SHAPING AND PLANING

Shaping and planing ➔ the simplest of all machine operations

Straight line cutting motion with single-point cutting tool creates smooth flat surfaces.

Mainly plain surfaces are machined

- Shaping and planing operations are not production effective
- They are used mainly in tool and die work
SHAPERS - The machine tool

- reciprocating for single point cutting tool – a cycle
- feed – across the line of reciprocating of the tool, between strokes to produce a flat horizontal surface
HORIZONTAL TYPE SHAPERS

- BASE supports a HORIZONTAL RAM – that will carry the tool
- COLUMN

A QUICK RETURN MECHANISM

- The tool is held in RAM in a clapper box
- Tool holder – the tool firm on the cutting route
- The return stroke releases the tool so as not to dig into the work. (a swivel mounting)

QUICK RETURN MECHANISM

- Crank and shaft are oscillating type
- Crank length can be varied by a screw mechanism → the stroke is changed

Cutting time \( CT = \frac{W}{N_s \times f_c} \)
- \( W \) is width of the work piece
- \( N_s \) is the bull wheel rpm
- \( F_c \) is the feed rate per stroke
Cutting speed  \[ CS = \frac{2 \times L \times N_s}{R_s} \]  
L is stroke length, \( R_s \) is the stroke ratio

\[ R_s = \frac{\text{cutting _ stroke _ angle}}{360^\circ} \]

Material removing rate  \[ MRR = \frac{L \times W \times t}{CT} \]  
t is the chip thickness

SHAPERS:

**Horizontal**  
Push cut, Pull cut or draw cut shapers

**Vertical**  
Regular (slotters), keyseaters

**Special**

Disadvantages
- cutting speed is not constant
- force of cutting varies with the position of the crank

Advantages
- return of the tool – faster
- tool hits the work at lower speed

Hydraulic Shaper
- Ram –driven by hydraulic cylinder
- cutting speed and the force on the ram are constant
- return speed
- cutting speed
VERTICAL SHAPER

- Used mainly for machining of circular and internal surfaces
- The ram reciprocates vertically; the table has a rotary movement. \(\rightarrow\) angular feed, circular surfaces can be processed.

WORK SET-UP IN SHAPERS

- Heavy vices are used; can be rotated and clamped about vertical axis (and a horizontal axis sometimes).
- Work-piece must be clamped solidly against the bottom of the vice.
- At the beginning of the stroke – a dynamic force trying to dislodge the work-piece.
• The tool can be also fed across the work piece (planing)

• tool cuts only in one direction during one stroke.
• a slow process with no reverse cutting action
• it is difficult to generate curvilinear surfaces by shaping
• it is still used despite all these disadvantages (is very cheap)
• Low qualification of the machinist
• low cost tools
PLANING – on planers

- The work-piece is moved in a straight line against a single – edge tool
- adopted to much larger work-pieces than the shaper also suitable to machine multiple small parts held in line or in matrix on the table
- Less in use – there are more effective milling processes
- Some of the places – leave the tool heads arranged so that cut can be carried in both directions.
- For multiple pieces – multiple tools

Drivers for Planers

Gear drive
Screw drive uniform cutting
Belt drive smaller inertia forces
Crank drive uniform cutting forces
Variable speed motor drive less noised in operation
Hydraulic devices less power consumption

Open side planers for wide work-pieces
Double Housing Planers

BEDS
- are providing parallel motion of table in machine tools
- Planners which have very long table need accuracy in moving the work-piece
  - material – stabilized cast iron
  - narrow tables
- For wider table – two V– ees and a support (for temperature compensation)

PIT TYPE PLANER
- Workpiece is fixed – very large in size the tool is moved over the workpiece
- Tow Ram–type heads are mounted on a cross rail
- Each is furnished with double clapper box for two way planning.
- The reversing housings, which support the cross rail slide on ways
**Feeds** – at the both ends of the planing stroke or at one end only

