

GANDHI SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Manufacturing Engineering Lab-II

LABORATORY MANUAL

LIST OF EXPERIMENTS

Expt. No.	Date	Experiment
1		Drilling Exercise: Drill three different sized holes in various materials, maintaining uniform distance between them.
2		Milling: Create a square and hexagon from round bars with and without indexing.
3		Generation of Spur Gear Teeth on a Round Bar.
4		Simple Planing Exercise: Cut 'T' slots (one model).
5		Shaping a Hexagon on a Round Bar, Keyways, Grooves, and Splines.
6		Shaping Step Block: Cut dovetail at angles of 60°, 90°, and 120°.
7		Cylindrical Grinding: Grind external and internal surfaces using a universal grinding machine.
8		Grinding Cutting Tools to Required Angles.
9		Grinding Milling Cutters on a Tool and Cutter Grinder.
10		Grinding Flat Surface on a Surface Grinder Using Magnetic Chuck and Clamping Devices.
11		Dismantling and Servicing of Drilling Machine Components and Reassembly.

EXPERIMENT – 1

1. Aim

To drill three different-sized holes in selected work materials while maintaining a uniform centre-to-centre distance between the holes.

2. Machines / Tools / Instruments

Drilling machine (bench or pillar type), twist drills of three sizes, machine vice, centre punch, hammer, steel rule, scribe, try square, vernier caliper / depth gauge, cutting fluid and deburring tool.

3. Materials

Suitable metal workpieces such as mild steel, aluminium or brass, as specified by the instructor.

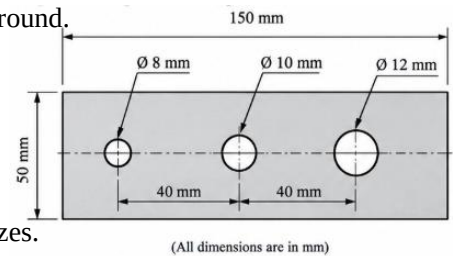
4. Principle / Theory

Drilling is a hole-making operation in which a rotating multi-point cutting tool (drill) removes material from a stationary or suitably supported workpiece. A twist drill generally has two main cutting lips and a chisel edge. The work is first marked and centre-punched to prevent drill wandering. For accurate location, the drill should be started with a centre drill or small pilot drill where appropriate. Different drill diameters require suitable spindle speeds.

Parameter	Typical relation / guidance
Cutting speed	$V = \pi DN / 1000$ (m/min), where D is drill diameter in mm and N is rpm.
Spindle speed	$N = 1000V / (\pi D)$. Use the speed recommended for the material and drill.
Hole location	Mark all centres from a common datum so the centre-to-centre spacing remains uniform.

5. Procedure

1. Clean the workpiece and mark a datum line and three hole centres at equal spacing.
2. Centre-punch each marked location lightly and verify the spacing using a steel rule or vernier.
3. Select and inspect the first drill. Check that the drill is sharp, straight and properly ground.
4. Clamp the workpiece securely in the machine vice. Support thin work adequately.
5. Fit the drill in the chuck and remove the chuck key before starting.
6. Set a suitable spindle speed and feed. Align the drill with the first centre.
7. Start the machine and drill the first hole. Use cutting fluid where appropriate.
8. Repeat the operation for the second and third holes using the specified larger drill sizes.
9. Break sharp edges with a deburring tool and clean the holes.
10. Measure hole diameters and verify centre-to-centre distances.



6. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Hole 1 diameter	_____ mm	_____ mm	
2	Hole 2 diameter	_____ mm	_____ mm	
3	Hole 3 diameter	_____ mm	_____ mm	
4	Distance between holes 1-2	Equal / _____ mm	_____ mm	
5	Distance between holes 2-3	Equal / _____ mm	_____ mm	

7. Result

Three holes of the specified sizes were drilled successfully with approximately uniform centre-to-centre spacing.

8. Precautions

- Clamp the job firmly; never hold a loose job by hand during drilling.
- Do not force the drill. Use suitable feed and cutting fluid.
- Keep hands away from the rotating drill and do not wear gloves near rotating spindles.
- Stop the spindle completely before measuring or removing the workpiece.

EXPERIMENT – 2

1. Aim

To produce square and hexagonal surfaces from a round bar by milling, using both indexing and non-indexing methods where applicable.

2. Machines / Tools / Instruments

Milling machine, vice, plain / end mill or side-and-face cutter as suitable, dividing (indexing) head, tailstock where required, dial indicator, vernier caliper, steel rule and parallels.

3. Principle / Theory

Milling removes material by a rotating multi-point cutter while the workpiece is fed against the cutter. A square can be produced by milling four equally spaced faces. A regular hexagon requires six equally spaced faces. With a standard dividing head, indexing is commonly obtained from the relation: crank movement = $40/N$ per division, where N is the number of divisions (teeth/sides). Thus for a hexagon, the crank movement is $40/6$ turns per side.

