cost of parts to be replaced and repaired exceeds 50% of the prevailing cost of the new equipment. Another very important aspect governing the decision to recondition the machine tool is the time factor. It is very important to estimate the time required to put the machine back in normal operation considering the availability of reconditioning facilities and spares required for replacement. This will give the figures of production loss due to direct or inter related effect on manufacturing process. Sometimes replacement proves to be more economical that to recondition the machine.

The basic principles for maintenance, repair and rebuilding of the machine tools are identical with those for manufacturer of the machine tools. Test charts of machine tool provide best information regarding its accuracy and performance.

The design and manufacture and subsequent industrial application of new models of machine tools is one of the major factors in increasing productivity. Periodic renovation of production capacities is essential to ensure a normal economic growth rate.

11.9. Erection of Machine Tools

A machine tool should give sufficient accuracy and should be reliable. To achieve higher accuracy and productivity the machine tool should have dynamic stability. The performance of a machine tool and its service life depend to a considerable degree upon its proper installation on the foundation which enables the load due to weight of machine tool and mounted workpiece to be uniformly transmitted to a larger area of soil and secondly foundation protects the machine tool against vibrations. Erection of a machine tool means placing it on the foundation. Erection of machine tools should be carried out with maximum care and as per the instructions given in the operating manuals supplied by respective machine tool manufacturers. Poor erection of machine tools causes many problems. Erection of machine tool should be carried out by skilled labour and supervisions. Successful and efficient operation of machine tool depends greatly on erection of machine tools. Some general rules followed during erection of machine tools are as follows :

(*i*) Foundation made for the machine tool should be such that machine tool works vibration free.

(*ii*) Foundation bolts should be placed as per recommendations of machine tool suppliers keeping enough space for final concreting of bolts.

(*iii*) The quality of soil for foundation should be determined. It should be rigid and should not get settled by external pressure.

(*iv*) The machine tool should be isolated from vibration sources by using materials like rubber, cork, springs etc.

After erecting the machine tool perfect levelling of machine tool should be done. It is necessary that the proper alignment is produced when the machine tool is erected on its foundation. The foundation bolts should be tightened evenly and firmly.

11.10. Foundation

Foundation should be strong enough to support the machine tool. The foundation is made up of the following materials :

(*i*) Plain concrete or reinforced concrete.

(*ii*) Masonry of bricks or stones.

(*iii*) Combination of concrete and masonry.

(*iv*) Structural steel.

PROBLEMS

11.1. Why testing of machine tool is essential ?

11.2. Describe

(*a*) Geometrical tests (*b*) Practical tests

(*c*) Acceptance test.

11.3. Write short notes on the following :

(*a*) Testing equipment (*b*) Order of carrying out a test

(*c*) Two geometrical tests for a general purpose lathes with swing over bed upto 800 mm.

11.4. What is maintenance of machine tools ?

11.5. Describe the following :

(*a*) Preventive maintenance

(*b*) Corrective maintenance

(*c*) Reconditioning of tools.

(*d*) Erection of machine tools.

11.6. Describe the procedure for acceptance test.

11.7. State the advantages of testing of a machine tool.

12 Typical Problems

12.1. Measurement of Tool-chip Inter-face Temperature

Several methods have been used for measuring temperatures at the chip tool inter face. Tool work thermocouple is quite commonly used to measure the tool-chip interface temperature.

In this method the tool-work contact area serves as the hot junction in a thermo-electric circuit and the e.m.f. generated is proportional to its temperature. The e.m.f. developed is measured by a suitable millivoltmeter.

The e.m.f. in the thermoelectric circuit depends only on the difference in temperature between the hot and cold functions. Fig. 12.1 shows the thermocouple technique to measure the tool chip interface temperature for a work piece fitted on a lathe in which the chip and tool junction constitutes the hot junction while *A* and *B* the cold junction remain at room temperature.

Tool life is more dependent upon the temperature reached at the tool chip interface than the total amount of heat following into the tool or work.

The rate of tool wear is generally observed to increase with increased tool temperature.

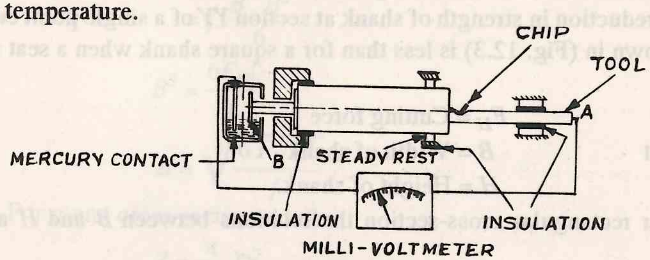


Fig. 12.1

12.2. Measurement of Cutting Forces

The cutting forces are measured in order to achieve the following :

(*i*) To determine the power required during cutting process.

(*ii*) To observe the characteristics of workpiece and tool material.

(*iii*) Cutting forces when determined help in proper design of machine tool components.

The cutting forces are generally measured by an instrument called cutting tool dynamometer. There are different designs of dynamometers although their basic principle is same. The general principle used in deflection type cutting tool dynamometer is shown in Fig. 12.2. A stiff member M resting on a solid pivot carries a cutting tool at one end and is attached to a frame N by means of a leaf spring at the other end. The cutting force F_H deflects the member M relative to N by an amount depending on the magnitude of F_H and stiffness of spring. The deflection so produced is taken up by the dial gauge which is calibrated to real the magnitude of F_H proportional to deflection. The feed force (F_V) can be measured by housing the frame in a further solid member so that it deflects in a plane perpendicular to the plane of the given projection.

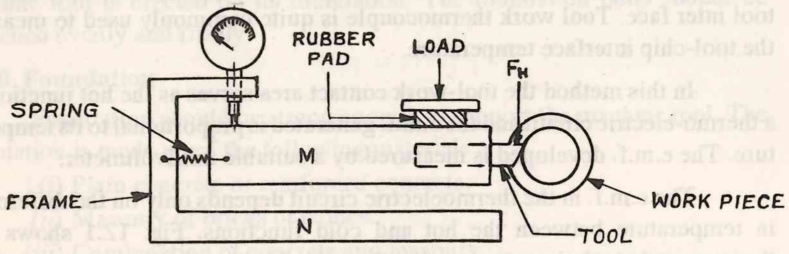


Fig. 12.2

12.3. Design of a Single Point Lathe Tool

The design on the cutting tool depends upon the cutting forces acting on the cutting surfaces of the tool and rigidity of the machine on which cutting tool is used. The shank of a single point tool may be rectangular, square or rounding cross-section. The rectangular cross-section is commonly used because the reduction in strength of shank at section YY of a single point cutting tool as shown in (Fig. 12.3) is less than for a square shank when a seat is cut for a tip.

Let F_H = Cutting force
B = Width of shank
H = Height of shank.

For rectangular cross-section the relations between B and H are as follows :

$$\frac{H}{B} = 1.25 \text{ for roughing operations}$$

$$\frac{H}{B} = 1.6 \text{ for semi-finishing and finishing operations.}$$

The minimum permissible size of the shank cross-section on strength basis is calculated by equating the actual bending moment to the maximum moment permitted by cross-section of the shank.

M_1 = Bending moment due to cutting force F_H

$$= F_H \times l$$

where l = Cutting tool overhang
($l \cong 1$ to $1.5\,H$)

M_2 = Maximum moment permitted by the cross-section of the shank

$$= f \times Z$$

where f = Permissible bending stress for the shank material
Z = Section modulus of the tool shank

$$\therefore \quad M_1 = M_2$$

$$F_H \times l = f \times Z$$

For rectangular cross-section of tool shank

$$Z = \frac{BH^2}{6}$$

$$\therefore \quad F_H \times l = f \times \frac{BH^2}{6}$$

$$BH^2 = \frac{6F_H \cdot l}{f}$$

$$H = \sqrt{\frac{6F_H \cdot l}{f \cdot B}}$$

For square cross-section shank

$$F_H \times l = f. \frac{BH^2}{6}$$

$$= f. \frac{B \cdot B^2}{6}$$

$$B^3 = \frac{6F_H l}{f}$$

$$B = \sqrt[3]{\frac{6\,F_H \cdot l}{f}}$$

For round cross-section shank

$$Z = \frac{\pi}{32} D^2$$

where D = Diameter of shank.

$$F_H = fZ.$$

$$= f. \frac{\pi}{32} D^3$$

$$D^3 = \frac{32.\,F_H \cdot l}{\pi \times f}$$

$$D = \sqrt[3]{\frac{32F_H \cdot l}{\pi f}}$$

Square shank tools are commonly used for boring machines, screw machines and turret lathes. Round shank tools are generally used for boring and thread cutting operations.

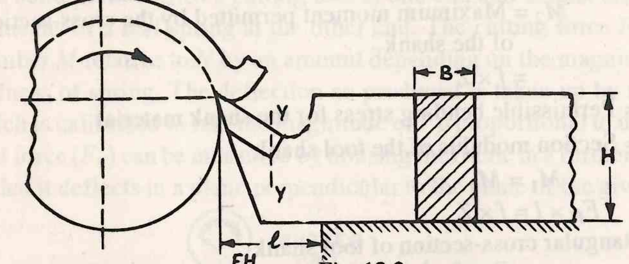


Fig. 12.3

Example 12.1. *In orthogonal cutting of a mild steel bar on a lathe the feed (f_1) used is 0.3 mm per revolution and the depth of cut (t) is 2 mm. Determine the cross-section of a rectangular tool, shank if the allowable stress in the shank material is 7 kg/m² and the cutting force (F_H) can be calculated by the relation $F_H = 200 \times f_1^{0.75} \times t$.*

Solution. Let H = Height of a shank

B = Width of shank

$$\frac{H}{B} = 1.6 \text{ (assume)}$$

we know
$$H = \sqrt{\frac{6F_H \cdot l}{f \cdot B}}$$

where F_H = cutting force

$= 200 \times f_1^{0.75} \times t$

$= 200 \times 0.3^{0.75} \times 2$

$= 170$ kg.

t = Cutting tool overhang

$= 1.25\,H$ (assume)

$= 7$ kg/mm²

$$H = \sqrt{\frac{6 \times 170 \times 1.25\,H}{7 \times \frac{H}{1.6}}}$$

$H = 17$ mm.

$$B = \frac{H}{1.6} = \frac{17}{1.6} = 10.6 \text{ mm. Ans.}$$

12.4. Hydraulic Drive for Shaper

Fig. 12.4 shows the hydraulic shaper mechanism. During forward stroke of the ram the oil under pressure is pumped from the reservoir to the right side of the oil cylinder. Which exerts pressure on the piston. This causes

the ram connected to the piston to perform the forward stroke. The oil present on the left side of the cylinder flows through the throttle valve to the reservoir. On the completion of forward stroke of the ram the reversing dog presses the reversing lever and the positions of the valves (*V*) is changed. The oil under pressure is then pumped to the left side of the piston and the ram performs the return stroke and any oil present on the right side of piston flows to the reservoir. On completion of the return stroke the reversing dog operates the reversing lever and position of valves (*V*) is changed and oil under pressure again flows to the right side of the piston and the forward stroke of ram takes place. This way the cycle continues.

The return stroke of the ram is completed in less time as compared to forward stroke because the constant discharges oil pump, within a fixed period

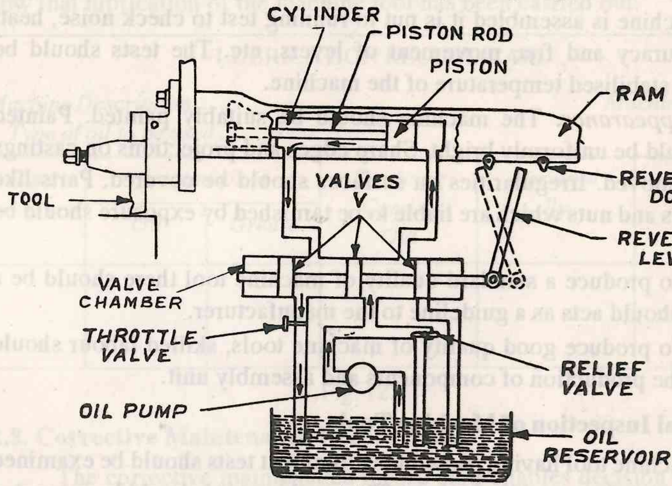


Fig. 12.4

pumps same amount of oil into the right or left hand side of the cylinder and as the left hand end smaller is due to the presence of the piston rod, therefore the oil pressure will be more on the left hand end and piston will be moved back at faster speed. Thus the return stroke will be completed in lesser time.

The throttle valve and relief valves are used to change the cutting speed. When throttle valve is partially closed the excess oil flows to the reservoir through the relief valve and a uniform pressure is maintained during the cutting stroke.

12.5. Quality and Performance of a Machine Tool

The real criterion of a machine tool is the accuracy of the work it produces over a long period.

The quality and performance of a machine tool depends upon the following factors :

(*i*) *The technical standard of design.* In developing a machine tool it is necessary to test the prototype thoroughly to ensure that the design meets the requirements aimed at :

(*ii*) *Materials.* The use of correct materials and proper manufacture of components and assembly are quite essential to get quality and proper output from the machine tool. Hardness of important parts like bed of the machine tool should be checked at different points of the guide ways to make sure that the hardness is uniform. Important parts should be stress relieved after rough machining.

(*iii*) *Inspection.* To maintain quality rigid inspection is required in all the stages. In sub-assembly all the units are assembled and tested before it is given for final assembly. During sub-assembly it is checked in every stage. After the machine is assembled it is put to running test to check noise, heat, working accuracy and free movement of levers, etc. The tests should be conducted at stabilised temperature of the machine.

(*iv*) *Appearance.* The machine should be suitably painted. Painted surfaces should be uniformly bright. Sharp edges and projections on castings should be removed. Irregularities on surfaces should be covered. Parts like levers, screws and nuts which are liable to be tarnished by exposure should be electroplated.

(*v*) To produce a standard quality of machine tool there should be a code which should acts as a guideline to the manufacturer.

(*vi*) To produce good quality of machine tools, skilled labour should be used for the production of components and assembly unit.

12.6. General Inspection of Machine Tools

A machine tool having passed the alignment tests should be examined for mechanical defects and limitations. The machine tool should be inspected to ensure that :

(*i*) The machine tool works satisfactorily at all designed feeds and speeds.

(*ii*) The gears, belts, pulleys etc. run quietly at all speeds.

(*iii*) There are no vibrations during cutting operations.

(*iv*) The lubrication system functions properly.

(*v*) The operating levers clear each other in the minimum positions.

(*vi*) Safety devices are fitted on the machine tool to avoid accidents.

12.6.1. Care and maintenance of machine tools

Machine tools should be handled carefully in order to give good and longer service. The following precautions are essential to maintain a machine tool in good condition.

(*i*) The machine tool should be cleaned frequently.

(*ii*) The electric motor should be protected from dust and moisture.