**Plate Planer or Edge Planer**

- For machining the edges of heavy steel plates.
- Carriage with the cutting tool as moved back and forth along the edge.
- Most edge planers use milling cutters for greater speed and accuracy

**TOOLS**
- heavier in construction – they face impact
- tool holders with removable lid are more used than forged tools
- the tip of the tool is backed to avoid digging into metal and to reduce chatter

**Issues:** blocking of tool.
DRILLING AND REAMING

Drilling: Operations that creates internal cylindrical surfaces

DRILLING

HOLES
- blind hole

- through hole
DRILLING AND REAMING

- FLUTE
- TOOL
- CHIP
- TOOL MOTION
- WORKPIECE (STATIONARY)

BEFORE
- ROD
- PLATE
- CASTINGS
- EXTRUDED

AFTER
Introduction

• Drilling \(\Rightarrow\) about 25 % of all
  – Looks simple \(\Rightarrow\) but complex (two cutting edges or lips)
  – Flexible tool and the cutting edges at the end
  – Cutting takes place inside the workpiece \(\Rightarrow\) chip removal
  – Additional friction to that of chip formation \(\Rightarrow\) additional heat
  – Counterflow of the chips \(\Rightarrow\)
    lubrication and cooling difficulties

– At the tool tip \( V=0 \Rightarrow \)
  high difficulties of engagement (starting the hole)
Introduction – 2

Twist drill
250 M pieces/year!!!

Nomenclature and geometry of conventional twist drill. Shank style depends upon the method used to hold the drill. Tangs or notches prevent slippage: (a) Straight shank with tang, (b) tapered shank with tang, (c) straight shank with whistle notch, (d) straight shank with flat notch.

Leading edge of the land (terminating in the point) forms the cutting edge.
COUNTERBORING - to seat bold heads or sockets

COUNTERSINK

SPOT FACING
BORING
- enlarging an already existent hole
- better tolerance control
- deeper holes
- surface finish

REAMING
- enlarges to proper size
- smooth finish
- finishing of the hole surface
DRILLING

Problems

FLEXIBILITY AND LENGTH OF THE DRILL
DIFFICULT CHIPS RELEASE
Chips counter flow → difficult COOLING & LUBRICATION
at the tip V=0 → high difficulties of engagement
**TOOLS- TWIST DRILLS**

- Two flutes \(\rightarrow\) two chips
- Two cutting edges
- Cylinder or tapered shank
- Why Land?
- Cone angle affects the chip flow
- High cone angles, 118-135° \(\rightarrow\) ductile
- Small cone angles, 90-118° \(\rightarrow\) brittle

What to know

- To draw the drill
- Names of the basic parts of the drill
- Helix (Rake)- angle 24° – cannot be changed
- Point angle (118°) can be different
• The cone-shaped point: cutting edges + various clearance angles
• **Cone angle** ➔ direction of the chip flow into the flute
• **118° cone angle** ➔ mild steels, general purpose drilling
• **Cone angles 90°-118°** ➔ brittle materials (gray cast iron, magnesium alloys)
• **Cone angles 118°-135°** ➔ more ductile materials (aluminum alloys)
• **Cone angles < 90°** ➔ drilling plastics
• Drills can be ground to produce various cone angles
FIGURE 24-3 Types of twist drills and shanks. Bottom to top: Straight-shank, three-flute core drill; taper-shank; bit-shank; straight-shank, high-helix-angle; straight-shank, straight-flute; taper-shank, subland drill.
Drilling

In drill, $D =$ diameter of the drill which rotates 2 cutting edges at rpm $N_s$. $V =$ velocity of outer edge of lip of drill.

$N_s = 12V/\pi D$

$CT = L + A/f_r N_s$ where $f_r$ is the feed rate in in. per rev. The allowance $A = D/2$. The $MRR = (\pi D^2/4)f_r N_s$ in.$^3$/min which is approximately $3DVf_r$.