Shape	Number of equal faces	Standard indexing movement (40/N)
Square	4	10 turns of the indexing-head crank per full face interval
Hexagon	6	$6\frac{2}{3}$ turns of the indexing-head crank per full face interval

4. Procedure – Square

1. Mount the round bar securely in the vice, with adequate projection.
2. Align the vice and indicate it if required by the job.
3. Set the cutter at a safe height and establish a reference face.
4. Mill the first flat surface to the required depth.
5. For a non-indexing method, rotate/reposition the work manually using the appropriate fixture or vice arrangement and verify each 90° position accurately.
6. For indexing, mount the work in the dividing head and index by $1/4$ revolution of the work between faces using the appropriate head setting.
7. Repeat for all four faces and measure across flats.

5. Procedure – Hexagon

1. Mount the round bar in the dividing head and support the free end if necessary.
2. Set the first reference surface and take a light trial cut.
3. For a six-sided regular section, index the work by $1/6$ revolution between successive faces; with a 40:1 head this corresponds to $6\frac{2}{3}$ crank turns per division.
4. Mill each face using equal depth and suitable feed.
5. Deburr the job and check the six faces and across-flats dimension.

6. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Initial bar diameter	_____ mm	_____ mm	
2	Required across flats – square	_____ mm	_____ mm	
3	Required across flats – hexagon	_____ mm	_____ mm	
4	Indexing head ratio	40:1 / _____	_____	

7. Result

Square and hexagonal profiles were produced from the round bar by controlled milling and indexing.

8. Precautions

- Use rigid workholding and minimum necessary overhang.
- Never change indexing or move the work while the cutter is rotating.
- Use light finishing cuts for dimensional accuracy.
- Verify cutter clearance before indexing.

Fig. 1 : Workpiece (Round Bar)



Fig. 2 : Square Surface (Non-Indexing Method)

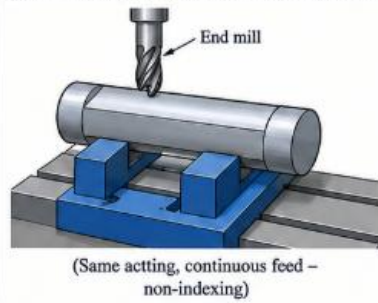


Fig. 3 : Square Surface (Final View)

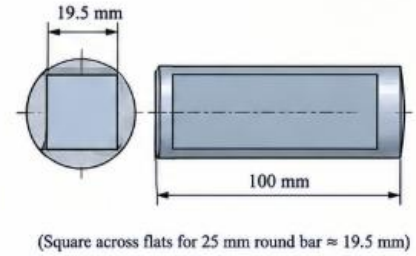


Fig. 4 : Hexagonal Surface (Indexing Method)

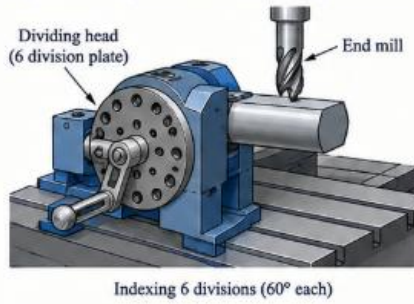


Fig. 5 : Hexagonal Surface (Final View)

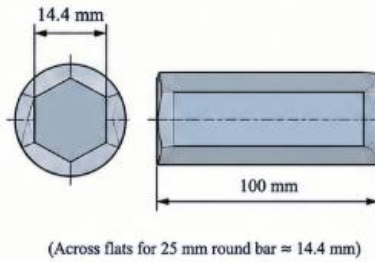


Fig. 6 : Indexing Method - 6 Division Plate

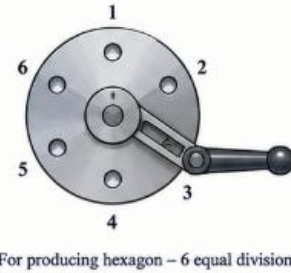


Fig. 7 : Tool Angles for Milling

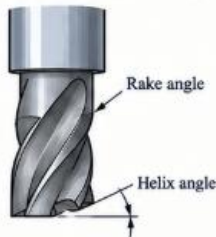


Fig. 8 : Setup for Non-Indexing Method (Square)