(*iii*) The guide ways should be protected from foreign materials like chips.

(*iv*) Before starting the work, check whether all levers are in position.

(*v*) All hand lubricating points should be lubricated daily. Poor lubrication causes early wear.

(*vi*) The temperature of the bearings should not exceed the body temperature.

(*vii*) The machine tool should not be over loaded.

12.7. Lubrication Record Card

A record card of the type shown in Fig. 12.5 should be maintained to show that lubrication of the machine tool has been carried out.

LUBRICATION RECORD CARD

Machine Description ...... *Macnine No. ....*
Type of oil to be used ....

Date	*Amount Used*		*Servicing Carried Out*	*Serviced By*	*Approved By*
	Oil	*Grease*			

Fig. 12.5

12.8. Corrective Maintenance Record Card

The corrective maintenance record card enables decision to be made regarding the need to withdraw the machine tool from production not only for corrective maintenance record card is shown in Fig. 12.6.

CORRECTIVE MAINTENANCE RECORD CARD

Machine Description .... *Machine No. ....*
Department ....

Date	*Maintenance Breakdown*	*Replacement Parts*			*Down Time Hours*	*Total Cost of Repairs*	*Remarks*
		Ordered	*Received*	*Cost*			

Fig. 12.6

12.9. Geneva Wheel Mechanism

Geneva mechanisms are used in Machine tools mainly in indexing devices with a constant angle of periodic rotation. They are commonly used in indexing of spindle carriers in automatic and semi automatic lathes, and of turrets. They are also used in indexing rotary table of a rotary indexing table transfer machine. Fig. 12.7 shows the principle of geneva indexing mechanism. This mechanism make use of a genera plate, locking plunger, an indexing plate and a pin. The geneva plate can have any number of slots to suit the number of machining stations. One revolution of the indexing plate pushes the slotted geneva plate having six equally spaced slots as shown in the figure through one sixth of a revolution by means of the pin engaging the slot. The locking plunger then engages positively with the table to lock it in position after each indexing.

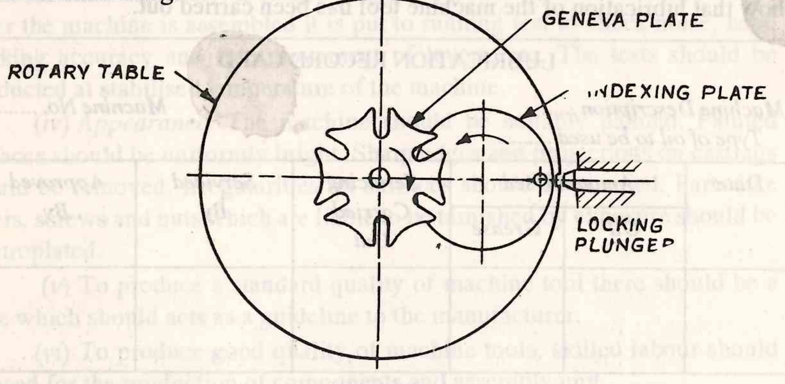


Fig. 12.7

12.10. High Speed Steel (H.S.S.) Tools Bits

The hardened and ground H.S.S. bits are available in the following general sizes :

6 × 6 × 100 mm.
8 × 8 × 100 mm.
10 × 10 × 100 mm.
12 × 12 × 150 mm.
16 × 16 × 150 mm.
20 × 20 × 150 mm.
25 × 25 × 150 mm.

H.S.S. tool bits have an average chemical composition as follows :

C = 0.75%
W (Tungsten) = 18%
Cr. (Chromium) = 4%
V (Vanadium) = 1%
Cobalt = 5 or 10%

(5% cobalt H.S.S. is used for free machining steel whereas 10% cobalt H.S.S. is used for high tensile steel).

12.10.1. Specifying a Single Point Tool

The following details should be specified while ordering a single point tool.

(*i*) Shape of the tool.
(*ii*) Size of the shank.
(*iii*) Grade of the carbide tip.
(*iv*) Direction of cutting.
(*a*) Right Hand (R.H.)
(*b*) Left Hand (L.H.)

12.11. Valves Used in Hydraulic Systems

Some of the valves commonly used in hydraulic systems of machine tools are as follow :

(*i*) Throttle valve.
(*ii*) Pressure relief valve.
(*iii*) Non-return valve.
(*iv*) Pressure valve.

Throttle Valve or Flow Control Valve

The throttle valve is used to regulate a fluid flow to an adjust able value. Fig. 12.8 shows a throttle valve. The fluid entering the valve goes out through an annular gap. This gap is the throttle which can be enlarged or reduced by means of throttling screw.

In these valves the area of the constricted passage is varied by displacing a movable member. Fig. 12.8 (A) shows a globe valve in which the moving member is a disc whereas in needle valve [Fig. 12.8 (B)] the moveable member is a needle. Both globe valve and needle valves are throttle valves.

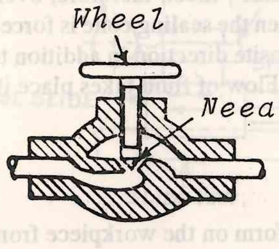


Fig. 12.8 (A)

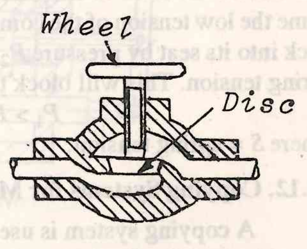


Fig. 12.8 (B)

Pressure Relief Valve

It relieves the working pressure at definite present pressure and safe guard the system against over loading due to high pressure.

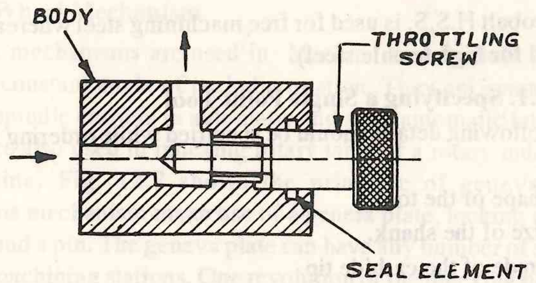


Fig. 12.8

A pressure relief valve is shown in Fig. 12.9. In the initial position the cone is pressed by the compression spring into the mouth of the hole. When the fluid force *P* exceeds the spring pressure the cone is pushed back and the fluid comes out through the opening. The tension exerted on the cone can be set by means of adjusting screw and compression spring.

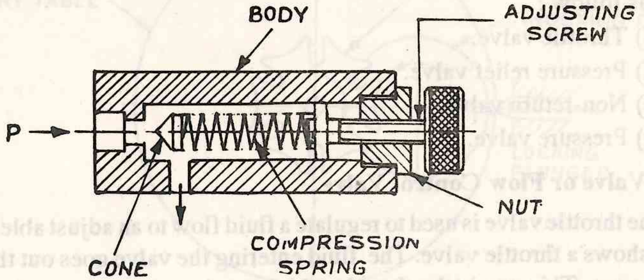


Fig. 12.9

Non-return Valve

It is used to allow the confined fluid to flow in one direction only. The flow in the opposite direction is blocked. A non-return valve is shown in Fig. 12.10 when a pressure *p*, impacts on the sealing cone it is lifted from its seat and allows the fluid to flow through. The pressure P_1 must, therefore, overcome the low tension of the compression spring then the sealing cone is forced back into its seat by pressure P_2 acting in the opposite direction in addition to spring tension. This will block the flow of fluid. Flow of fluid takes place if,

$$P_1 > P_2 + S$$

where S = spring tension.

12.12. Copying Systems for Machine Tools

A copying system is used to reproduce a form on the workpiece from a template within the limits of accuracy required. Many copying systems are available for almost all types of machine tools, some built as an integral part of the machine tool while some are fitted as an attachment. The copying systems are of the following types depending upon the power used by the system.

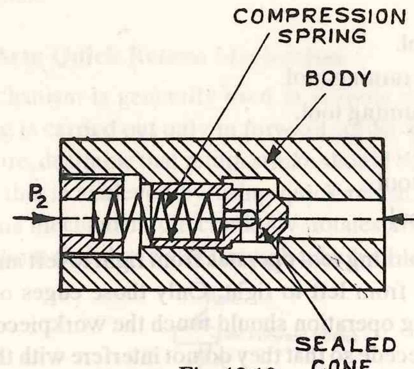


Fig. 12.10

(*i*) Hydraulic copying system.
(*ii*) Mechanical copying system.
(*iii*) Electric copying system.
(*iv*) Pneumatic copying system.

Fig. 12.11 shows the principle of operation of a hydraulic copying system for a lathe. In this system when the lathe saddle traverses along the bed the stylus follows the template the stylus is always kept in contact with the template by spring pressure. When the stylus while following the template moves to the right, the spool also move to the right and the oil to the left of the piston flows out and then oil flows to the right of the piston and pushes the piston to the left. Thus the tool slide and tool will move to the left reproducing the template shape upon the workpiece. The accuracy of the system depends upon the accuracy with which the spool valve is manufactured.

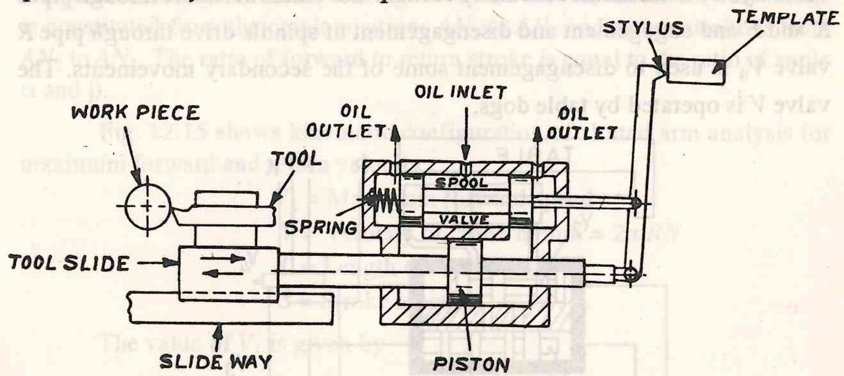


Fig. 12.11

12.13. Types of Tool Bits

The various types of tool bits shown in Fig. 12.12, are as follows :

1. Parting tool.

2. Turning tool.
3. Right hand turning tool.
4. Left hand turning tool.
5. Radius tool.
6. Threading tool.
7. Chamber tool.

A right hand turning tool operates from right to left and that a left hand turning tool operates from left to right. Only those edges of tool which are involved in the cutting operation should touch the workpiece. All other faces should be ground to recede so that they do not interfere with the cutting action.

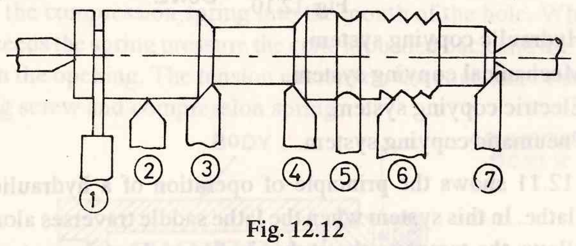


Fig. 12.12

12.14. Hydraulic Drive for Milling Machine

Fig. 12.13 shows a typical hydraulic circuit for milling machine. M is a variable delivery pump controlled by table dogs. Oil is supplied by the gear pump N to the pilot valve V_3 for controlling the valves V_1 and V_2 whereby direction and rate of the table movement respectively are determined. The valve V_3 also controls the secondary vertical movement of saddle through pipes K and F and engagement and disengagement of spindle drive through pipe R valve V_4 is used to disengagement some of the secondary movements. The valve V is operated by table dogs.

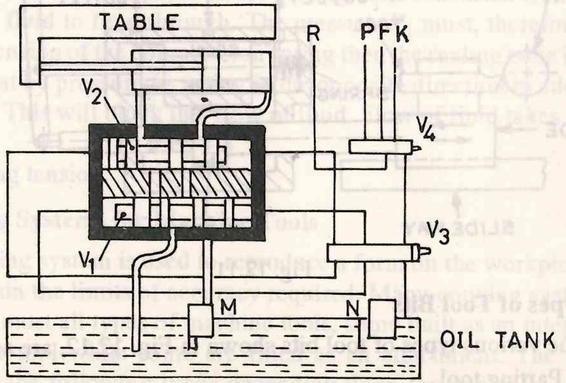


Fig. 12.13

12.15. Slotted Arm Quick Return Mechanism

The mechanism is generally used in shaping machine. In shaper the cutting operating is carried out only in forward stroke and backward stroke is idle. It is, therefore, desirable that return stroke should be completed as quickly as possible and this is achieved by using quick return mechanism shown in Fig. 12.14. In this mechanism the crank AN rotates about centre A. The link OM can rotate about O. It has a slot through which a block N can slide. When

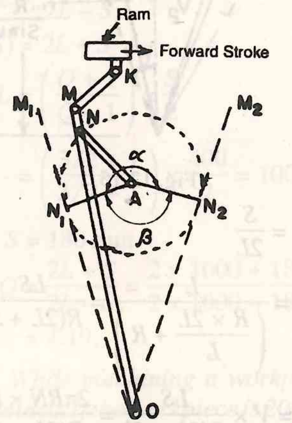


Fig. 12.14

the crank rotates about A link OM oscillates about centre O between its ultimate position OM_1 and OM_2. The oscillating motion of OM makes the ram to reciprocate through link MK. During clockwise movement the forward stroke is constituted from the crank positions AN_1 to AN_2 and return stroke is from AN_2 to AN_1. The ratio of forward to return stroke is equal to the ratio of angle α and β.

Fig. 12.15 shows kinematic configuration of slotted arm analysis for maximum forward and return velocity

V_1 = Maximum forward speed
V = Velocity of crank m/min = $2\pi RN$
L = Length of slotted arm
S = Stroke length

The value of V_1 is given by

$$\frac{V_1}{V} = \frac{L}{\left(\frac{R}{\sin\psi} + R\right)}$$

where R = crank radius in metre
N = crank R.P.M.

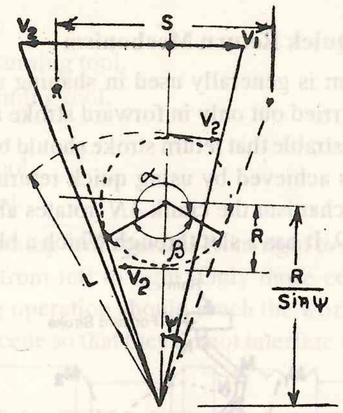


Fig. 12.15

Now $\sin \psi = \frac{S}{2L}$

$$\frac{V_1}{V} = \frac{L}{\left(\frac{R \times 2L}{L} + R\right)} = \frac{LS}{R(2L + S)}$$

$$V_1 = V \times \frac{LS}{R(2L + S)} = \frac{2\pi RN \times LS}{R(2L + S)}$$

$$= \frac{\pi N \times LS}{S + \frac{S}{2}}$$

Again V_2 = Maximum return speed

$$\frac{V_2}{V} = \frac{L}{\left(\frac{R}{\sin \psi} - R\right)}$$

$$V_2 = \frac{2\pi RN \, . \, L}{\left(\frac{R \times 2L}{S} - R\right)}$$

$$= \frac{\pi NL \, . \, S}{L - \frac{S}{2}}$$

$\therefore$ Q = Maximum quick return ratio

$$= \frac{V_2}{V_1} = \frac{\pi NLS}{L - S/2} \times \frac{L + S/2}{\pi NLS}$$

$$= \frac{2L + S}{2L - S}.$$

Example 12.2. *In a slotted arm quick return mechanism for a shaping machine the maximum quick return ratio is 3/2 and design stroke is 400 mm. Calculate the value of maximum quick return ratio when stroke is 180 mm.*

Solution. Q = Maximum quick return ratio = 3/2

L = Length of slotted arm

S = Stroke = 400 mm.