$v = \pi DN, m/min, Din m$

$MRR = (\pi D^2/4)f_r N, m^3/min$
DRILLING OPERATION

• Is efficient to remove metal in thick chips than to increase the RPM

• Feed recommended $f_a = 0.005 – 0.01 \text{ in/rev}$
  
  $0.1 – 0.2 \text{ mm/rev}$

• Cutting liquid helps in chip removal

• For chip evacuation – periodic removal of drill recommended

• Drilling horizontally – more advantageous for deep hole drilling

DRILLING TIME ESTIMATION  

(F = 0.1/0.2 mm/rev)  

($v \approx 30\text{m/min}$)

$$CT = \frac{L + A}{fr \times \text{RPM}}$$

$$Vol = \frac{\pi d^2 L}{4}$$

$$MRR = Volume / CT$$
Torque increases with feed and dia.

Thrust influenced by chisel and web end design
Fundamentals – 2

\[ T_m = \frac{(L + A)}{f_r N} = \frac{L + A}{f_m} \]

\[ \text{MRR} = \frac{\text{volume}}{T_m} \]

\[ = \frac{\pi D^2 L / 4}{L / f_r N} \]

\[ \text{MRR} = (\pi D^2 / 4) f_r N \]

\[ \text{MRR} \approx 3DV f_r \]
Secondary angle 30° – 40° (true)
Primary angle 4° – 8° (true)

Four-facet
Good self-centering ability
Breaks up chips for deep-hole drilling
Can be generated in a single grinding operation
Eliminate center drilling in NC

Helical (S-shape chisel point)
Can eliminate center drilling on NC machining centers
Excellent hole geometry
Close relationship between drill size and hole size
Increased tool life
Lower thrust requirements
Leaves burr on breakthrough

S-point
"S" form chisel

Secondary angle 17° – 27° (true)
Primary angle 10° (true)

10° notch
130°

Bickford
Combination of helical and Racon point features
Self-centering and reduced burrs
Excellent hole geometry
Increased tool life

Racon (radiused conventional point)
Increased feed rates
Increased tool life (8–10 times in C.I.)
Reduced burrs at breakthrough
Not self-centering

Split point
Combination of helical and Racon point features
Self-centering and reduced burrs
Excellent hole geometry
Increased tool life

Relieved helical
Reduces thrust force
Eliminate chisel edge
Equil, rake angle

Twisted flute
Margin
Convex rake face
Carbide tip
Noncutting zone
Body

Center core drill or Slot point drill
Greatly reduced thrust
Center core removed by ductile fracture (tension)

Thrust force [lbs]

<table>
<thead>
<tr>
<th>Feed, ipr</th>
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</thead>
<tbody>
<tr>
<td>0.008</td>
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<td>0.015</td>
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<tr>
<td>0.020</td>
</tr>
<tr>
<td>0.027</td>
</tr>
</tbody>
</table>

Conventional
Helical
Four-facet
Relieved helical
The chip – depends on the point angle

Thick chips – less energy per unit volume than thin chips

Drill Point:
- chisel edge at the end of the web that connects the two cutting edges
- This edge DOES NOT CUT EFFECTIVELY
- large negative rake angle
- high axial forces and excessive heat at the point speed is ~0 here
- buckling – static instability

FAILURES -

Tendency - to try to engage a cutting edge when a drill engages in metal

SOLUTIONS

1. **Spiral point drill** -
   - Spiral edge – much better provides cutting action
   - Difficult to grind it?