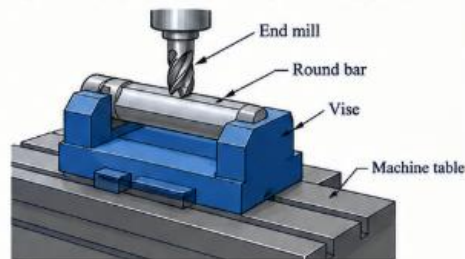
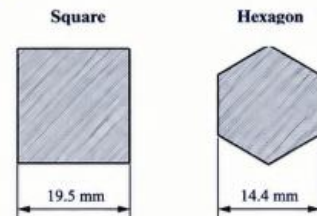
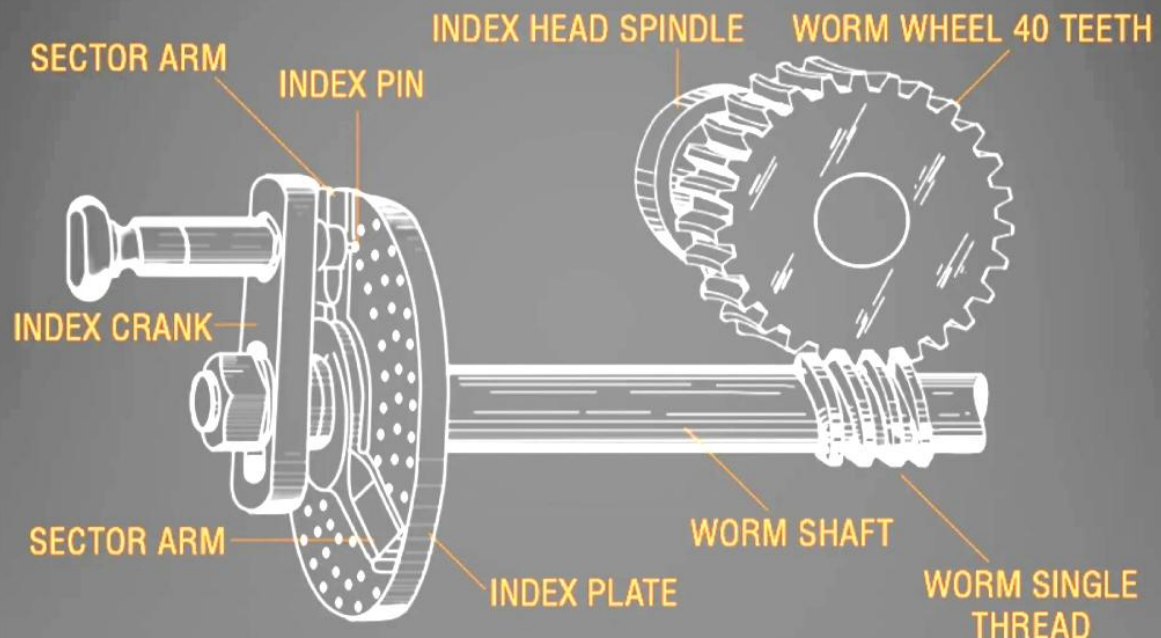


Fig. 9 : Comparison of Cross Sections



INDEX HEAD PARTS



EXPERIMENT – 3

1. Aim

To generate spur gear teeth on a round bar using a milling machine, dividing head and involute gear cutter.

2. Apparatus

Milling machine, dividing head, involute gear cutter, tailstock/centre support, gear blank, vernier caliper, gear tooth vernier and measuring tools.

3. Theory

A spur gear has straight teeth parallel to its axis. In form milling, an involute cutter corresponding to the required module and tooth number range is used. For a gear of module m and number of teeth Z : pitch circle diameter $d = mZ$; outside diameter $d_a = m(Z+2)$; whole depth $\approx 2.25m$ for standard full-depth involute teeth; addendum $= m$; dedendum $\approx 1.25m$. The cutter must match the module and tooth-number range. The work is indexed accurately between teeth.

Quantity	Formula / relation
Module	$m = d/Z$
Pitch circle diameter	$d = mZ$
Outside diameter	$d_a = m(Z + 2)$
Addendum	$h_a = m$
Approx. dedendum	$h_f = 1.25m$
Indexing crank movement per tooth	$40/Z$ turns for a 40:1 dividing head

4. Procedure

1. Determine the required module and number of teeth from the job drawing.
2. Prepare the round gear blank to the specified outside diameter and width.
3. Mount the blank concentrically between the dividing-head centre/chuck and tailstock support.
4. Select the correct involute cutter for the module and tooth-number range.
5. Set the cutter at the gear centre line and establish the required tooth-space depth according to the drawing.
6. Take a light trial cut and verify the setup.
7. Cut the first tooth space. Withdraw the table before indexing.
8. Index the blank by $40/Z$ crank turns for each successive tooth space.
9. Repeat until all tooth spaces are generated.
10. Deburr, clean and inspect the gear teeth. Check tooth spacing and dimensions.

5. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Module	_____ mm	_____ mm	
2	Number of teeth	_____	_____	
3	Pitch circle diameter	_____ mm	_____ mm	
4	Outside diameter	_____ mm	_____ mm	
5	Cutter number / type	_____	_____	
6	Indexing movement	$40/Z =$ _____ turns	_____	

6. Result

Spur gear teeth were generated on the round gear blank using the specified module and indexing arrangement.