We know that

$$Q = \frac{2L + S}{2L - S}$$

$$Q\,(2L - S) = 2L + S$$

$$L = \left(\frac{Q + 1}{Q - 1}\right) \times \frac{S}{2}$$

$$= \left(\frac{3/2 + 1}{3/2 - 1}\right) \times \frac{400}{2} = 1000 \text{ mm.}$$

When S = 180 mm.

$$Q = \frac{2L + S}{2L - S} = \frac{2 \times 1000 + 180}{2 \times 1000 - 180}$$

$$= 1.19.$$

Example 12.3. *While machining a workpiece on a shaper a quick return ratio of 3/2 is obtained. If the workpiece is 200 mm long and is machined at a cutting speed of 18 metres per minute, calculate R.P.M. of crank.*

Solution. Q = Quick return ratio

$$= \frac{3}{2}$$

V = cutting speed = 81 m/min

L = Length of workpiece (stroke length)

= 200 mm.

N = R.P.M. of crank

The cutting speed is given by

$$V = \frac{N.L.(1 + 1/Q)}{1000}$$

$$18 = \frac{N \times 200 \times (1 + 2/3)}{1000}$$

N = 54 R.P.M.

12.16. Fellow's Gear Shaper

Gear shapers may be automatic and semi-automatic. They are used to cut external and internal spur and helical gears, cluster gears, gear racks etc. In gear shaping machines the cutting tool is either a rack type cutter (Fig. 12.16) or a rotary type cutter (Fig. 12.17).

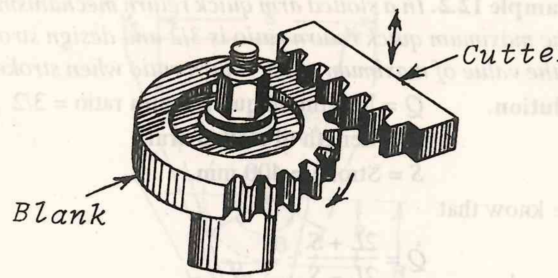


Fig. 12.16

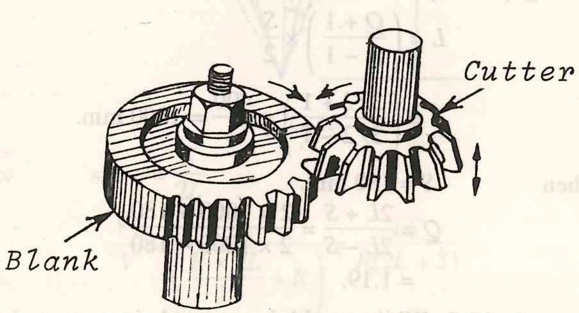


Fig. 12.17

Fellow's Gear shaper uses a rotary type cutter. This gear shaper has the following motions (Fig. 12.18).

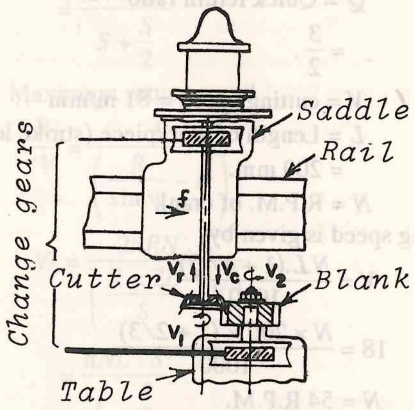


Fig. 12.18

(*i*) The straight line primary cutting motion (V_c) achieved by travel of cutter only in one direction during cutting stroke and return (V_r) of cutter to initial position during return stroke.

(*ii*) To obtain circular feed (indexing motion) there is continuous rotation of shape cutter at speed V_1 and gear blank at V_2. Change gears are used to co-ordinate the speeds of cutter and blank in such a manner that in one revolution of cutter blank makes T_c/T_g where T_c is the number of teeth on cutter and T_s is the number of teeth on gear to be cut.

(*iii*) The feed in motion (*f*) which may be radial or circular of cutter is obtained by travel of cutter axis in a direction towards the blank axis with reciprocation of cutter and, circular feed. The feed in motion comes stops automatically when the cutter has fed into the required depth of teeth while the cutting motion continues till the gear blank makes one revolution so that all the teeth get cut. Then the machine is automatically stopped. There can be one, two or three passes to cut the gear.

(*iv*) The table with the blank is withdrawn from the cutter or the cutter is withdrawn from blank during each return stroke. This is done to prevent rubbing and consequent intensive wear of cutting edges and damage to gear to tooth profile.

Example 12.4. *The force on the cutting tool of a planning machine is 800 kg and the table of the machine, makes a total of 300 forward and return strokes per hour of length 1.8 metre. The friction resistance on the forward (cutting) stroke is 60 kg. Calculate the power required neglecting friction on the return stroke. If the table is driven by hydraulic pressure on a piston 80 mm diameter determine the hydraulic pressure on the piston.*

Solution. N = Number of cutting strokes per second

$$= \frac{300}{60 \times 60} \times \frac{1}{2} = \frac{1}{24}$$

Speed of table $= 1.8 \times \frac{1}{24} = \frac{3}{40}$ metre per second

W_1 = Work done is cutting

= Cutting force × Speed

$$= 800 \times \frac{3}{40}$$

= 60 kg-m per sec.

W_2 = Work done against friction

= Friction force × Speed

$$= 60 \times \frac{3}{40} = 4.5 \text{ kg-m per sec.}$$

W = Total work done

$W = W_1 + W_2 = 60 + 4.5$

= 64.5 kg-m per sec.

$$\text{H.P.} = \frac{64.5}{75} = 0.86$$

Let p = pressure on the piston (kg/cm^2)

A = Area of piston

$$= \frac{\pi}{4} D^2 \text{ (cm}^2\text{)}$$

where D = Diameter of piston in cms.

Total force on piston $= 800 + 60$

$= 860$ kg.

$$p \times \frac{\pi}{4} D^2 = 860$$

$$p \times \frac{\pi}{4} 8^2 = 860$$

$p = 17$ kg/cm^2. **Ans.**

Example 12.5. *A medium carbon steel black is to be machined with a high speed steel tool bit on a crank shaper. The ratio of return time to cutting time is 2 : 3 and feed is 0.25 mm per stroke. If the width of blank is 100 mm, length of stroke is 150 mm and cutting speed is 25 metre per minute determine the following :*

(a) Machining time,

(b) Return speed.

Solution. V_1 = Cutting speed

V_2 = Return speed

B = Width of block

L = Length of stroke

f = Feed.

Cutting stroke time (T_1)

$$= \frac{L}{v_1} = \frac{150}{25 \times 1000}$$

$= 0.006$ minute.

T_2 = Return time,

$$\frac{T_2}{T_1} = \frac{2}{3} \text{ (Given)}$$

$$T_2 = \frac{2}{3} \times T_1 = \frac{2}{3} \times 0.006 = 0.004 \text{ minute.}$$

Total time per cycle (T_3)

$= T_1 + T_2$

$= 0.006 + 0.004 = 0.01$ minute

Number of cycles required (N)

$$= \frac{B}{f}$$

$$= \frac{100}{0.25} = 400$$

T = Total machining time

$= T_2 \times N = 0.01 \times 400$

$= 4$ minutes. **Ans.**

$$V_2 = \text{Return speed} = \frac{3}{2} V_1 = \frac{3}{2} \times 25$$

$= 37.5$ metre per min. **Ans.**

Example 12.6. *The circumference of a regulating wheel on a centre-less grinder is 300 mm and its P.P.M. is 400. Determine the angle of regulating wheel to achieve a through feed of 830 cm per minute.*

Solution. The feed (f) of the work is given by

f S.N. sin α

N = R.P.M. of feed wheel

α = Angle of inclination of the regulating wheel.

Now $f = 830$ cm per minute

$S = 300$ mm $= 30$ cm.

$N = 400$ R.P.M.

$840 = 30 \times 400 \times \sin \alpha$

$\alpha = 4°$. **Ans.**

12.17. Care and Maintenance of Cutting Tools

A properly maintained cutting tools has more life. The main causes of deterioration of a tool are as follows :

(i) Damaging during use. It is always desired to use tool properly. Wrong application of tool damages the tool.

(ii) Deterioration when not in use. The tools are deteriorated because of corrosion when not in use keeping a light film of oil on tools prevents the tools from rusting.

(iii) Damage during storage. Damage during storage usually results when cutting tools are piled up together in a tool box or drawer. Edged tools are best storaged on a panel in clips or racks tool remaining separate from the next.

(iv) Loss of sharpness. When the tool looses sharpness at the cutting edge it should be sharpened in time.

12.18. Effect of Various Factors on the Axial Thrust and Torque in Drilling

The various factors which have effect on axial thrust F (see Fig. 1.48) and torque (T_1) are as follows :

(i) Composition and hardness of material. The greater the tensile strength and hardness of work piece material the greater the axial the thrust and the moment of forces of resistance to cutting in drilling.

(*ii*) *Rake angle.* The larger the rake angle of drill, the smaller the axial thrust and moment (*M*) of forces of resistance.

(*iii*) *Drill diameter and feed.* The larger the drill diameter and feed the greater the axial thrust and torque.

(*iv*) *Cutting fluid.* Axial thrust and torque is reduced by the use of suitable cutting fluids.

(*v*) *Cutting speed.* The torque and axial thrust first increase with the increase in cutting speed and then decrease with the increase in cutting speed.

(*vi*) *Drilling depth.* The axial thrust and torque are increased with an increased in depth of hole being drilling because removal of chip becomes difficult and also more-heat is produced which can not be efficiently removed by the coolant.

12.19. Surface Treatment of Tools

Steel tools are given surface treatment to reduce sliding friction and to increase abrasion resistance by physically and chemically altering the surface of the tool.

The various surface treatment processes are as follows :

(*i*) *Nitriding.* In this surface treatment a surface layer of about 0.025 mm thick that is high in complex iron nitrides can be produced by treating a finished tool in a NaCN—kCN bath at about 1000°F for about $\frac{1}{2}$ hour. Surface layer so produced can have hardness up to 1000 Brinell hardness. This surface treatment is generally used for tools taking light cuts such as broaching bits and taps.

(*ii*) *Lapping and super finishing.* These surface treatment processes produce a fine finish of the order of 1 to 2 microns. Tools with such surface finishes are found to perform better.

(*iii*) *Chromium plating.* By this surface treatment process a layer of about 0.003 mm can be produced on tool surface. The hardness of such layer is estimated to be nearly 800 Brinell.

(*iv*) *Carburising.* By this surface treatment process a high carbon layer of nearly one milimeter thick can be produced by heating the tool surround by charcoal at 1950°F for about 30 minutes. The layer so produced is very hard. However the layer is brittle and the tool performance is not much improved.

(*v*) *Oxidation.* In this surface treatment process the tool is treated in an aqueous bath of Na OH and Na NO_2 at 285°F from 5 to 10 minutes. The layer of black Fe_3O_4 so produced is nearly 0.005 mm thick and provides a lower coefficient of friction because the oxide layer can hold oil better than polished surface.

During the last three decades surface enhancement technologies like (*i*) chemical vapor deposition (CVD)

(*ii*) Physical vapor deposition (PVD)
(*iii*) Carbide sputtring etc.

These processes increase tool life and enhance performance of cutting tools. However these surface treatment methods are quite expensive.

A low cost high performance surface enhancement technology for improving performance and extending the life of cutting tool is molybdenum.

Di-sulphide (MOS_2) spray coating. This coating has a very low coefficient of friction and high wear resistance.

While applying the MOS_2 spray coating following method should be adopted.

(*i*) Surface to which coating is to be applied should be absolutely clean and dry.

Oil and grease films should be removed by solvent cleaning.

(*ii*) Burrs on the cutting edges should be removed.

(*iii*) Apply a single coat of spray from spray bottle uniformly so that the entire cutting portion of the tool is coated.

The film thickness is nearly 2 to 4 microns. Allow the tool to cure MOS_2 film at ambient temp. for about 30 minutes.

(*iv*) Whenever the tool is reground this produce should be repeated for recoating of tool.

12.20. Preventive Maintenance Planning

Preventive maintenance can be defined as planned and coordinated inspections, adjustments, repairs and replacement in maintaining the machines. The purpose is to reduce unscheduled interruption or undue deterioration of operating equipment. It is a scientific way of tackling maintenance problem. It helps in maintaining a reliable production system.

12.21. Programme of Preventive Maintenance

The programme of preventive maintenance of a machine includes the following operations.

(*i*) Cleaning of parts
(*ii*) Lubrication
(*iii*) Application of protective coatings
(*iv*) Repair of cracks and other repairable damages.
(*v*) Adjustments
(*vi*) Inspection of state of components
(*vii*) Replacement of worn out/broken components
(*viii*) Analysis of history of behaviour of machine tool and its parts

(*ix*) Preventive maintenance cost calculations.

Cleaning prevents corrosion and abrasion due to dust whereas lubrication reduces friction. Adjustments of alignments or tightening of loose nuts and bolts eliminate undue stresses. Protective coatings guard against rust and corrosion. These actions increase the useful life of parts and therefore constitute an intrinsic part of preventive maintenance.

Whenever there is minor or major fault in the machine tool, it is desireable to pay proper attention at appropriate time to such faults. This will keep the machine tool running and the production loss will be minimum.

A machine tool is stopped due to the following reasons.

(*i*) Breakdown maintenance
(*ii*) Preventive maintenance.

Break down maintenance not only brings a serious production hold up but also up sets production flow of the industry. Preventive maintenance is a more scientific way of tackling maintenance problem and is quite commonly used now a days.

Preventive maintenance helps

(*i*) to prolong the life of the machine
(*ii*) to reduce un-expected break downs
(*iii*) to improve accuracy of machine tool
(*iv*) to ensure quality and continuity of production.

Preventive maintenance calls for taking are equipment for repair at planned intervals of time so that uncalled for break downs can be prevented. These intervals are decided mainly keeping into view the following factors.

(*i*) Complexity of the machine tool
(*ii*) Load conditions
(*iii*) Position of machine.