2. **Spilt point drill** -
   - has a spilt point and thinned web
   - used to drill hard materials
   - it has secondary cutting edges

3. **Drills with chip – breakers** - to increase the efficiency of the drilling process.
DRILL SIZES

Three size series:

- **Millimeters series:** 0.01 – 0.5 mm, increments starting from \( \phi .015 \) mm
- **Numerical series:** No. 80 – to No. 1 (0.0135” to 0.228”)
- **Fractional series:** 1/64 to 4” + increments (LARGE)

TiN coating of drill increases the life by 200-1000%
FIGURE 24-5  Effects of improper drill grinding. (Left) angles of two tips are different; (Right) lengths of the lips are not equal. (Courtesy of Cleveland Twist Drill Company.)

Angle Unequal
Length Unequal
Holes Oversize
High speed, long flute $\rightarrow$ tool support $\rightarrow$ centering, tool change

THIS CHISEL HAS THE TENDENCY TO WALK AWAY

- a center drill is used prior to a regular drill
- drill combined with a countersink

OLD

NEW
DEEP HOLE DRILLS or GUN DRILLS

Very long holes compared to diameter!

Eg. Gun barrel

What could be the problems, if long drill is used?

• Removal of chip
• Cooling of the tool, Coolant can not reach
• Tool drifting and bending
• Increase of side friction and heating

→ COOLING, LUBRICATION, CHIP EVACUATION

SOLUTIONS

• Different cutting mechanism
• Include passages through which the coolant can be delivered to the cutting edge
• Enlarged flute section to evacuate the chips
• Straight Flute
FIGURE 24-6  BTA drills for boring trepanning, counterboring, and drilling deep holes.
Deep hole drilling machines

Special machines for rifle barrels, connecting rods for engines, etc.

**REQUIREMENTS:**
- high cutting speed
- small feeds
- intensive reverse flow of cooling liquid to ease chip removal
- adequate support for the long drill

Special horizontal machines: the piece is rotating → One single flute drill is used

- high pressure oil is brought through hole.
LARGE HOLE DRILLS

1. Saw cutting

or 2. Two single – point tools (fly-cutter) pilot at the center

Tendency to walk away is eliminated
Double margin drills - made to better lead the drill?

Step drills - combinations of drills – different diameters, difficult to sharpen

FIGURE 24-10 Special-purpose subland drill (above), and some of the operations possible with such drills (below).
• **Spade drills:** for making holes with Ø 1 in or larger
  • Low speeds and high feed
  • Deep holes in solid or stacked materials (over an existing hole)
  • Drilling end mounted on a long supporting bar (ordinary steel)
  • Drill point can be ground with a minimum chisel edge
  • No flutes → more rigid body (maybe a central hole for cooling and chip removal)
**Carbide-tipped drills**

*Drills with indexable inserts* (w/one or two-piece inserts)

- Four times faster than a spade drill $\Rightarrow$ shallow holes $\Rightarrow$
  
  high speed/low feed $\Rightarrow$ roughing tools $\Rightarrow$ more closer to boring process

- Requirements: extremely rigid machine tool, enough horsepower, cutting fluids
Effect of L/D ratio on tool Selection

<table>
<thead>
<tr>
<th>Sector</th>
<th>Typical drill types</th>
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<tbody>
<tr>
<td>A</td>
<td>Twist drill (HSS)</td>
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<tr>
<td>A</td>
<td>Center core drill</td>
</tr>
<tr>
<td>B</td>
<td>Twist drill</td>
</tr>
<tr>
<td>B</td>
<td>Gun drill</td>
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<tr>
<td>B</td>
<td>BTA</td>
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<tr>
<td>B</td>
<td>Ejector drill</td>
</tr>
<tr>
<td>C</td>
<td>Twist drill</td>
</tr>
<tr>
<td>C</td>
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<tr>
<td>D</td>
<td>BTA</td>
</tr>
<tr>
<td>D</td>
<td>Ejector drill</td>
</tr>
</tbody>
</table>
Jigs and Fixtures

Jigs: are used in production like drilling, tapping and reaming operations

Help drilling the part (quick loading and unloading) must guide cutting tool

Advantages:
- the operations can be performed by unskilled operators
- bushing to pilot (guide) the drill