7. Precautions

- Select the correct involute cutter for module and tooth-number range.
- Ensure the blank is concentric and the dividing head is locked during cutting.
- Withdraw the table before indexing to avoid accidental cutter contact.
- Do not touch the cutter while the spindle is rotating.

EXPERIMENT – 4

1. Aim

To machine a T-slot on a job using a planing machine and suitable T-slot cutting tools.

2. Apparatus

Planer, T-slot cutter(s) / side milling arrangement as specified, workpiece, straight edge, vernier, scribe, try square, marking tools and measuring instruments.

3. Theory

A T-slot consists of a narrow upper slot with an enlarged undercut below it. T-slots are commonly used on machine tables for fastening fixtures and workpieces with T-bolts. The slot is produced in stages: first a straight slot is made, followed by the wider undercut portion using a suitable T-slot tool or cutter. The tool must have adequate clearance and rigidity.

4. Procedure

1. Mark the centre line and dimensions of the T-slot on the workpiece.
2. Clamp the job rigidly on the planer table and align the reference edge.
3. Select the correct tool and set its height and stroke clearance.
4. Machine the upper straight slot to the specified width and depth.
5. Replace or adjust the tool for the undercut portion.
6. Machine the lower wider portion carefully on both sides to form the T profile.
7. Take finishing cuts and verify the width, depth and symmetry of the slot.
8. Remove burrs and clean the workpiece.

5. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Top slot width	_____ mm	_____ mm	
2	Top slot depth	_____ mm	_____ mm	
3	Undercut width	_____ mm	_____ mm	
4	Total depth	_____ mm	_____ mm	

6. Result

A T-slot was machined to the dimensions specified in the job drawing.

7. Precautions

- Provide adequate clearance at the ends of the planer stroke.
- Ensure the tool does not interfere with the job or table.
- Use rigid clamping to prevent job movement.
- Measure only after stopping the machine.

Fig. 1 : T-slot Dimensions (Example)

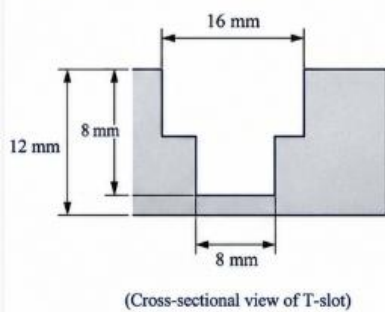


Fig. 2 : T-slot Cutter (Typical)

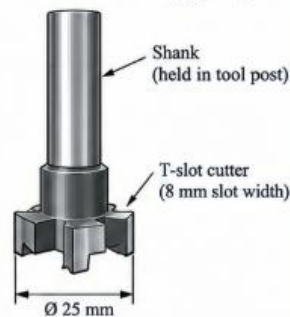


Fig. 3 : Planing Machine Setup

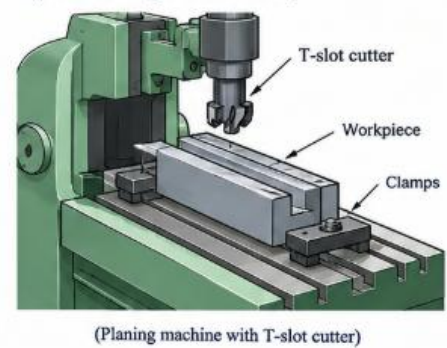


Fig. 4 : Sequence of Operation

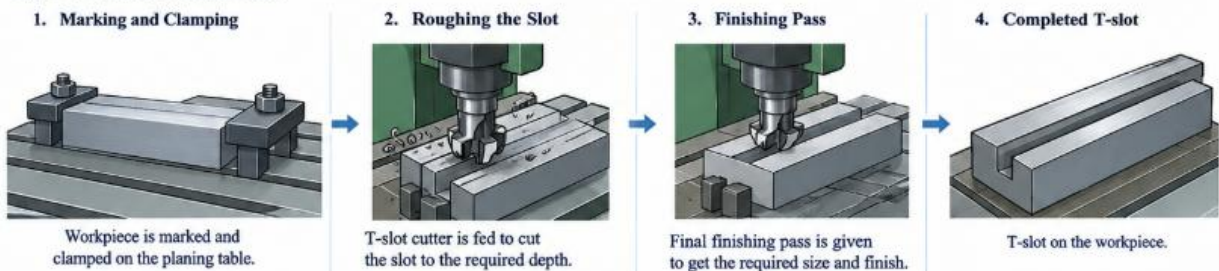


Fig. 5 : Finished T-slot (Top View)

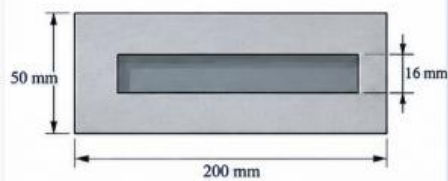


Fig. 6 : T-slot Cross-section (Detailed View)