Repair complexity is a relative index to give a comparative idea of the complexity of a machine and takes into account the mechanical gearing, hydraulic and pneumatic units, guide surfaces and transmission units of machine.

The complexity of machine tool plays a very important role in the maintenance and in deciding the duration of the individual repair and in turn the repair cycle.

Further the spares stock, repair cost and the man power planning depends upon the total complexity of the machine tool.

Although there is no absolute measurement of the repair complexity of a machine but for the purpose of planning, relative figures are decided which give a comparative idea about the repair complexity of the machine.

The concept of repair complexity of a machine tool is used to determine.

(*i*) Maintenance staff
(*ii*) Spares and parts needed for maintenance
(*iii*) Maintenance cost
(*iv*) Percentage break downs and hence the efficiency etc.

The average repair complexity (RC) is indicated in table 12.1.

Table 12.1

S. No.	*Type of machine tool*	*RC*
1.	Light machine tool	8
2.	Medium machine tool	9
3.	Heavy machine tool	11
4.	Tools and cutters	7.5

12.22. Preventive Maintenance Repair Cycle

Repair cycle of preventive maintenance consists of four stages as indicated below :

(*i*) Inspection (I)
(*ii*) Small repair (S)
(*iii*) Medium repair (M)
(*iv*) Complete overhaul (C).

For example a typical repair cycle of a centre lathe is given by :

$$C - I_1 - S_1 - I_2 - S_2 - I_3 - M_1 - I_4 - S_3 - I_5 - S_4 - I_6 - M_2 - I_7 - S_5 - I_8 - S_6 - I_9 - C - I_1$$

This means that :

(*i*) Lathe would be taken up for first inspection I_1.
(*ii*) After about 6 months the first small repair (S_1) will be carried out.
(*iii*) First medium repair (M_1) after second inspection (I_2), second small repair (S_2) and third inspection (I_3).
(*iv*) Second medium repair (M_2) after fourth inspection (I_4), third small repair (S_3), fifth inspection (I_5), fourth small repair (S_4) and sixth inspection (I_6).
(*v*) Finally the lathe would be taken up for complete overhaul after sixth small repair (S_6) and ninth inspection (I_9).
(*vi*) The cycle would thus follow same sequence after 9 years (6 × 18 months).

The volume of work to be carried out in each of repair categories (I, S, M, C) is as follows.

1. **Inspection (I)**

(*i*) To inspect various mechanisms at all speeds and feeds.
(*ii*) To adjust spindle bearings, clutches, brakes, couplings, lead nut play, clamping devices.
(*iii*) To tighten nut, bolts and to replace damaged ones.
(*iv*) To change oil and to clean oil and coolant filters and lubricating distributors.
(*v*) To clean chips removers.

2. **Small repair (S)**

(*i*) To dis-assemble some unit (say 2 to 3) of machine tool which are expected to get worn out. For example to dis-assemble Toolpost and Apron of a lathe and to replace worn out part and to clean other parts.
(*ii*) To check the working of guide surfaces.

(*C*) **Medium repair**

(*i*) To dis-assemble more units of machine tool such as headstock, tool post, tail stock etc. and to replace worn out parts and to check working of each part.
(*ii*) To grind/scrap the guide surfaces.
(*iii*) To check the machine as per standard accuracy test charts.

(*D*) **Complete Overhaul**

(*i*) To dis-assemble every part, to clean the various parts and to replace worn out parts.
(*ii*) To grind or scrap all the guide surfaces.
(*ii*) To check foundation condition and to repair it if required.

12.23. Man Power Planning

Following four main categories of workers are required for maintenance work.

(*i*) Fitters
(*ii*) Machine operators
(*iii*) Oilers, welders etc.
(*iv*) Helpers.

(*A*) For breakdown maintenance

For metal cutting machine tools the number of filters, machine operators and oilers required are calculated as follows :

$$\text{Fitters} = \frac{a}{400}$$

$$\text{Machine operators} = \frac{a}{1650}$$

$$\text{Oilers} = \frac{a}{950}$$

where a = Total repair complexity of the equipment.

(*B*) For preventive maintenance one helper should normally be provided with two fitters.

For various stages of preventive maintenance the typical man hours required per unit of repair complexity are indicated in table 12.2.

Table 12.2

Preventive maintenance stages	*MH*		
	Fitters	*Machine operators*	*Oilers, Welders etc.*
Inspection (I)	1.0	0.5	0.5
Small repair (S)	5.0	4.0	1.0
Medium repair (M)	20	10	2.0
Complete overhaul (C)	30	20	4.0

where MH = Man hours required per unit of repair complexity.

12.24. Preventive Maintenance Stages for Metal Cutting Equipment

The work to be carried out during various stages of preventive maintenance for metal cutting machines is as follows.

1. **Inspection**

(*i*) To externally inspect pulleys, flywheels, gears, sprockets, friction discs etc. and to tighten the joints.
(*ii*) To open out covers and check the condition of mechanisms.
(*iii*) To regulate :
(*a*) spindle bearings
(*b*) friction and brake tension
(*c*) smooth sliding of tables, slides, saddles, slotter ram.
(*d*) belts, chains.
(*iv*) To tighten wedges and clamping plates.
(*v*) To check the condition of guides of the beds, carriages traverse and other friction surfaces.
(*vi*) To check lubricating and hydraulic system and to carry out minor repairs. To replace lubricating oil in reservoirs.
(*vii*) To inspect guards, fencings etc and to carry out repairs.
(*viii*) To replace worn out parts.

2. **Small repair**

(*i*) To dis-assemble 2 to 3 units of the machine. To clean the parts and to check working of the various parts. For the remaining units of the machine open the covers and clean the parts.
(*ii*) To check working of spindles, and bearings and to replace worn out bearings.
(*iii*) To clean lead screws of slides, carriage, traverses etc. and to replace worn out mating nuts.

(*iv*) To check for proper working of levers, handles, and safety mechanisms.

(*v*) To clean and repair scratches and other damages on friction surfaces of bed guides, carriages, slides, traverses, columns etc.

(*vi*) To check and repair the coolant system.

(*vii*) To check for proper functioning of limits, reverses and stoppers.

3. Medium repair

(*i*) To dis-assemble the machine partly and to clean and check the working of various parts.

(*ii*) To grind spindle shanks.

(*iii*) To replace worn out bearings, gears, fasteners.

(*iv*) To restore/replace worn out lead screws and nuts of longitudinal and transverse feeds.

(*v*) To replace/restore and scrap regulating wedges and clamping devices.

(*vi*) To check the accuracy of the machine as per accuracy chart.

4. Complete overhaul

(*i*) To completely dis-assemble the machine and all its units.

(*ii*) To clean and inspect all parts and to replace worn out parts.

(*iii*) To check lubricating system, hydraulic system, cooling system and to repair them. To replace oil, coolant etc.

(*iv*) To repair or replace guards and fencings.

(*v*) To check the foundation.

(*vi*) To check the machine for accuracy as per accuracy chart.

12.25. Machine Stoppage During Preventive Maintenance

In order to carry out preventive maintenance the machine tool is stopped for some time. Table 12.3 indicates the number of days for which a machine can be stopped for preventive maintenance.

Table 12.3

Preventive Maintenance Category	*N*
Inspection	Few hours
Small repair	0.25
Medium repair	0.55
Complete overhaul	1.0

where N = Permissible number of days per unit of repair complexity.

12.26. When to Replace a Machine Tool

As the age of machine increases the cost of maintenance rises and

quality and quantity of production make an old machine more or less obsolete in relationship to new demands. These factors are considered while replacing the existing machine at some stage in its life by a new machine.

12.27. Control Systems for Machine Tools

The control system of a machine tool is defined as the control of the machining process. This is accomplished by transmitting instructions or commands from a transmitter through a chain of transmitting elements to the operative member which receives the commands at the required time and is activated to perform the required machining process.

The various elements of machine tool control system are indicated in Fig. 12.19.

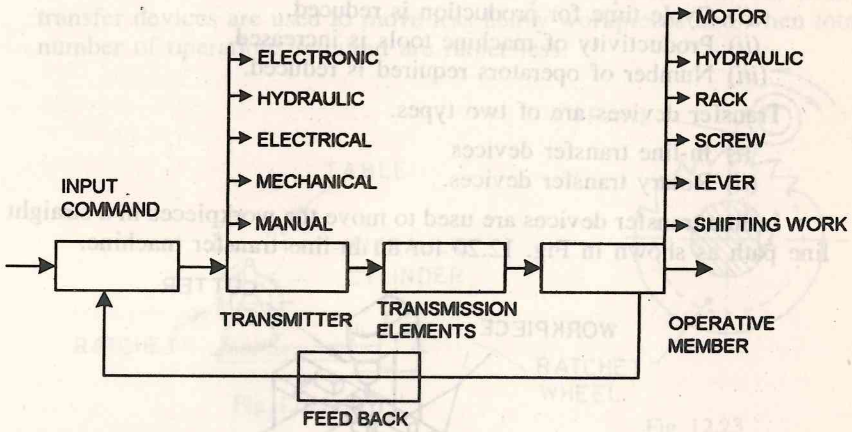


Fig. 12.19

Manual control makes use of levers, hand wheels and push buttons etc. whereas mechanical control is by cams, drums, clutches etc. and electrical control makes use of limit switches. Electronic control uses punched card, tape and magnetic tape.

Feedback may be by

(*i*) Visual (*ii*) Electrical/Electronic servos observation.

Machine tool control system performs the following functions during machining by the machine tool.

(*i*) Positional controls.

(*ii*) Control of speeds, feeds and depth of cut.

(*iii*) Change over from one set of conditions to another set.

(*iv*) Controls for safety.

Machine tool control system should possess the following requirements.

(*i*) Ease of handling.

(*ii*) Ensuring safety to operator and machine from anticipated control movements.
(*iii*) To minimise machining time.
(*iv*) Simplification of the varieties of designs of handles, levers, push buttons, and other control elements.

12.28. Transfer Devices in Automatic Machine Tool Systems

Transfer device is a mechanism used to move the workpieces from station to station while maintaining their orientation. Transfer devices place the workpieces at the required point and at the required time so that working operations can be performed at each station.

Advantages of using transfer devices are as follows :

(*i*) Cycle time for production is reduced.
(*ii*) Productivity of machine tools is increased.
(*iii*) Number of operators required is reduced.

Transfer devices are of two types.

(*i*) In-line transfer devices
(*ii*) Rotary transfer devices.

In-line transfer devices are used to move the workpieces in a straight line path as shown in Fig. 12.20 for an In-line transfer machine.

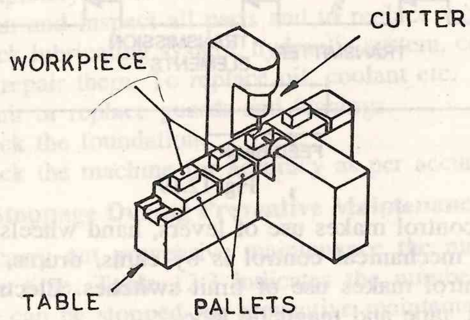


Fig. 12.20

The in-line transfer devices are of two types as follows :

(*i*) Pallet-type transfer machines
(*ii*) Plain-type transfer machines (also called non-pallet type).

Fig. 12.21 shows a typical in line transfer device. In this transfer device the workpieces are loaded at a point remote from the work station and then through a drive unit transferred to work station.

In rotary transfer devices around a rotary table a number of workstations are located where both horizontal and vertical machines perform the required machining operations. In such devices the principal element is the rotary mechanism for the table which is indexed periodically. Fig. 12.22 shows a pawl and ratchet type of indexing operated from a

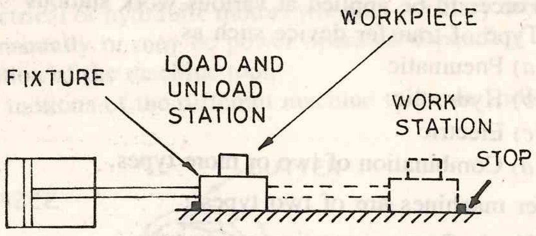


Fig. 12.21

hydraulic cylinder and Fig. 12.23 shows pawl and ratchet whereas Fig. 12.24 shows a Geneva Indexing mechanism for rotary table. In-line transfer devices can be used to feed heavy workpieces whereas rotary transfer devices are used to move less heavy workpieces and when total number of operations required are rather less.

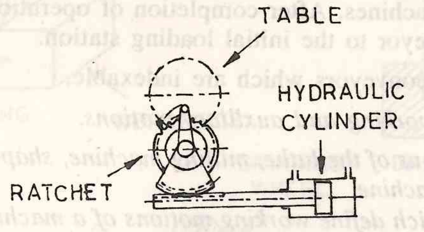


Fig. 12.22

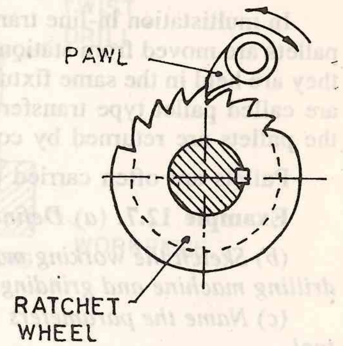


Fig. 12.23

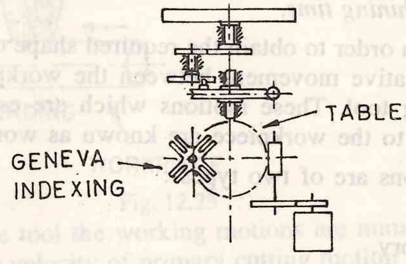


Fig. 12.24

In rotary transfer devices the rotary mechanisms for the table which are indexed periodically are of two types :

(*i*) Pawl and ratchet type of indexing.
(*ii*) Geneva-indexing mechanism.

Choice of transfer devices depends on the following factors.

(*i*) Number of operations required
(*ii*) Size and weight of workpieces
(*iii*) Desired rate of production

(*iv*) Forces to be applied at various work stations
(*v*) Type of transfer device such as
 (*a*) Pneumatic
 (*b*) Hydraulic
 (*c*) Electric
 (*d*) Combination of two or more types.

Transfer machines are of two types :

(*i*) Single flow progressive action type
(*ii*) Multiple-flow parallel type.

Selection of transfer machines depends on the following factors.

(*a*) Product size and machining requirements
(*b*) Handling systems used
(*c*) Floor space available.

In multistation in-line transfer machines parts fixed in fixtures called pallets are moved from station to station. Throughout the entire operation they are held in the same fixture. These types of in-line transfer machines are called pallet type transfer machines. After completion of operations the pallets are returned by conveyor to the initial loading station.

Pallets are often carried in conveyors which are indexable.

Example 12.7. (*a*) *Define working and auxiliary motions.*

(*b*) *Sketch the working motions of the lathe, milling machine, shaper, drilling machine and grinding machine.*

(*c*) *Name the parameters which define working motions of a machine tool.*

(*d*) *Define machining time.*

Solution. (*a*) In order to obtain the required shape on the workpiece, there should be relative movement between the workpiece and cutting edge of the cutting tool. These motions which are essential to impart the required shape to the workpiece are known as working motions.