Clearance:
- under drill clearance – for chips escaping
- cleaning of the jig from chips

Built of standard parts → to reduce the cost

Fixtures:
- Work holding and work supporting devices
- They do not guide the tool
- Jigs perform the junction of a fixture (not vice-versa)
FIGURE 28-18 Master jig designed for part family: (a) part family of round plates (six parts); (b) group jig for drilling, showing adapter and part A.
Machine Tools for Drilling

Axial Thrust Force

Based on:
Mat.: Alloy steel (4140)
Hardness: 240 HB
Cutt. speed: 400 SFM

\[ F_v = \frac{D^x K_s f_r^y}{q} \]

- \( f_r = 0.010 \text{ IPM} \)
- \( f_r = 0.008 \text{ IPM} \)
- \( f_r = 0.006 \text{ IPM} \)
- \( f_r = 0.005 \text{ IPM} \)
- \( f_r = 0.004 \text{ IPM} \)

- \( D = \text{Diameter (in.)} \)
- \( K_s = \text{Specific cutting force value (lb/in.)} \)
- \( f_r = \text{Feed rate IPM (in./rev)} \)

Thrust (lbs) x 1000

Drill diameter

\[\begin{align*}
\frac{3}{4} & \quad 1 & \quad 1\frac{1}{2} & \quad 2 & \quad 2\frac{1}{2} & \quad 3 & \quad 3\frac{1}{2} & \quad 4 & \quad 4\frac{1}{2} \\
1 & \quad 2 & \quad 4 & \quad 6 & \quad 8 & \quad 10 & \quad 12 & \quad 14 & \quad 16
\end{align*}\]
### Axial Thrust Formula

\[ F_v = D^{1.15} \times K_s \times f_r^{0.8} \]

where
- \( D \) = Drill diameter (inches)
- \( K_s \) = Specific cutting energy from table (in-lb/in\(^2\))
- \( f_r \) = Feed (in./rev)

#### Table of Feed (IPR)

<table>
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<tr>
<th>MATERIAL</th>
<th>BRINELL HARDNESS</th>
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<th>.005</th>
<th>.006</th>
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Values in in.-lb/in\(^2\)
Early drills: 3rd century BC - 19th Century

Portable drills – for field operations up to 3/8 in dia
Bench type drilling machine

Hand moved to provide feed. (Rack and pinion is operated by hand)

Spindle – driven by step – cone – pulley shaft, 6-8 speeds.

Sensitive drilling machines

similar to the bench – type drilling machines

- high speeds 30,000 – 1,000,000 RPM
- high skilled operators
Upright drilling machines – Production machines

- stay on the floor
- single spindle and power feeding mechanism
- speeds 60 – 3500 RPM
- feed 4 - 12 steps 0.1/0.6 mm/rev
- feed clutch - disengages automatically at the preset depth of drilling
- Coolant supply system and a collecting system.
- Vertical movement of the table

Gang drilling machines

- several drilling spindles mounted on a single table
- for production when many operations are required
- holes of several sizes
- boring, counterboring, reaming etc → mobile jigs → one operator
Radial Drilling Machines:

- large work-pieces → several holes are drilled
- vertical arm that carries a drilling head
- the arm can be swung around to any position over the work.
- the drilling head → radial adjustment along the arm

**PLAIN MACHINES**  - vertical holes

**SEMI-UNIVERSAL MACHINES**  – head swiveled on the arm to drill holes at various angles
Multi-spindle drilling machines

- Can drill several holes simultaneously
- Production machines with high accuracy – for cylinder blocks
- Guiding plates are used to guide the drills accurately

**Design:**
- A central gear + an assembly of gear boxes and universal joints → the spindles can be adjusted over a large area (each spindle can bore its own RPM)

*FIGURE 24-20* Three basic types of multiple-spindle drill heads: *(left)* adjustable; *(middle)* geared; *(right)* gearless. *(Courtesy of Zagar Incorporated.)*
UNIVERSAL MACHINES – additional swiveling adjustment for the arm and can drill holes at any angle.