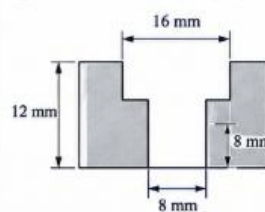
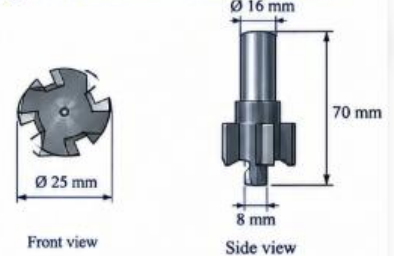


Fig. 7 : T-slot Cutter – Front and Side View



EXPERIMENT – 5

1. Aim

To produce a hexagonal section on a round bar and to machine keyways, grooves and splines using a shaping machine.

2. Apparatus

Shaper, vice, shaping tool, workpiece, angle/setting tools, vernier caliper, keyway tool, grooving tool and spline-forming arrangement as specified.

3. Theory

A shaper removes material with a single-point cutting tool during the forward cutting stroke. The return stroke is idle. A hexagon can be formed by machining six equally spaced faces. Keyways are slots cut in shafts or hubs to accommodate keys for torque transmission. Grooves are recesses of specified width/depth. Splines are multiple longitudinal teeth or grooves used for positive torque transmission and axial sliding where required.

4. Procedure – Hexagon

1. Mark the round bar and clamp it securely in the vice.
2. Set the tool perpendicular to the surface to be generated.
3. Take a light cut and produce the first flat.
4. Rotate/reposition the work by the required angular increment and repeat until six flats are produced.
5. Check the across-flats dimension and symmetry.

5. Procedure – Keyway / Groove / Spline

1. Mark the location and dimensions of the keyway, groove or spline.
2. Select a tool matching the required width/profile.
3. Set the job and tool so the cutting action is correctly aligned.
4. Take successive cuts to reach the required depth/profile.
5. For splines, use the indexing arrangement specified by the machine/job drawing to obtain equal spacing.
6. Measure the finished feature and deburr.

6. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Hexagon across flats	_____ mm	_____ mm	
2	Keyway width × depth	_____ × _____ mm	_____ × _____ mm	
3	Groove width × depth	_____ × _____ mm	_____ × _____ mm	
4	Number of splines	_____	_____	

7. Result

The specified hexagonal surface, keyway, groove and/or spline profile was produced successfully.

8. Precautions

- Use a rigid tool with minimum overhang.
- Allow the shaper ram to complete its return before making adjustments.
- Check angular indexing carefully for multiple equally spaced features.
- Avoid excessive depth of cut that may cause tool chatter.