Working motions are of two types :

(*i*) Rotary
(*ii*) Translatory.

The auxiliary motions do not participate in the process of formation of the required surface but are nonetheless necessary to make the working motions fulfill their assigned function.

Some of the auxiliary motions in a machine tool are as follows :

(*i*) Clamping and unclamping of workpiece.
(*ii*) Idle travel of the cutting tool to the position from where cutting is to proceed.
(*iii*) Changing the speed of the drive and feed motions.
(*iv*) Engaging and dis-engaging of working motions.

In machine tools the working motions are powered by an external source of energy (electrical or hydraulic motor) whereas auxiliary motions may be carried out manually or may be power operated depending upon the degree of automation of the machine tool.

(*b*) The working motions of the different machine tools are indicated in Fig. 12.25.

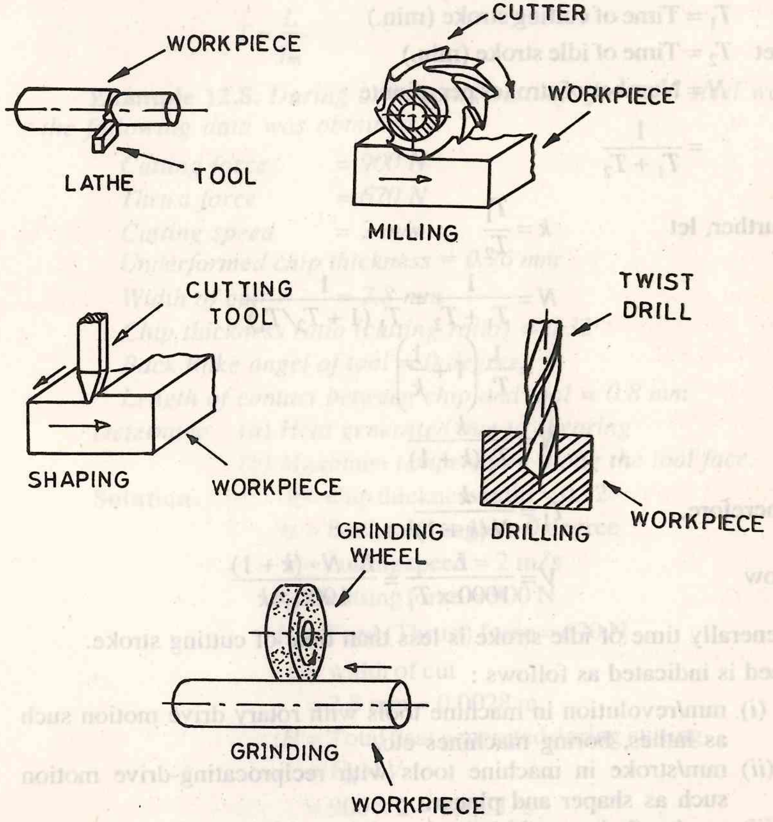


Fig. 12.25

(*c*) For a machine tool the working motions are numerically defined by their velocity. The velocity of primary cutting motion or drive motion is known as cutting speed while velocity of feed motion is known as feed.

In machine tools with rotary primary cutting motion the cutting speed is determined as follows :

$$V = \frac{\pi DN}{1000} \text{ m/min.}$$

where v = Cutting speed (m/min)
D = Diameter of work piece (as in lathe) and cutter (as in milling machine) in mm.
N = RPM of workpiece or cutter.

In machine tools with reciprocating primary cutting motion the cutting speed is determined as follows :

$$V = \frac{L}{1000 \times T_1} \text{ m/min.}$$

where L = Length of stroke (mm)

T_1 = Time of cutting stroke (min.)

Let T_2 = Time of idle stroke (min.)

N = Number of strokes per minute

$$= \frac{1}{T_1 + T_2}$$

Further, let $k = \frac{T_1}{T_2}$

$$N = \frac{1}{T_1 + T_2} = \frac{1}{T_1\,(1 + T_2/T_1)}$$

$$= \frac{1}{T_1}\left(1 + \frac{1}{k}\right)$$

$$N = \frac{k}{T_1\,(k+1)}$$

Therefore, $T_1 = \frac{k}{N\,(k+1)}$

Now $V = \frac{L}{1000 \times T_1} = \frac{L \cdot N \cdot (k+1)}{1000 \times k}$

Generally time of idle stroke is less than time of cutting stroke.

Feed is indicated as follows :

(*i*) mm/revolution in machine tools with rotary drive motion such as lathes, boring machines etc.

(*ii*) mm/stroke in machine tools with reciprocating-drive motion such as shaper and planer.

(*iii*) mm/tooth in machine tools using multiple-tooth cutters such as milling machine

Let f_m = Feed per minute

f = Feed per revolution or feed per stroke

n = RPM or strokes per minute.

Then $f_m = f \cdot N$

In multiple tooth cutters

$$f = f_1 \times Z$$

where f_1 = Feed per tooth of cutter

z = Number of teeth on the cutter

(*d*) *Machining Time*. It is the time required to machine the given surface.

T = Machining time (min.)

f_m = Feed per minute (mm/min.)

L = Length of machined surface (mm)

$$T = \frac{L}{f_m}$$

Example 12.8. *During orthogonal cutting of a mild steel workpiece the following data was obtained.*

Cutting force = *900 N*
Thrust force = *670 N*
Cutting speed = *2 m/s*
Underformed chip thickness = *0.26 mm*
Width of cut = *2.8 mm*
Chip thickness ratio (cutting ratio) = *0.32*
Back Rake angel of tool = *0 degree*
Length of contact between chip and tool = *0.8 mm*

Determine *(a) Heat generated due to shearing*
(b) Maximum temperature along the tool face.

Solution. r = chip thickness ratio = 0.32

α = Back rake angle = 0 degree

V = cutting speed = 2 m/s

F_H = cutting force = 900 N

F_v = Feed (Thrust) force = 670 N

b = width of cut

= 2.8 mm = 0.0028 m

H = Total heat generated during cutting

$= F_H \times V$

$= 900 \times 2 = 1800$ J/s

H_1 = Rate of heat generated by friction between chip and tool

$= P \times V_c$

where V_c = velocity of chip relative to tool

$= r \times v$

$= 0.32 \times 2$

P = Frictional force

$= F_v$ as rake angle is zero

$H_1 = 670 \times 0.32 \times 2 = 428$ J/s

H_2 = heat rate from shearing

$H = H_1 + H_2$

$$1800 = 428 + H_2$$

$$H_2 = 1372 \text{ J/s}$$

$$T = T_1 + T_2 + T_3$$

Where T = maximum temperature along tool face

T_1 = Temperature rise of material passing through primary deformation zone

T_2 = Temperature rise of material passing through the secondary deformation zone.

T_3 = Initial temperature of the workpiece

R = Thermal Number

L = Length of heat source divided by chip thickness.

$$= \frac{L_1}{t_2}$$

Where L_1 = Length of contact between chip and tool

$= 0.8$ mm

$$r = \frac{t_1}{t_2}$$

Where t_1 = undeformed chip thickness = 0.26 mm

t_2 = chip thickness after cutting

$$t_2 = \frac{t_1}{r} = \frac{0.26}{0.32}$$

$$L = \frac{L_1}{t_2}$$

$$L = \frac{0.8 \times 0.32}{0.26} = 0.98$$

$$R = \frac{\rho \cdot C \cdot V \cdot t_1}{k}$$

Where ρ = Density of steel

$= 7200 \text{ kg/m}^3$ (Assume)

C Specific heat capacity = 500 J/kg K

k = Thermal conductivity = 43.5 J/s mk

$$t_1 = \frac{0.26}{1000} \text{ m} = 0.00026$$

$$R = 7200 \times 500 \times 2 \times \frac{0.26}{1000} \times \frac{1}{43.5} = 43$$

$$T_1 = \frac{(1-p) \times H_2}{\rho \cdot C \cdot V \cdot t_1 \cdot b}$$

Where p = proportion of shearing heat conducted into the workpiece = 0.1

$$T_1 = \frac{(1-0.1) \times 1372}{7200 \times 500 \times 2 \times 0.00026 \times 0.0028}$$

$= 235.5°\text{C}.$

It is the mean temperature rise in the primary deformation zone and since it is a temperature difference can be expressed in either centigrade (°C) or degree Kelvin (°K)

T_4 = Average temperature rise of the chip resulting from secondary deformation (Frictional heat source)

$$= \frac{H_1}{\rho\, C \cdot V\, t_1\, b}$$

$$\frac{428}{7200 \times 500 \times 2 \times 0.00026 \times 0.0028}$$

$$= \frac{428}{5.24} = 81.7°\text{C}$$

Now $\frac{R}{L} = \frac{43}{0.98} = 43.87.$

The value of $\frac{T_2}{T_4}$ depends on the values of $\frac{R}{L}$ and width of secondary deformation zone.

A typical value of $\frac{T_2}{T_4} = 4.2$ when $\frac{R}{L} = 43.87$

$$\frac{T_2}{T_4} = 4.2$$

$$T_2 = 4.2 \times T_4$$

$$= 4.2 \times 81.7 = 343°\text{C}$$

T_3 = Initial temperature of work piece

= Room Temperature

= 25°C (say)

$$T = T_1 + T_2 + T_3$$

$$= 235.5 + 343 + 25 = 603.5°\text{C}.$$

Example 12.9. *A mild steel rod is machined on a lathe. Find power of motor using following data.*

Cutting speed	*= 90 m/min*
Feed	*= 0.5 mm/rev.*
Depth of cut	*= 2.54 mm*
Correction factor	*= 0.5.*

Solution. The formula for calculating power of motor is as follows

P = Power (kW)

$$= \frac{V \cdot f \cdot d \cdot F}{6000 \times \eta}$$

where v = cutting speed = 90 mpm

f = feed = 0.5 mm/rev.

F = specific resistance

= 270 – 300 kg/mm² (assume) for steel

d = Depth of cut = 2.54 mm

η = correction factor = 0.5

$$P = \frac{90 \times 0.5 \times 2.54 \times 280}{6000 \times 0.5} = 10.7 \text{ kW}.$$

Example 12.10. *(a) A carbide cutting tool lasted for 100 minutes while machining mild steel work material at a cutting speed of 40 m/min. Determine the tool life of the tool is used for machining mild steel at a 20% higher speed.*

(b) Also calculate the value of cutting speed of the tool is required to machine for 160 minutes without failing. Assume n = 0.26.

Solution. *(a)* V_1 = cutting speed = 40 mpm

T_1 = Tool life = 100 minutes

V_2 = cutting speed

$= 1.2 \times V_1 = 1.2 \times 40$

= 48 mpm

T_2 = Tool life

$n = 0.26$

$$V_1 T_1^n = V_2 T_2^n$$

$$40 \times 100^{.0026} = 48 \times T_2^{0.26}$$

T_2 = 48.6 minutes

T_3 = Tool life = 160 minutes

Now $V_1 T_1^n = V_3 T_3^n$

$$40 \times 100^{0.26} = V_3 \times 160^{0.27}$$

V_3 = 33.6 mpm.

Example 12.11. *In an orthogonal cutting operation on a copper workpiece following data has been obtained.*

Back rake angle = 20°

Chip thickness before cutting = 0.12 mm

Width of chip before cutting = 3.75 mm

Width of chip after cutting = 4.1 mm

Chip length before cutting = 130 mm

Chip length after cutting = 50 mm

Shear stress of work material = 20 kg/mm²

Coefficient of friction = 0.55

Cutting speed = 30 mpm

Determine the forces and power consumption.

Solution. α = Back rate angle = 20°

t_1 = 0.12 = chip thickness before cutting

t_2 = chip thickness after cutting.

Chipwidth, (b_1) = 3.75 mm

b_2 = 4.1 mm

Chip length (L_1) = 130 mm

Chip length (L_2) = 50 mm

Now according to volume continuity equation

$$L_1 \cdot b_1 \cdot t_1 = L_2\, b_2 \cdot t_2$$

$$130 \times 3.75 \times t_1 = 50 \times 4.1 \times t_2$$

$$\frac{t_1}{t_2} = 0.42 = r$$

where r = chip thickness ratio

Now let β = shear angle

$$\tan \beta = \frac{r \cos \alpha}{1 - r \sin \alpha}$$

$$= \frac{0.42 \times \cos 20}{1 - 0.42 \sin 20}$$

β = 24 degrees

γ = Friction angle of tool face

$\tan \gamma = \mu$ where μ = coeff. of friction = 0.55

γ = 29 degrees

F_s = shear force

$$= f_s \times \frac{b_1 \cdot t_1}{\sin \beta}$$

where f_s = shear stress

= 20 kg/mm²

[τ is also used as symbol for shear stress]

$$F_S = \frac{20 \times 3.75 \times 0.12}{\sin 24} = 22.5 \text{ kg}$$

$$F_H = \text{cutting force} = \frac{F_S \times \cos(\gamma - \alpha)}{\cos \theta}$$

where $\theta = \beta + \gamma - \alpha$

$= 24 + 29 - 20 = 33$ degrees

$$F_H = \frac{22.5 \cos(29 - 20)}{\cos 33} = 26.5 \text{ kg}$$

F_V = Feed force

From merchant circle diagram

$$\frac{F_V}{F_H} = \tan(\gamma - \alpha)$$

$$F_V = F_H \tan(\gamma - \alpha)$$

$$= 26.5 \tan(29 - 20) = 4.1 \text{ kg}$$

$$v = \text{cutting speed} = 30 \text{ mpm}$$

$$\text{Power consumption} = \frac{F_H \times V}{4500}$$

$$= \frac{26.5 \times 30}{4500} = 0.18 \text{ H.P.}$$

Example 12.12. *(a) State the forces to which a machine tool is subjected.*

(b) Name the variables which affect metal removal rate.

(c) Represent the cutting tool wear.

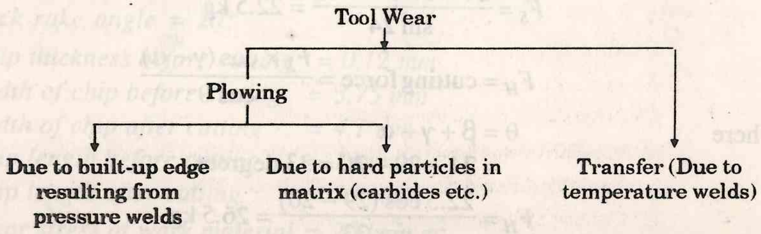
Solution. (*a*) Various types of forces to which a machine tool is generally subjected to are as follows :

(*i*) Cutting forces
(*ii*) Friction forces
(*iii*) Inertia loads
(*iv*) Reaction at the supporting surfaces
(*v*) Forces due to starting and braking.

