Drilling Process and Tool Geometry

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Outline

- Hole making Processes - Overview
- Drill Point Geometry
- Mechanics of Drilling
- Problems in Drilling
  - Special Drill Points

What is a Hole?

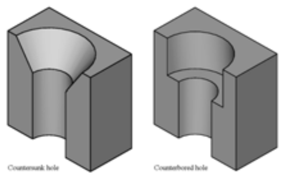
Internal *functional* Cavity or a *Passage* in a part.

Applications

- Coolant (Fluid) Flow
- Lubrication passage
- Fastener locations for Assembly
- Motion between parts

Types of Holes

- Circular / Noncircular
- Through/ Blind
- Plain/ Threaded
- Compound
  - Counter Bore
  - Counter Sunk



Hole Requirements

- Based on Diameter
  - Normal range
  - Micro holes -50 -1000 microns
- Based on L/D ratio
  - Normal range (L/D < 5)
  - Extra Long and Deep Holes

Hole making Processes

- Hole Generation
  - Drilling, Punching, EDM, LBM, EBM
- Hole Enlargement
  - Core drilling, Counter Bore/ Sunk, WEDM
- Hole Finishing
  - Reaming, Boring, Grinding

Hole Enlarging Tools

Core Drills

Counter Bore

Counter Sunk

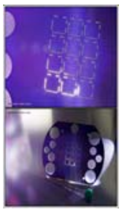
Hole Finishing and Forming Tools

Reamer – Finishing Tool

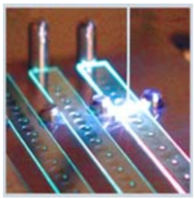
Tap – Thread cutting

Micro Hole Applications

Cooling Turbine blades
Size: 50 microns



Array in Silicon Carbide wafers



Micro holes in glass
Size: 5 microns

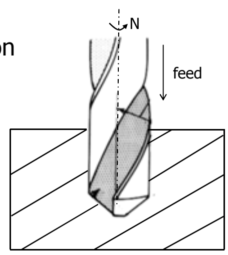
Micro Drilling Processes - Comparison

Parameters	Laser	EDM	ECM	Electron Beam	Ultrasonic
Hole Size (µm)	50-400	>100	>50	80-200	100-500
Surface Roughness(µm)	20	6	6	4	10
Dim. Accuracy (µm)	0.05-0.2	±0.025	±0.025	±0.025	±0.025
Drilling speed Common (mm/s)	<1	>0.05	0.125	<1	N/A

Drilling

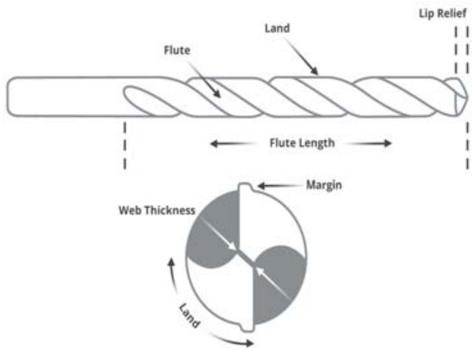
Primary Process of Hole Production

- Drill Rotates and Feeds into job
- Drill geometry
  - Cone Point – machines hole
  - Flutes – Chip and coolant flow
  - Shank – Holding
- Drill has Two Helical Flutes



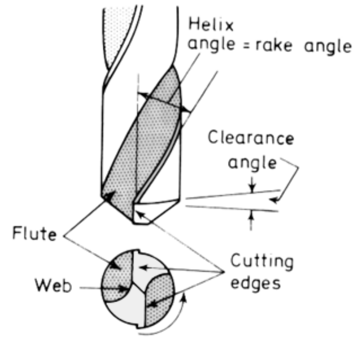
Workpiece

Twist Drill



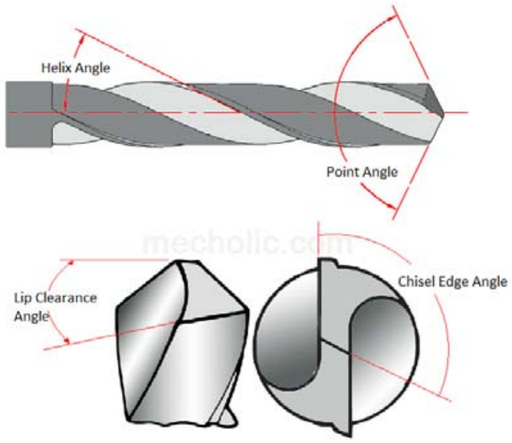
Drill Point Geometry

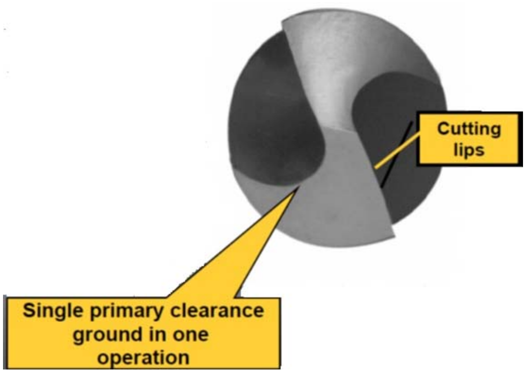
- Drill – a complex cutting tool
- Two cutting edges (Lips)
- Curved Rake and Relief surfaces
- Complex cone point geometry
- Oblique cutting phenomena
  - Severe chip deformations



Elements of a Drill Point

- Cone Point – Roof Top geometry
  - Point Angle
- Helix Angle
- Rake Angles
  - Axial and Normal
- Chisel Edge
- Web Thickness/ web Taper
- Clearance / Relief angles