Fig. 1 : Shaping Machine Setup

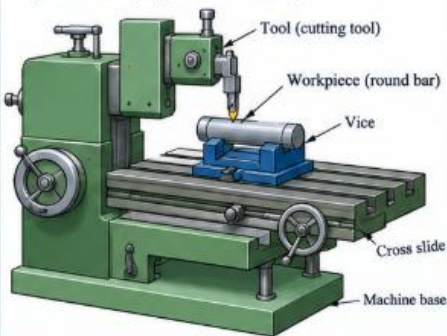


Fig. 2 : Hexagonal Section on Round Bar

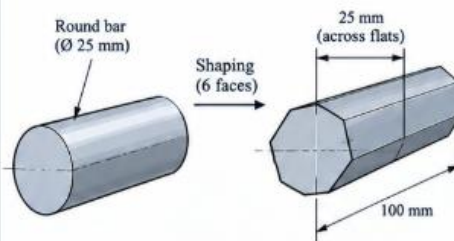


Fig. 3: Top View of Hexagon

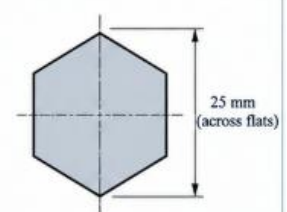


Fig. 4 : Keyway on Round Bar

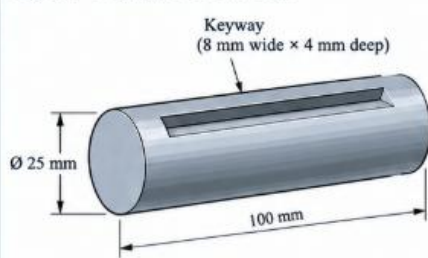


Fig. 5 : Cross Section of Keyway

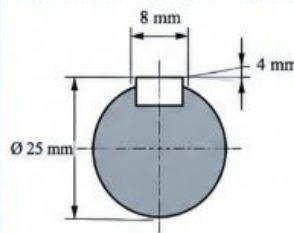


Fig. 6 : Groove on Round Bar

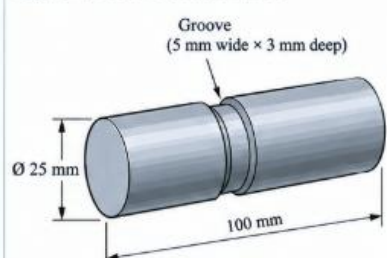


Fig. 7 : Cross Section of Groove

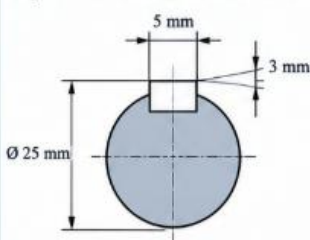


Fig. 8 : Spline on Round Bar

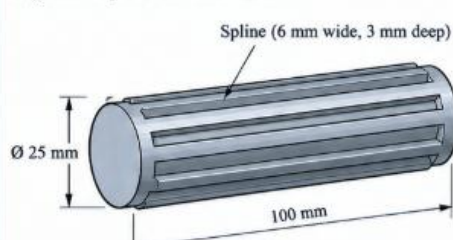
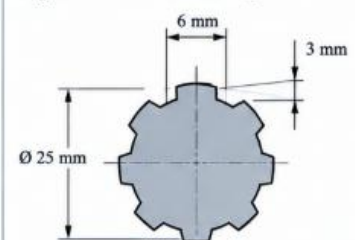


Fig. 9 : Cross Section of Spline



EXPERIMENT – 6

1. Aim

To machine a step block and cut dovetail features at 60°, 90° and 120° as specified in the job drawing.

2. Apparatus

Shaping machine, vice, dovetail/angled tool, bevel protractor, vernier caliper, depth gauge, surface gauge, scribe and suitable workpiece.

3. Theory

A dovetail is an inclined-sided slot or projection used for accurate location and guidance, commonly in machine slides and fixtures. The included angle is controlled by accurately setting the tool or workpiece. A bevel protractor or suitable angle-setting device is used to verify the angle.

4. Procedure

1. Mark the step-block dimensions and dovetail location from the reference surfaces.
2. Clamp and align the block in the shaper vice.
3. Set the first inclined tool angle using a bevel protractor or machine setting arrangement.
4. Machine the first inclined face using light successive cuts.
5. Set the opposite side to obtain the specified included angle.
6. Repeat the setup for the 60°, 90° and 120° forms required by the job.
7. Finish the surfaces and check angle, width and depth.
8. Deburr and clean the job.

5. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Dovetail angle – 1	60°	_____°	
2	Dovetail angle – 2	90°	_____°	
3	Dovetail angle – 3	120°	_____°	
4	Width / depth	As per drawing	_____ mm	

6. Result

The step block with dovetail features at the specified angles was machined and inspected.

7. Precautions

- Check angle setting before taking the finishing cut.
- Use light cuts on inclined surfaces to avoid tool deflection.
- Ensure the workpiece remains firmly clamped.
- Do not measure while the machine is running.

Fig. 1 : Job Drawing (All dimensions in mm)

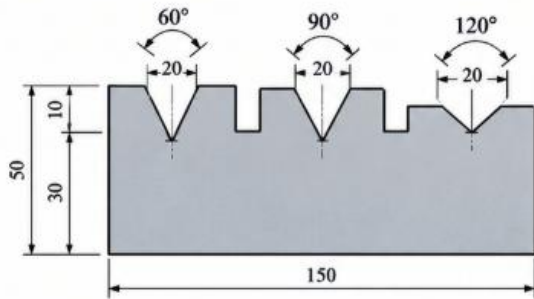


Fig. 2 : Isometric View of Finished Workpiece

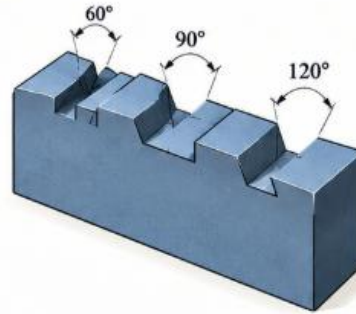


Fig. 3 : End View (Dovetail Angles)

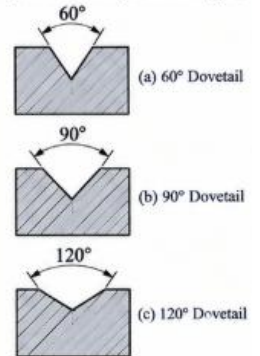


Fig. 4 : Side View (Step Block with Dovetails)