(*b*) Total energy required per unit volume of metal cut is function of the following variables.

(*i*) Workpiece material
(*ii*) Friction condition on tool face
(*iii*) Tool sharpness
(*iv*) Cutting speed, feed and depth of cut
(*v*) Rake angle
(*vi*) Clearance angle
(*vii*) Cutting fluid used.

(*c*) The cutting tool wear is thus represented as follows.



Tool wear at very low cutting speeds is due to the flowing action of the built up edge debris and other hard particles in the matrix such as carbides while at high cutting speeds the wear takes place due to transfer resulting from temperature welds as well as the flowing action of hard particles.

PROBLEMS

12.1. Describe a method of measuring tool chip interface temperature.

12.2. Describe the principle used in deflection type cutting tool dynamometer used to measure cutting forces on a single point tool.

12.3. Write short notes on the following :

(*i*) General inspection of machine tools.
(*ii*) Design of a single point tool.
(*iii*) Hydraulic drive for shaper.

12.4. Describe the factors which affect the quality and performance of a machine tool.

12.5. Write short notes on the following :

(*a*) Lubrication record card.
(*b*) Corrective maintenance record card
(*c*) Geneva wheel mechanism.
(*d*) High speed steel tool bits.
(*e*) Care and maintenance of machine tools.

12.6. Describe the following valves used in the hydraulic drives of machine tools :

(*i*) Throttle valve. (*ii*) Pressure relief valve.
(*iii*) Non-return valve.

12.7. Describe hydraulic copying system.

12.8. Describe hydraulic drive of a milling machine.

12.9. Make a neat sketch of slotted arm quick return mechanism for shaping machine and describe its working.

12.10. Describe Fellows gear shaper.

12.11. Show that for an oscillating mechanism for a shaper the maximum quick return ratio (Q) is given by

$$Q = \frac{2l + S}{2L - S}$$

where L = Length of slotted lever
S = Stroke length.

12.12. Write short notes on the following :

(*a*) Surface treatment of cutting tools.
(*b*) Preventive maintenance planning.
(*c*) Program of preventive maintenance.
(*d*) Preventive maintenance stages for metal cutting equipment.
(*e*) Transfer devices in automatic machine tools.
(*f*) Control systems for machine tools.

13

Objective Type Problems

1. Tick mark the correct answer :

(*A*) The metal cutting wedge is fundamental to the geometry of
- (*a*) Head tools only
- (*b*) Power driven tools only
- (*c*) Sheet metal cutting tools only
- (*d*) All cutting tools.

(*B*) Continuous chips are formed when cutting
- (*a*) Brittle materials (*b*) Ductile materials
- (*c*) Amorphous plastic materials
- (*d*) Free cutting non ferrous alloys only.

(*C*) The rake angle of a cutting tool
- (*a*) Controls the chip formation
- (*b*) Prevents rubbing
- (*c*) Determine the profile of tool
- (*d*) Determine whether the cutting action is oblique or orthogonal.

(*D*) Back rake angle for H.S.S. single point cutting tool to machine free cutting brass is
- (*a*) 15° (*b*) 0°
- (*c*) 5° (*d*) 10°.

2. In the list of processes given below tick (√) mark the chip removal processes
- (*a*) Die casting (*b*) Extruding
- (*c*) Forging (*d*) Rolling
- (*e*) Broaching.

3. In the list of processes given below tick (√) mark the non-chip removal processes
- (*a*) Grinding (*b*) Spinning on lathe
- (*c*) Thread cutting (*d*) Drilling
- (*e*) Milling.

4. State whether the following statements are true or false :

- (*a*) For a given cutting speed cemented carbide tool removes more work material than H.S.S. tool
- (*b*) Optimum rake angle of a tool is not a function of the properties of work material
- (*c*) Cemented carbide is more tough than high speed steel
- (*d*) In oblique cutting the cutting edge of tool is not perpendicular to the cutting direction
- (*e*) Chip reduction coefficient is always more than unity
- (*f*) Larger value of chip reduction coefficient indicates poor machinability
- (*g*) Grinding wheel is a single point cutting tool
- (*h*) Decreasing wedge angle of tool reduces mechanical strength of tool.

5. Fill in the blanks
- (*a*) The point angle of twist drill to machine steel is ...
- (*b*) The cutting speed of H.S.S. twist drill to machine grey cast iron is ...
- (*c*) The cutting speeds of H.S.S. milling cutter to machine aluminium is ...

6. Tick mark the correct answer.

(*A*) A twist drill has its point thinned in order to
- (*a*) Reduce the hole diameter
- (*b*) Increase the rake angle
- (*c*) Locate in the centre punch mark
- (*d*) Reduce the axial (feed) pressure.

(*B*) A reamer is used to correct the
- (*a*) Size and roundness of a drilled hole
- (*b*) Size and position of a drilled hole
- (*c*) Finish and position of a drilled hole
- (*d*) Finish and depth of a drilled hole.

(*C*) An oversize hole is produced by a drill if
- (*a*) Lips of drill are of unequal length
- (*b*) Feed is too high
- (*c*) Insufficient coolant is used
- (*d*) Cutting speed is too high.

(*D*) Cemented carbide tipped tools can machine metal even when their cutting elements get heated up to the temperature
- (*a*) 1650°C (*b*) 1400°C
- (*c*) 1000°C (*d*) 1800°C.

(*E*) Cemented carbide tools are usually provided with
- (*a*) Positive back rake angle
- (*b*) Neutral back rake angle
- (*c*) Negative back rake angle.

7. State whether the following statements are true or false :

(a) The rates of feed and cutting speeds for twist drill are lower than for most other machining operations
(b) Like any other cutting tool the twist drill must be provided with correct tool angles
(c) A twist drill produces a hole of fine finish and accurate size
(d) No cutting fluids are used for carbide tipped milling cutters.

8. Tick mark the correct answer
The time taken to drill hole through a 20 mm thick plate at 300 R.P.M. and at a feed of 0.2 mm/revolution is
(a) 15 seconds (b) 12 seconds
(c) 20 seconds.

9. State the usually recommended value of rake angle for machining aluminium with cutting tools made up of
(a) High speed steel tool (b) Cemented carbide tool
(c) Diamond tool.

10. Two major factors which determine the r.p.m. of milling cutter are the material being cut and
(a) Number of teeth in cutter
(b) Diameter of cutter
(c) Time allowed to complete the job
(d) Depth of cutter.

11. Mark against each statement according to the key given below :
Mark A—If the condition produces discontinuous chips
Mark B—If the condition produces continuous chips
Mark C—If the condition produces built up chips
(i) Brittle materials and slow cutting speeds.
(ii) Ductile materials and high depth of cut
(iii) Ductile materials with coarse feed
(iv) Ductile materials with fine feed
(v) Mild steel with sharp cutting edge of tool
(vi) Mild steel with high cutting speed
(vii) Mild steel with low rake angle.

12. Friction between chip and tool may be reduced by
(a) Increased sliding velocity
(b) Increased shear angle
(c) Use of low tool finish.

13. State whether the following statements are true or false :
(a) Aluminium oxide abrasives are used for grinding high tensile strength materials
(b) Silicon carbide abrasives are used for grinding low tensile strength materials
(c) Selection of grinding wheel does not depend on the work piece material
(d) Fine grain wheels are used to grind soft ductile materials
(e) Hard and brittle materials and finishing cuts require dense

(f) Grade of grinding wheel is denoted by a number
(g) Structure of grinding wheel is denoted by alphabets.

14. State whether the following statements are true or false :
(a) Machinability index implies the degree of easiness in machining
(b) Free cutting steel cannot be easily machined
(c) Heat resisting steels possess low machinability
(d) Cast iron does not permit as high a cutting speed as structural carbon steel
(e) A most machinable metal one which permits fastest removal of largest amount of material per grind of the tool
(f) For the same amount of applied force orthogonal cutting removes more metal
(g) For the same amount of metal removal the shear stress induced in orthogonal cutting is more than in oblique cutting
(h) In orthogonal cutting the cutting edge of the tool remains inclined to the direction of the work feed.

15. The studs used as a coolant in general machine shop consists of :
(a) A solution of detergent and water
(b) A straight mineral oil
(c) An emulsion of oil and water
(d) A chemical solution.

16. State whether the following statements are true or false :
(a) A cutting fluid should have low conductivity
(b) Use of cutting fluids promotes a better surface finish.

17. State whether the following statements are true or false :
(a) The structure of a grinding wheel indicates the relative spacing of grains in the wheel
(b) The grade of a grinding wheel indicates the relative strength of the bond which hold the abrasive grains in place
(c) About 75% of grinding wheels have vitreous bonds
(d) Super-finishing is used to remove more metal than honing
(e) Coolant is not required during super-finishing
(f) Corundum contains more aluminium oxide than emery.

18. Select the suitable peripheral speeds for following grinding operations given in column A from the column B and indicate in the space provided

A *Type of grinding operation*		B *Speed in metres/min.*
(i) Cylindrical grinding	□	(a) 1200—1800
(ii) Internal grinding	□	(b) 2700—4800
(iii) Snagging off hand grinding with vitrified wheel	□	(c) 600—1800
(iv) Surface grinding	□	(d) 1600—1950
(v) Rubber, shellac and resinoid bonded wheel.	□	(e) 1500—1800

19. Match the words of column A with the words of column B and fill in the space provided

Column A		*Column B*
(*i*) Emery	☐	(*a*) To machine external cylindrical surfaces
(*ii*) Silicon carbide	☐	(*b*) Artificial abrasive
(*iii*) Surface grinding	☐	(*c*) To machine flat surfaces
(*iv*) Centre type cylindrical grinding	☐	(*d*) Natural abrasive
(*v*) Symbol used for silicate bond	☐	(*e*) E
(*vi*) Symbol used for shellac bond.	☐	(*f*) S

20. State whether the following statements are true or false :
(*a*) Cast iron is often ground dry
(*b*) The workpiece is supported between the centres during centreless grinding
(*c*) Surface grinder is used to grind flat surfaces.

21. Milling cutter is sharpened on :
(*a*) Tool and cutter grinder (*b*) Centreless grinder
(*c*) Cylindrical grinder (*d*) Surface grinder.

22. State whether the following statements are true or false :
(*a*) Ordinarily the surface finish improves with cutting speed.
(*b*) An increase in back rake angle of a cutting tool deteriorates surface finish
(*c*) Some degree of roughness which may be extremely small is always present on any machined surface.

23. Arrange the following machining processes in the increasing order of good surface finish
Milling, filling, hand grinding, drilling, surface grinding, lapping, sawing, super finishing, turning.

24. State whether the following statements are true or false :
(*a*) Grey cast iron is the most commonly used material for slide ways
(*b*) The clearance adjustment of dovetail slide ways is difficult
(*c*) Spindles of machine tool are generally made solid
(*d*) In generating the work surface produced is independent of the shape of the tool.

25. State the degrees of freedom possessed by the parts given below, indicate translation by *T* and rotation by *R*.
(*a*) Single point tool operating in lathe tool post
(*b*) Arm of radial drill
(*c*) Plug gauge in component bore.

26. The common ratio ϕ for spindle speeds in G.P. series is given by
(*a*) $1/4 \le \phi < 2$ (*b*) $1 \le \phi \le 2$

(*c*) $1 \le \phi \le 8$.

27. In machine tool drives, the modulus for gears are usually selected between
(*a*) $10 \ge m \ge 1$ (*b*) $2 \ge m \ge 1$
(*c*) $20 \ge m \ge 1$.

28. State whehter the following statements are true or false :
(*a*) Plain cylindrical bearings have high stiffness and good load carrying capacity.
(*b*) Ball bearings have comparatively high frictional losses than plain cylindrical bearings
(*c*) The spindle oil used for lubrication should be corrosive in nature
(*d*) Rolling bearings have less maintenance cost
(*e*) Gear pumps used in hydraulic system are of fixed delivery type.

29. Gear pumps used in hydraulic system are used for
(*a*) Low and medium pressure
(*b*) Medium and high pressure
(*c*) Low and high pressure.

30. Fill in the blanks :
(*a*) A gear pump can be used to obtain as high as ... pressure in the hydraulic drive of machine tools
(*b*) Multiple piston pump can be used to obtain a maximum pressure of ... in a hydraulic drive.
(*c*) The pressure most commonly used in hydraulic machine tool ranges from ... to ...

31. Electron beam machining (E.B.M.) process is quite suitable for a material having
(*a*) High melting point and high thermal conductivity
(*b*) High melting point and low thermal conductivity
(*c*) Low melting point and low thermal conductivity
(*d*) Low melting point and high thermal conductivity.

32. Identify the following tools as single point cutting tools or multi point cutting tools
(*i*) Twist drill
(*ii*) Grinding wheel
(*iii*) Roughing tool of shaper
(*iv*) Parting tool in lathe
(*v*) Milling cutter
(*vi*) Reamer.

33. Emery is a
(*a*) Artificial abrasive (*b*) Natural abrasive
(*c*) Type of cloth.

34. Grinding is
(*a*) Metal fusing operation (*b*) Metal powdering operation
(*c*) Metal finishing operation.

35. Grinding is done wherever
(*a*) Other machining operations cannot be carried out
(*b*) A large amount of material is to be removed
(*c*) High accuracy is required.

36. Name the abrasives to be used (Aluminium oxide or Silicon carbide) to grind the following materials :
(*a*) Steels (*b*) Cast iron
(*c*) Aluminium (*d*) Wrought iron
(*e*) Copper (*f*) Non-metallic materials
(*g*) Bronze.

37. Laser beam machining process is used to machine
(*a*) Thicker materials
(*b*) Thinner materials
(*c*) Heavier materials.

38. The size of abrasive grains in a abrasive a jet machining varies from
(*a*) 60 to 100 microns (*b*) 10 to 50 microns
(*c*) 1 to 5 microns.

39. In collet the included angle of taper is usually
(*a*) 50° (*b*) 30°
(*c*) 20° (*d*) 10°.

40. State whether the following statements are true or false :
(*a*) The head stock remains stationary in a swiss type automatic screw machine
(*b*) Collets are used when the components are to be produced from bar stock
(*c*) The overhead charges of an engine lathe are more than a turret lathe
(*d*) Multi-spindle automatic screw machines maintain better accuracy than single spindle automatic screw machines
(*e*) Silicon carbide is most efficient when used for grinding softer materials
(*f*) Aluminium oxide is efficient when used for grinding hard materials.

41. State four properties of work material which affect the cutting tool life.

42. State three requirements which should be fulfilled for ideal all gear drives.

43. State three conditions for the formation of continuous chips with built up edges.

44. The Young's modulus of carbide tools is about
(*a*) Three times than for steel
(*b*) Six times than for steel
(*c*) Nine times than for steel
(*d*) None of the above.

45. Twist drills are usually considered suitable for machining holes having a length less than
(*a*) Two times their diameter
(*b*) Five times their diameter
(*c*) Ten times their diameter.