Sizes 3 – 20ft available
Speed 20 – 1600 RPM
Feeds 0.075 – 3 mm/rev

**Turret type drilling machines**

- Substitutes the gang drill press when there is space restriction.
- Used when series of operations are required.
- A turret feeds the spindle with the required tool.
Counterboring, Countersinking & Spot Facing

(a) Surfaces produced by counterboring, countersinking, and spot facing.
(b) Counterboring tools: (bottom to top) interchangeable counterbore; solid, taper-shank counterbore with integral pilot; replaceable counterbore and pilot; replaceable counterbore, disassembled. (Courtesy of Ex-Cell-O Corporation and Chicago Latrobe Twist Drill Works.)
Step 1  Centering and countersinking
Step 2  Drilling
Step 3  Truing hole with boring cutter
Step 4  Final sizing with reamer
REAMING

-To finish the existing hole - IMPROVEMENT OF SURFACE QUALITY -

- geometry – many teeth

SURPLUS OF MATERIAL

0.005 – 0.030 in

0.15 – 0.75 mm

• If surplus is not enough – the cutting hole – Reamer has to float when the hole is trimmed.

• Reamer cannot improve the position of the hole
TYPE OF REAMERS

HAND REAMERS
- straight flutes
- shank ended with a square tang for handle
- different starting taper available

CHUCKING REAMERS
- for machine use
  Straight flute, Rose reamer – soft materials
  Helical flute – hard materials
  Taper reamer – for finishing hole to produce exact taper (Morse taper)

EXPANSION REAMERS
- can be adjusted in size (few thous) to fit the hole size after regrinding

SHELL REAMERS
- > ¾” dia
- mounted on a tapered holder
- is saving expensive tool material

ADJUSTABLE REAMERS – adjustable blades
- can be adjusted in size (few thous) to fit the hole size after regrinding
Types of Drills – 9

<table>
<thead>
<tr>
<th>Sector</th>
<th>Typical drill types</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Twist drill (HSS)</td>
</tr>
<tr>
<td></td>
<td>Center core drill</td>
</tr>
<tr>
<td>B</td>
<td>Twist drill</td>
</tr>
<tr>
<td></td>
<td>Gundrill</td>
</tr>
<tr>
<td></td>
<td>BTA</td>
</tr>
<tr>
<td></td>
<td>Ejector drill</td>
</tr>
<tr>
<td>C</td>
<td>Twist drill</td>
</tr>
<tr>
<td></td>
<td>Indexable insert drill</td>
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<tr>
<td></td>
<td>Spade drill</td>
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<tr>
<td></td>
<td>Center core drill</td>
</tr>
<tr>
<td>D</td>
<td>BTA</td>
</tr>
<tr>
<td></td>
<td>Ejector drill</td>
</tr>
</tbody>
</table>

Toolholders for drills

(a) 3 jaw Jacobs chuck
(b) Collet chuck
(a) Synthetic rubber support for jaws
(b) Chuck key
Toolholders for drills – 2

Workholding for Drilling:
• vise or specially designed workholders (*jigs*) ➔ Chapter 29
• for too large workpieces ➔ clamping directly on to the machine tool table
Machine Tools for Drilling

• *Rotation + feed* $\rightarrow$ drilling can be done on a variety of machine tools $\rightarrow$ lathes, vertical milling machines, boring machines and machining centers

• Power (in the form of torque) + thrust

• Rigidity is essential $\rightarrow$ machine tool dynamics $\rightarrow$ chatter & form errors
Transfer – Type Production drilling machines

- automated machines → on a synchronized line
- the work piece is loaded at the front work station →

is transferred and completed.

Types

A. Indexing Table Type
B. Transfer Type
C. Manipulators (robots)