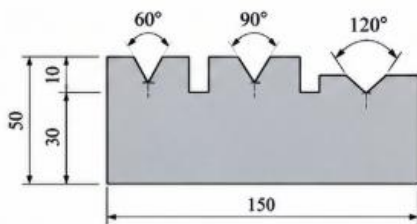


Fig. 5 : Top View

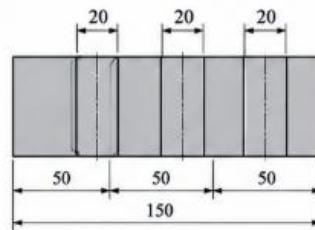


Fig. 6 : Sectional View of Dovetails

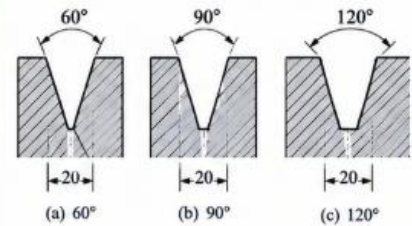


Fig. 7 : Machining Setup (Vice on Milling Machine Table)

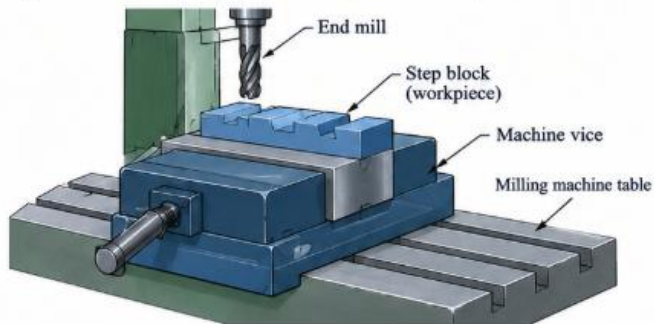
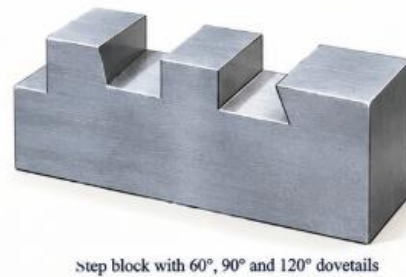


Fig. 8 : Actual Machined Workpiece (Photograph/Illustration)



EXPERIMENT – 7

1. Aim

To grind external and internal cylindrical surfaces using a universal cylindrical grinding machine.

2. Apparatus

Universal cylindrical grinding machine, grinding wheel, workholding arrangement/chuck or centres, internal grinding attachment, micrometer, vernier, dressing tool and coolant system.

3. Theory

Cylindrical grinding is an abrasive machining process used to obtain high dimensional accuracy and surface finish on cylindrical surfaces. External grinding removes material from the outside diameter; internal grinding removes material from the inside diameter of a bore. A universal cylindrical grinder can accommodate work between centres, in a chuck and with suitable internal grinding attachments. Wheel dressing restores wheel geometry and cutting action.

4. Procedure – External Grinding

1. Inspect the machine, wheel and workholding arrangement.
2. Mount the work securely between centres or in the chuck as prescribed.
3. Balance and dress the grinding wheel if required.
4. Set the work and wheel centres correctly and establish safe clearance.
5. Start the wheel and work rotation at the specified speeds.
6. Apply small infeed and traverse the wheel across the work.
7. Use coolant as required and take successive finishing passes.
8. Measure the diameter after stopping the machine.

5. Procedure – Internal Grinding

1. Mount the workpiece securely and ensure the bore is accessible.
2. Fit the internal grinding attachment and select a suitable small wheel.
3. Set the wheel concentric with the bore and check clearance.
4. Start the wheel and work rotation.
5. Apply very small infeed and traverse through the bore.
6. Use coolant where appropriate and make finishing passes.
7. Measure bore diameter and surface quality.

6. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	External initial diameter	_____ mm	_____ mm	
2	External final diameter	_____ mm	_____ mm	
3	Internal initial diameter	_____ mm	_____ mm	
4	Internal final diameter	_____ mm	_____ mm	
5	Grinding wheel specification	_____	_____	

7. Result

The specified external and internal cylindrical surfaces were ground to the required dimensions and finish.

8. Precautions

- Inspect the wheel and use the machine guard.
- Do not take heavy infeed on a grinding wheel.
- Maintain adequate coolant flow where required.
- Keep the wheel dressed and avoid loading or glazing.
- Stand clear during wheel start-up.

EXPERIMENT – 8

1. Aim

To grind a cutting tool to the required geometry and angles for effective machining.

2. Apparatus

Bench/pedestal tool grinder, suitable grinding wheel, high-speed steel tool blank or tool bit, angle gauge / bevel protractor, cooling arrangement and eye protection.

3. Theory

A single-point cutting tool requires correct rake, clearance, cutting-edge and nose geometry. Typical tool angles include back rake, side rake, end relief, side relief and cutting-edge angles. Exact values depend on tool material, work material and machining operation; therefore the job drawing or instructor's specification must be followed. Grinding is carried out in small stages to avoid overheating and to maintain geometry.

Tool feature	Purpose
Rake angle	Helps chip flow and reduces cutting resistance.
Clearance / relief angle	Prevents rubbing between tool flank and machined surface.
Cutting edge angle	Controls entry of the cutting edge and load distribution.
Nose radius	Improves strength and surface finish when properly selected.