46. A hard grade grinding wheel is suitable for grinding
(*a*) Hard materials
(*b*) Soft materials
(*c*) Both hard and soft materials
(*d*) None of the above.

47. The relative motion of workpiece in planning is
(*a*) Rotary (*b*) Translatory
(*c*) Rotary and translatory (*d*) None of the above.

48. The accuracy obtained by the grinding process can be of the order of
(*a*) 0.25 mm (*b*) 0.025 mm
(*c*) 0.00025 mm.

49. In quick return mechanism of shaping machine the ram stroke length is proportional to
(*a*) Slotter arm length (*b*) Crank length
(*c*) Ram length (*d*) None of the above.

50. The usual ratio of forward and return stroke in quick return mechanism of shaping machine is
(*a*) 3 : 2 (*b*) 6 : 8
(*c*) 3 : 1.

51. Name the materials used for making laps and lapping media in lapping process.

52. State the height in microns of irregularities resulting in surface profile during the following microfinishing processes.
(*a*) Grinding (*b*) Honing
(*c*) Lapping (*d*) Superfinishing.

53. Name the materials which can be easily machined by ultrasonic machining process.

54. Describe the various types of costs of engineering products. The cost of engineering products can broadly be grouped as follows :
(*a*) Direct costs (*b*) Indirect costs.

Direct costs are the costs of material and labour. Indirect costs or overhead costs can be sub-divided as under :
(*i*) Works overheads such as wages of works superintendents, foremen, inspectors, storekeepers etc. and costs of depreciation of machines, costs of cutting oil, cost of heating lighting etc.
(*ii*) Office overheads such as cost of wages of all office staff, postage, legal expenses etc.
(*iii*) Sales overheads such as cost of sales staff, advertising etc.
Costs may be more conveniently grouped as follows :

(*a*) Fixed costs (*b*) Variable costs.

Fixed costs includes depreciation cost, interests, cost of tooling, setting up etc.

Variable cost includes directs labour cost, material cost and part of indirect costs which will vary as production varies.

55. The amount of metal removed by honing process is less than

(*a*) 0.125 mm (*b*) 0.225 mm

(*c*) 0.015 mm.

56. In ECM process normal current requirement is

(*a*) 800 amps/cm^2 of workpiece area

(*b*) 100 amps/cm^2 of workpiece area

(*c*) 200 amps/cm^2 of workpiece area.

57. The voltage applied between tool (cathode) and workpiece (anode) in E.C.M. process is

(*a*) 30—50 V (*b*) 3—20 V

(*c*) 60—90 V (*d*) None of the above.

58. Name the electrolytes used in ECM process.

59. *Statements* :

(*i*) With carbide tools better cutting conditions can be achieved with negative rake and high cutting speeds.

(*ii*) In metal cutting it is always desirable to obtain a shortest possible shear plane because for a fixed shear strength reduction in shear plane area reduces the shearing force required to produce sufficient stress.

60. Name H.S.S. commonly used for making tools.

61. The diameter (D) of a plain milling cutter is approximately related to arbor diameter (d) as

(*a*) $D = 2.5\,d$ to $3\,d$ (*b*) $D = 4.5\,d$ to $6\,d$

(*c*) $D = 1.5\,d$ to $2\,d$.

62. State whether the following machining operation are forming or generating or a mixture of each :

(*a*) Milling a keyway using an end milling cutter

(*b*) Drilling a hole using a twist drill

(*c*) Finish shaping a flat surface using a broad tool

(*d*) Face milling on flat surface.

63. *Statements*

(*i*) The larger the cutting angle and the smaller the thickness of uncut chip, the more tightly the chip will curl (the smaller its radius of curvature will be)

(*ii*) The used of cutting fluids reduces the radius to which the chip curls.

(*iii*) An increase in nose radius leads to greater chip contraction.

(*iv*) Greater the cutting angle (or smaller the positive rake-angle) the greater is chip contraction.

64. State the factors which affect the chip contraction.

65. Name four fine finishing operations.

66. Name the cutting fluids used for machining, the following metals

(*i*) Cast iron

(*ii*) Mild steel and free cutting steel

(*iii*) Aluminium and aluminium alloys.

67. State whether the following statements are true or false.

(*a*) A cutting tool with large back rake angle is weak and tool point may break off readily.

(*b*) A cutting tool with negative back rake angle has better heat conductivity.

(*c*) Negative back rake angles are specially provided on cemented carbide tipped tools because the comented carbide possesses very high compressive strength and comparatively very low tensile and shear strengths.

(*d*) Nose radius provided on cutting tool imparts strength to the cutting point.

(*e*) Manually operated machine tools are economical for smaller batch size production.

(*f*) Transfer machines are economical for larger batch size production.

(*g*) During drilling the chips produced are removed automatically out of drill hole by helical flutes.

68. Suggest the electric motors for the drive of the following machine tools :

(*i*) Lapping machine

(*ii*) Rotary shears

(*iii*) Main drive of a boring machine.

69. State the accuracy that can be achieved on NC machines.

70. *Statements*

(*a*) There is MCU in CNC

(*b*) CNC facilities part programming of complex shaped parts

(*c*) MCU converts the information from the tape program into the desired command signals.

71. Name the commonly used actuation systems in N.C. equipment.

72. Classify the manufacturing plants in terms of production volume.

73. Fill in the blank

(*i*) In spark erosion work pieces has ... potential (Positive, negative)

(*ii*) The surface finish obtained by spark erosion is ... as compared to ultrasonic machining (High, low).

74. State the type of twist drill to be used for machining the following material :

(*a*) Laminated plastics (*b*) Brass

(*c*) Cast Iron (*d*) Steel

(*e*) Copper
(*f*) Aluminium alloy cutting long chips.

75. Name the three regions in which heat is generated during metal cutting.

76. The type and number of bearings to be used for spindles of machine tool depend on
(*a*) Type of spindle (*b*) Type of machine tool
(*c*) Load on the bearing (*d*) None of the above.

77. State the basic requirements of a machine tool drive.

78. State the common requirements of machine tool spindle supports.

79. State three factors which influence the stiffness of hydrodynamic bearings.

80. *Statements*
(*a*) Forced vibrations in machine tools are most often caused by cyclic variations in the cutting forces.
(*b*) In planer the relative motion between cutting tool and work is rectilinear.

81. Define (*a*) cutting oils (*b*) emulsions.

82. H.S.S. cutting tools are generally provided with
(*a*) Positive rake angle
(*b*) Negative rake angle.

83. Cemented carbide and ceramic cutting tools are usually provided with
(*a*) Positive rake angle (*b*) Negative rake angle.

84. State the initial information required for designing a speed ger box.

85. The range ratio (R_n) of spindle speeds in speed gear boxes of machine tools, is related to range ratio of cutting speed (R_v) and range ratio of work piece diameters (R_d) as
(*a*) $R_n = R_v \times R_d$ (*b*) $R_n = R_v + R_d$
(*c*) $R_n = R_v - R_d$ (*d*) None of the above.

86. Define the following for a speed gear box.
(*i*) Range ratio of spindle speeds (R_n)
(*ii*) Range ratio of cutting speeds (R_v)
(*iii*) Range ratio of work piece diameters (R_d).

87. Give reasons for the following statements
(*a*) C.I. is commonly used for making machine tool structures.
(*b*) Use of disposable ceramic tools reduces the machining cost.
(*c*) Metallic work pieces with high hardness have poor machinability.

88. State five factors which restrict the use of plastic slide ways.

89. State four factors which commonly contribute to the natural surface roughness of a workpiece.

90. Name the materials which can be easily machined by cemented carbide tools.

91. State whether the following statements are true or false.

(*i*) In a cutting tool with positive rake angle the direction of thrust is towards tip of tool.
(*ii*) In a cutting tool with negative rake angle the thrust is directed into the body of the tool.

92. State three applications of negative rake carbide tools.

93. What is the difference between forming and generating of surfaces?

94. State three demerits of N.C. control machine tools.

95. Define the factors of productive time.

96. Why cast iron and bronze are usually milled dry ?

97. What will happen if the frequency of vibration coincides with the natural frequency of any mode of machine tool ?

98. The quantity of metal removed (Q) per unit time in rotational metal cutting operations is given by
(*a*) $Q = 1000 f.t.V \text{ mm}^3/\text{min}$ (*b*) $Q = f.t.V \text{ mm}^3/\text{min}$
(*c*) $Q = \dfrac{f \cdot t \cdot V}{1000} \text{ mm}^3/\text{min}$ (*d*) None of the above.
where f is feed (mm). t is depth of cut (mm) and
v is cutting speed (m/min).

99. State four applications of each of the following D.C. motors.
(*i*) Shunt motors (*ii*) Series motors
(*ii*) Compound motors.

100. State whether the following statements are true or false :
(*i*) D.C. shunt motor runs practically at constant speed at almost all loads.
(*ii*) D.C. series motor has the characteristic of decreasing speed for increasing load.
(*iii*) D.C. series motor is well suited for lighter starting torque.
(*iv*) Three phase induction motor can either be squirrel cage or phase wound.
(*v*) In three phase induction motor starting torque is low because resistance in the armature circuit can not be added.
(*vi*) In CNC machine tool structure close type structure is used.

101. State three main requirements of machine tools.

102. Coefficient of friction in anti-friction guide ways is
(*a*) High (*b*) Low.

103. State two characteristics of tool material in E.D.M.

104. Name the types of working motions in a machine tool.

105. The common ratio (ϕ) used for automats is
(*a*) 1.26 (*b*) 1.41
(*c*) 1.12 (*d*) None of the above.

106. Name three materials commonly used for making slide-ways

107. Statements
(*i*) Point to point N.C. system is generally used in drilling and

(*ii*) Contouring N.C. machine tools are expensive than those operating on point to point control principle.

(*iii*) A punched tape is most widely used programming medium in N.C. machine tools.

108. Name three programming medium in N.C. machine tools.

109. Numerically controlled systems with a feed back device are known as
(*a*) open loop systems (*b*) closed loop systems.

110. Short answer questions.
(*a*) compare group drive and individual drive of machine tools
(*b*) classify machine tool structures
(*c*) part program in N.C. system.

111. Carbon tetra chloride is used as cutting fluid at
(*a*) Low cutting speeds (*b*) High cutting speeds.

112. *Statements*
(*a*) High speed steel high in cobalt has the ability to retain its hardness at high temperature
(*b*) The machining accuracy which includes both profile as well as dimensional accuracy is determined by machine tool compliance.

113. Classify rolling guides based on geometrical form.

114. (*a*) In rolling guides the friction force becomes smaller with greater diameter of rolling elements.
(*b*) In rolling guides operating under light loads the resistance to motion is determined mainly by sliding friction.

115. In Taper roller guide ways the taper on roller is
(*a*) 0.5 to 1 μm (*b*) 2 to 4 μ m
(*c*) 6 to 8 μ m (*d*) None of the above.
(1 μm = 1 micron)

116. State the coolants used for milling the following materials
(*i*) Steel and brass (*ii*) Cast iron and bronze.

117. State the reasons for the following
(*a*) Limited use of diamond tools
(*b*) Why low values of rake angle are recommended for diamond tools.

118. State the commonly used rake angle of cutting tool while turning aluminium
(*a*) H.S.S. tool (*b*) Cemented carbide tool
(*c*) Diamond tool.

119. State two main requirements of slide ways materials.

120. *Statements*
(*a*) Longitudinal oil grooves sharply lower the hydrodynamic load carrying capacity of the guide ways
(*b*) In slide ways the hydrostatic friction takes place where a special lubricating system provides separation of the slide way

121. Name three factors that contribute to the rise of hydro-dynanmic pressure in slide ways.

122. State the drawbacks of stick-slip phenomenon during motion of machine tool slides on slide ways.

123. *True or false statements*
(*i*) By jogging the operator brings the tool to the reference position and sets this position through the control panel as (0, 0, 0) or the reference desired by the programmer.
(*ii*) A block corresponds to one line of instruction on the part program.

124. *Fill in the blanks*
(*a*) In N.C. machine tools the motors used to control, speed, feed and depth of cut are ...... (servomotors, electric motors)
(*b*) The rotary movement about *x*-axis is designated by ...... (*A, B, C*)
(*c*) The ...... axis of motion is always the axis of the main spindle of the machine. (*Y*-axis, *Z*-axis)
(*d*) Circular profiles can be produced on a CNC lathe using ...... codes. (G80, G81, G02, G03)

125. Name two typical elements of M.C.U. of N.C. machine tools.

126. Classify NC/CNC machines based on control systems.

127. *Fill in the blanks*
(*a*) In conventional machines, the cutting tool cuts metal for about ......% of the total machining time.
(*b*) In CNC machine tools the cutting time is about ......% of total machining time.

128. Name three types of actuation systems used in N.C. machines.

129. In CNC machines the rotary movements about *x*, *y* and *z* axis are represented by
(*a*) *A*, *B*, *C* respectively (*b*) *P*, *Q*, *R* respectively
(*c*) *x*′, *y*′, *z*′ respectively (*d*) None of the above.

130. Circular interpolation on CNC machine can be carried out using
(*a*) G02 (*b*) G03
(*c*) G02 or G03 code.

131. Nitriding process of surface treatment for steel tools is used for tools taking
(*a*) light cuts (*b*) medium cuts
(*c*) heavy cuts.

132. At very low cutting speeds the tool wear is due to
(*a*) plowing action (*b*) transfer

133. State the ways in which machine tools can be classified.

134. State general requirements of a machine tool.

135. State five requirements of a cutting tool.

Answers

1. (A) (*a*) (B) (*b*)
   (C) (*a*) (D) (*b*).
2. (*e*)
3. (*b*)
4. (*a*) True (*b*) False
   (*c*) False (*d*) True
   (*e*) True (*f*) True
   (*g*) False (*h*) True.
5. (*a*) 118° (*b*) 25—40 metre/min
   (*c*) 180—240 metre/min.
6. (A) (*d*) (B) (*a*)
   (C) (*a*) (D) (*c*)
   (E) (*c*)
7. (*a*) True (*b*) True
   (*c*) False (*d*) True
   (*e*) True
8. (*e*)
9. (*a*) 35° (*b*) 15°
   (*c*) 0°
10. (*c*).
11. (*i*) (*a*) (*ii*) (*c*)
    (*iii*) (*c*) (*iv*) (*b*)
    (*v*) (*b*) (*vi*) (*b*)
    (*vii*) (*c*).
12. (*a*)
13. (*b*) True (*b*) True
    (*c*) False (*d*) False
    (*e*) True (*f*) False
    (*g*) False.
14. (*a*) True (*b*) False
    (*c*) True (*d*) True
    (*e*) True (*f*) False
    (*g*) True (*h*) False.
15. (*c*)
16. (*a*) False (*b*) True
    (*c*) True (*d*) False
    (*e*) False (*f*) True.
18. (*i*) 1600—1950 (*ii*) 600—1800
    (*iii*) 1500—1800 (*iv*) 1200—1800
    (*v*) 2700—4800.
19. (*i*) [(*d*)] (*ii*) [(*b*)]

    (*iii*) [(*c*)] (*iv*) [(*a*)]
    (*v*) [(*f*)] (*vi*) [(*e*)]
20. (*a*) True (*b*) False
    (*c*) True.
21. (*a*).
22. (*a*) True (*b*) False
    (*c*) True.
23. (*i*) Sawing (*ii*) Hand grinding
    (*iii*) Filling (*iv*) Turning
    (*v*) Milling (*vi*) Drilling
    (*vii*) Surface grinding (*viii*) Lapping
    (*ix*) Super finishing.
24. (*a*) True (*b*) False
    (*c*) False (*d*) True.
25. (*a*) 2*T* (*b*) 1*T*, 1*R*
    (*c*) 1*T*, 1*R*.
26. (*b*). 27. (*a*).
28. (*a*) True (*b*) False
    (*c*) False (*d*) True
    (*e*) True.
29. (*a*).
30. (*a*) 30 kg/cm^2 (*b*) 70 kg/cm^2
    (*c*) 5 to 80 kg/cm^2.
31. (*b*).
32. Multipoint cutting tools are twist drill, milling cutter grinder wheel and reamer.
33. (*b*) 34. (*c*)
35. (*c*)
36. *Material* — *Abrasive used*
    (*a*) Steels — Aluminium oxide
    (*b*) Cast iron — Silicon carbide
    (*c*) Aluminium — Silicon carbide
    (*d*) Wrought iron — Aluminium oxide
    (*e*) Copper — Silicon carbide
    (*f*) Non-metallic material — Silicon carbide
    (*g*) Bronze — Silicon carbide
37. (*b*) 38. (*b*)
39. (*b*)
40. (*a*) False (*b*) True
    (*c*) False (*d*) False
    (*e*) True (*f*) True.
41. The properties of the work material which affect the cutting tool life are as follows :

(*i*) Shear strength of the metal
(*ii*) Coefficient of friction between the chip and the cutting tool
(*iii*) Hardness and strain hardenability of the work material
(*iv*) Micro structure particularly the presence of hard constituents.

42. Requirements to be fulfilled for ideal geared drives are as follows:
(*i*) Least possible gears, shafts and levers are used
(*ii*) It should give sufficient speed changes
(*iii*) Only gears required for power should be engaged at a time.

43. (*a*) Low rake angle (*b*) Low cutting speed
(*c*) High feed.

44. (*a*) 45. (*b*)
46. (*b*) 47. (*b*)
48. (*c*) 49. (*b*)
50. (*a*)

51. In lapping laps are made from the following materials :
(*i*) Cast iron (*ii*) Soft steel
(*iii*) Copper (*iv*) Brass
(*v*) Hard Wood (*vi*) Hardened Steel
(*vii*) Glass.
The lapping media include abrasive flours such a diamond dust, boron, carbide silicon carbide aluminium oxide and emery mixed with an oil or bonding vehicle such as gasoline, kerosene, petroleum, or vegetable oil.

52. (*a*) 0.9 to 5 (*b*) 0.13 to 1.25
(*c*) 0.08 to 0.25 (*d*) 0.01 to 0.25.

53. Materials with a comparatively low tensile strength such as glass, ceramics etc. can be easily machined by U.S.M. process

55. (*a*) 56. (*a*)
57. (*b*) 58. NaCl, KCl, $NaNO_3$
59. (*i*) True (*ii*) True.

60. 18—4—1 H.H.S. is commonly used for making cutting tools. It contains
18% Tungsten
40% Chromium
1% Vanadium.

61. (*a*)
63. (*i*) True (*ii*) True
(*iii*) True (*iv*) True.

64. The main factors affecting chip contraction are as follows :
(*a*) Geometric elements of cutting tool point (chiefly cutting angle and nose radius)
(*b*) Cutting variables such as cutting speed and feed
(*c*) Cutting fluid (*d*) Workpiece material
(*e*) Mechanical properties of workpiece material.

65. (*i*) Lapping (*ii*) Honing
(*iii*) Precision turning (*iv*) Precision boring.

66. (*i*) Dry machined
(*ii*) Mineral oil, lard oil, inactive E.P. oil
(*iii*) Mineral oil, inactive E.P. oil.

67. (*a*) True (*b*) True
(*c*) True (*d*) True
(*e*) True (*f*) True
(*g*) True.

68. (*i*) Adjustable speed D.C. or squirrel cage motor
(*ii*) D.C. shunt or general purpose squirrel cage motor
(*iii*) Squirrel cage or adjustable D.C. motor.

69. Positioning accuracy of ± 0.01/300 mm and ± 0.025 mm over the entire transverse and a repeatability of ± 0.005 mm is generally available on present day NC machines.

70. (*a*) True (*b*) True
(*c*) True.

71. Following three types of actuation systems are commonly used in NC equipment
(*i*) Electro-mechanical (*ii*) Hydraulic
(*iii*) Pneumatic.

72. In terms of production volume the manufacturing plants are classified as follows :
(*i*) Job shop production (*ii*) Batch production
(*iii*) Mass production.

73. (*i*) Positive (*ii*) low.

74. (*a*) *H* (*b*) *N*
(*c*) *N* (*d*) *N*
(*e*) *S* (*f*) *S*.

75. (*a*) A long shear plane (*b*) Tool chip interface
(*c*) Tool workpiece interface.

76. (*c*)

77. Basic requirements of machine tool drive are as follows :
(*i*) To transmit motion and power from the input shaft to the output spindle, ram, or table.
(*ii*) To convert rotary motion to the translatory or reciprocating motion or *vice-viersa*.

78. The common requirements of spindle supports are as follows :
(*i*) Guiding accuracy
(*ii*) High stiffness
(*iii*) Ability to perform satisfactory under varying conditions of spindle operation
(*iv*) Stability against vibrations
(*v*) Minimum heating.

79. The stiffness of hydrodynamic bearings changes with

(*i*) lubricant viscosity (*ii*) temperature
(*iii*) rotational speed of journal.

80. (*a*) True (*b*) True

81. (*a*) Cutting oils are mixtures of lard, cotton seed or rape-seed oils and mineral oils.

(*b*) Emulsions are usually mixtures of a soluble oil consisting of mineral oil, sodium or potassium base soaps, free fatty acids and glycerine or alcohol with a large proportion of water. Paste cutting compounds are usually solid emulsions of mineral oil, sodium or potassium base soaps and water.

82. (*a*) 83. (*b*)

84. The following information is required initially to design a speed gear box.

(*i*) Maximum output R.P.M. (N_{max})
(*ii*) Minimum output R.M.P. (N_{min})
(*iii*) The number of steps into which the range between N_{max} and N_{min} is divided.
(*iv*) The number of stages in which the required number of steps are to be achieved.

85. (A)

86. $R_n = \dfrac{N_{max}}{N_{min}}$ $\quad R_v = \dfrac{V_{max}}{V_{min}}$

$R_d = \dfrac{D_{max}}{D_{min}}$

where N_{max} = Maximum output RPM of spindle
N_{min} = Minimum output RPM of spindle
V_{max} = Maximum cutting speed
V_{min} = Minimum cutting speed
D_{max} = Maximum workpiece diameter
D_{min} = Minimum workpiece diameter.

87. (A) (*i*) Cast iron has better vibrations damping properties
(*ii*) Cast iron has better sliding properties.
(*iii*) Cast iron can be easily cast.

(B) Because much higher cutting speeds are possible while using ceramic tools.

(C) Because power consumption and temperature and hence tool wear rate will be more.

88. (*i*) Poor structural stiffness
(*ii*) Poor wear resistance when contaminated by abrasive dirt
(*iii*) Low thermal conductivity
(*iv*) Poor contact rigidity
(*v*) Tendency to smell by absorbing lubricant.

89. (*i*) The occurrence of chatter or vibrations of the machine tool.
(*ii*) Defects in the structural of work material

(*iii*) In accuracies in machine tool movements such as movement of saddle on lathe bed.
(*iv*) Surface damage caused by chip flow.

90. (*i*) C.I. (*ii*) Non-ferrous metals
(*iii*) Non-metallic materials like plastics and marble.

91. (*i*) True (*ii*) True.

92. Negative rake carbide tools, find a particular use in the milling of steel, planner and shaper tools and for facing cuts.

93. In forming, the shape of the surface is a replica of the shape of the cutting tool.

In generating the shape of the surface depends on the direction of motion of the tool with relation to the work and is practically independent of the tool shape.

Generated surfaces are ordinary easier to produce than formed surfaces and can be finished to a higher degree of precision particularly when the work is so hard that abrasive cutting materials must be employed.

94. (*i*) Cost of N.C. machine tools is very high.
(*ii*) Special skills in programming maintenance are essential
(*iii*) Down time of N.C. systems is very expensive.

95. Factors of productive time are as follows :
(*i*) Set up time. It is the preparatory time to get tools, to do paper work and to arrange tools on the machine.
(*ii*) Handling time. It consists of time for measurement, loading and unloading of work piece.
(*iii*) Machining time. It is the time to carry out machining of workpiece.
(*iv*) Down time. It is the time lost due to
(*a*) break downs (*b*) waiting for tools
(*c*) minor accidents etc.

96. Because chips tend to mix with the cutting fluid to make a sticky mass that clogs the cutter teeth.

97. It may result in complete or partial destruction of machine tool and decrease its life.

98. (*a*).

99. (*i*) Pumps, lathes, drilling machines, press, planers
(*ii*) Conveyors, trains, cranes, trams
(*iii*) Crushers, compressors, punch presses, refrigeration plants.

100. (*i*) True (*ii*) True
(*iii*) False (*iv*) True
(*v*) True (*vi*) True.

101. (*i*) Precision (*ii*) Productivity
(*iii*) Low cost.

102. (*b*)

103. The tool material in EDM should possess the following characteristics :
 (*i*) It should have a high melting point
 (*ii*) It should be a good conductor of heat and electricity.

104. (*i*) Drive motion or Primary cutting motion
 (*ii*) Feed motion.
 Working motions may be
 (*a*) Rotary
 (*b*) Translatory.

105. (*c*)

106. (*i*) Cast iron (*ii*) Low carbon steel
 (*iii*) Low alloyed steel.

107. (*i*) True (*ii*) True
 (*iii*) True

108. (*i*) Punched cards (*ii*) Magnetic tapes
 (*iii*) Punched tapes.

109. (*b*).

110. (*a*) Group drive and Individual drive
 Both group drive system and individual drive systems are used in machine tools. The choice depends on the following factors :
 (*i*) Initial cost
 (*ii*) Operating cost
 (*iii*) Machine tool requirements.
 Group drive is generally used where power consumption of individual machines is extremely variable with occasional high peaks. Group drive is more economical in fixed charges, power consumption and maintenance. The disadvantages of this system are as follows :
 (*i*) In case of breakdown all machines tools in group become idle.
 (*ii*) The shop is usually very noisy.
 Individual drive is preferred for machine tools requiring high power.

Machines requiring wide speed variations are also best driven by individual drive. In this system there better utilisation of floor and layout is simple.

 (*b*) Machine tool structures are classified as follows :
 (*i*) According to purpose of machine tool structures
 (*a*) Beds, frames
 (*b*) Bases, bed plates
 (*c*) Housings, columns, pillars brackets
 (*d*) Casings and covers.
 (*ii*) Based on method of manufacturing
 (*a*) Cast
 (*b*) Welded
 (*c*) Combined cast and welded.

 (*c*) Part program in N.C. system contains informations regarding the following :
 (*i*) Type of contour to be cut
 (*ii*) Starting and end position for each major section of contour to be cut.
 (*iii*) Cutter size, coolants, cutting speed, feed etc.
 (*iv*) Machining sequence.

111. (*a*).

112. (*a*) True (*b*) True.

113. By geometrical form the rolling guides are divided into two categories.
 (*i*) Prismatic
 (*ii*) Cylindrical.

114. (*a*) True (*b*) True.

115. (*a*)

116. (*i*) Lard oil and emulsions of water and soluble oils
 (*ii*) Cast iron and bronze are generally milled dry since the chips tend to mix with the fluid to make a sticky mass that clogs the cutter teeth.

117. (*a*) Because of relatively high cost of diamond tools
 (*b*) To provide a stronger cutting edge.

118. (*a*) 40° (*b*) 15°
 (*c*) Zero degree.

119. Two main requirements of materials used for slideways are as follows
 (*i*) Wear resistance including
 (*a*) resistance to abrasive wear
 (*b*) resistance to scuffing
 (*ii*) Good frictional properties including.
 Low coefficient of sliding friction and static friction and their little dependence on the sliding speed and on the duration of static contact.

120. (*a*) True (*b*) True

121. (*i*) Improved design of slide ways
 (*ii*) Better surface finish
 (*iii*) Higher viscosity of oil.

122. (*i*) Poor machining accuracy and surface finish
 (*ii*) Lower productivity
 (*iii*) Additional automatic loading of drive systems.
 (*iv*) Shorter life and breakdown of cutting tools.
 (*v*) Increased slide way wear rate.

123. (*i*) True (*ii*) True.

124. (*a*) Servomotors (*b*) A
 (*c*) z-axis (*d*) G02 or G03.

125. (*i*) Program reader
 (*ii*) Feed back system

126. Based on control system features the NC/CNC control systems are classified as follows :
  (*i*) Point to point control system
  (*ii*) Straight line control system
  (*iii*) Continuous path or contouring control system.

127. (*a*) 25% (*b*) 60–75%.

128. Three types of actuation systems commonly used in N.C. machine tools are as follows :
  (*i*) Electro mechanical
  (*ii*) Hydraulic
  (*iii*) Pneumatic

129. (*a*)

130. (*c*).

131. (*a*)

132. (*a*)

133. Machine tools can be classified in different ways as follows :
  (*i*) Based on the type of processing operations
  (*ii*) Degree of specialisation
  (*iii*) Accuracy of the machine tool
  (*iv*) Size and weight of the machine.

  Apart from this there is a general classification of machine tools based on the following :
  (*i*) The shape of generated surface
  (*ii*) The shape of cutter
  (*iii*) The type of finish
  (*iv*) The nature of relative movement between workpiece and cutter.

134. (*i*) Accuracy : Accuracy produced should be high.
  (*ii*) Rate of metal removal : It should be maximum
  (*iii*) Economical : Machine tool should have economical efficiency.

  Machining quality depends on the various factors as mentioned below:
  (*i*) Cutting tool
  (*ii*) Tool holder
  (*iii*) Workpiece and its clamping
  (*iv*) The cutting conditions.

135. Five major requirements of a cutting tool are as follows :
  (*i*) High wear resistance
  (*ii*) High hardness.
  The property of retaining hardness at the elevated temperature is known as hot hardness.
  (*iii*) More toughness
  (*iv*) Low coefficient of friction between tool and chip.
  (*v*) Easier manufacturing of tool.