4. Procedure

1. Study the required tool geometry and identify all specified angles.
2. Dress the grinding wheel if necessary and ensure a clean, safe grinding rest.
3. Hold the tool blank securely and present it to the wheel without forcing.
4. Grind the primary clearance surfaces first.
5. Grind the required rake surfaces and cutting-edge geometry.
6. Form the nose radius or point as specified.
7. Cool the tool frequently to prevent overheating and loss of hardness.
8. Check each angle using a suitable gauge or bevel protractor.
9. Remove burrs and inspect the cutting edge.

5. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Back rake angle	_____°	_____°	
2	Side rake angle	_____°	_____°	
3	End relief angle	_____°	_____°	
4	Side relief angle	_____°	_____°	
5	Nose radius	_____ mm	_____ mm	

6. Result

The cutting tool was ground to the specified angles and checked for proper cutting geometry.

7. Precautions

- Wear safety goggles and use the wheel guard.
- Use a tool rest with a small safe gap from the wheel.
- Do not press the tool hard against the wheel.
- Cool the tool frequently; avoid overheating.
- Never use a damaged or improperly mounted grinding wheel.

EXPERIMENT – 9

1. Aim

To grind a milling cutter on a tool and cutter grinder to restore or produce the required cutting geometry.

2. Apparatus

Universal tool and cutter grinder, suitable grinding wheels, cutter holding fixture/arbor, angle-setting device, dial indicator, magnifier and measuring instruments.

3. Theory

Tool and cutter grinders are precision machines used to sharpen and manufacture milling cutters, drills, reamers and other cutting tools. A milling cutter must have correctly ground relief and cutting edges. The cutter is mounted so that each tooth can be presented to the wheel at the same angular position. For a multi-tooth cutter, uniform indexing is essential for equal tooth geometry and balanced cutting action.

4. Procedure

1. Clean and inspect the cutter, arbor/fixture and grinding wheel.
2. Mount the cutter accurately and indicate it if required.
3. Set the required wheel type, speed, inclination and clearance.
4. Set the cutter tooth to the reference position.
5. Grind the specified relief surface with a light pass.
6. Index to the next tooth and repeat using identical settings.
7. Continue until all teeth have been ground uniformly.
8. Check tooth dimensions, edge condition and concentricity/run-out as applicable.
9. Deburr and clean the cutter.

5. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Cutter type / diameter	_____	_____	
2	Number of teeth	_____	_____	
3	Required relief angle	_____°	_____°	
4	Cutter run-out	≤ _____ mm	_____ mm	
5	Tooth uniformity	Uniform	_____	

6. Result

The milling cutter was ground/sharpened on the tool and cutter grinder with uniform tooth geometry.

7. Precautions

- Use the correct wheel for the cutter material and geometry.
- Index every tooth accurately.
- Use small grinding passes to avoid overheating and loss of geometry.
- Ensure the cutter and arbor are rigidly mounted.

EXPERIMENT – 10

1. Aim

To grind a flat surface on a surface grinder using a magnetic chuck and suitable clamping devices.

2. Apparatus

Surface grinding machine, grinding wheel, magnetic chuck, clamps/fixtures where required, dial indicator, surface gauge, vernier/micrometer and coolant.

3. Theory

Surface grinding produces accurate flat surfaces with good finish. A magnetic chuck holds ferromagnetic workpieces by magnetic force; non-magnetic or irregular workpieces require suitable mechanical clamping fixtures. The wheel is dressed to obtain the required cutting condition. Grinding is carried out using small controlled infeed and reciprocating table movement.

4. Procedure

1. Clean the magnetic chuck and workpiece contact surfaces.
2. Place the workpiece on the magnetic chuck and position it correctly. For non-magnetic jobs, use approved clamping devices.
3. Check workpiece seating and indicate the surface if necessary.
4. Dress the grinding wheel and set safe clearance.
5. Start the wheel and table movement.
6. Set a very small infeed and make a light grinding pass.
7. Traverse across the workpiece with suitable overlap and coolant as required.
8. Take successive small passes until the required dimension and finish are obtained.
9. Stop the machine, clean the work and measure flatness/thickness as specified.

5. Observation

Sl. No.	Parameter	Required / Set Value	Observed Value	Remarks
1	Initial thickness	_____ mm	_____ mm	
2	Final thickness	_____ mm	_____ mm	
3	Grinding allowance removed	_____ mm	_____ mm	
4	Surface finish / appearance	Good	_____	

6. Result

A flat surface was ground to the specified thickness and surface finish using a magnetic chuck / clamping arrangement.

7. Precautions

- Clean the chuck and job before clamping.
- Ensure the magnetic chuck is fully engaged and the job is securely seated.
- Use mechanical clamping for non-magnetic materials where required.
- Take small infeed to prevent wheel overload and thermal damage.
- Use the wheel guard and stand clear during start-up.