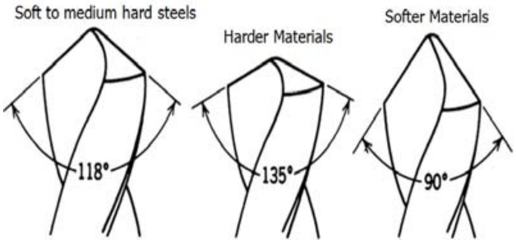
Drill Point Angle

- Governs *Smoothness* of drill entry into part
- Decides cutting edge Lip length for a drill diameter

$$L = \frac{D}{2\sin\varrho} \quad , \quad \text{Point angle} = 2\varrho$$

- Governs relation - Normal and Axial Rake angles
- Point angle depends on work material

Drill Point Angles

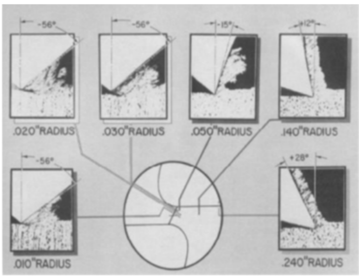


Helix and Rake Angles

- *Helix* angle at drill periphery is
  - *Axial Rake angle*
- Cutting edge Lip has a Curved Rake face
- Axial and Normal Rake angles exist for a lip
- Rake angle varies along the drill Lip
  - Reduces towards axis
  - Negative at Chisel edge (near axis)

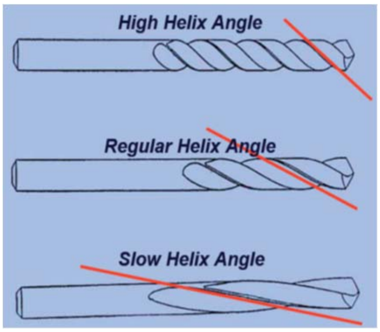
Rake Angle Variation along Lip

-56 -56 -15 + 12



-56 + 28

Drill Helix Angle



34 – 38 deg

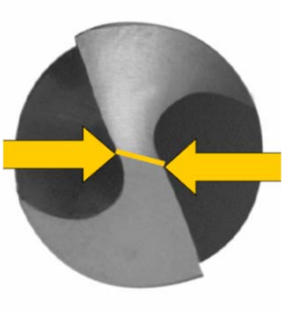
28 – 32 deg

12 – 22 deg

Web and Chisel Edge

- Web - Material between Drill Flutes
- Governs Torsional rigidity of drill
- Trade off - Flute area (Volume) and Rigidity
- Web thickness varies in Regrinding
  - Web Taper

Web Thickness



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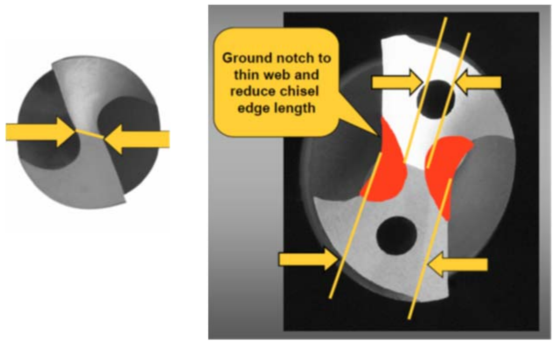
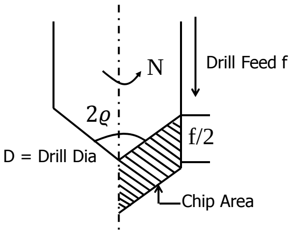
Chisel Edge

- Sharp edge
  - Intersection of cone point surfaces
- Non cutting action at chisel edge
  - Indentation
  - Near zero velocity
- Generates Very High Axial Force
  - 60-70 % of Thrust Force

Web Thinning



Mechanics of Drilling



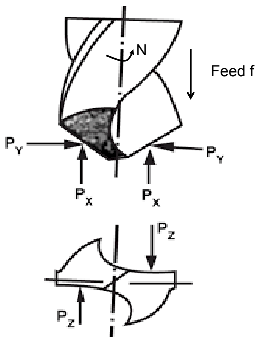
Chip area per lip = $\frac{f.D}{4}$

MRR = $\frac{\Pi}{4} D^2 f\, N$

Forces in Drilling

Thrust Force F = f (P_X)

Torque M = f (P_Z)



Torque and Thrust

Thrust Force : $F = C_1\, HB.D^{n_1}\, f^{n_2}$

Torque : $M = C_2\, HB.D^{n_3}\, f^{n_4}$

Constants - C_1 , C_2, n_1 , n_2 , n_3 , n_4 depend on work material.

Experimentally derived empirical equations.

Oxford Equation

Thrust F (N)

$F = 10^6 x(0.195 HB f^{0.8} D^{0.8} + 0.0022 HB\, D^2)$

Torque M (Nm)

$M = 2x10^6 HB^{0.7} D^2 f^{0.8}$

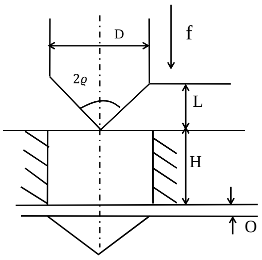
HB = Brinell Hardness Number of material
D = Drill diameter in m
F = feed in m/rev

Machining Time

L = Lip Height
H = Hole depth
O = Overtravel (Thru)
f = feed mm/rev
N = rpm

Machining Time (t)

$$t = \frac{L+H+O}{f.N}$$



Problems in Drilling

- Drill *walk* and *wobble*
  - Lack of Centering - Location error
  - Oversize holes – Circularity error
- Axis bending – Straightness error
- Burr production
  - Material extruded but not cut

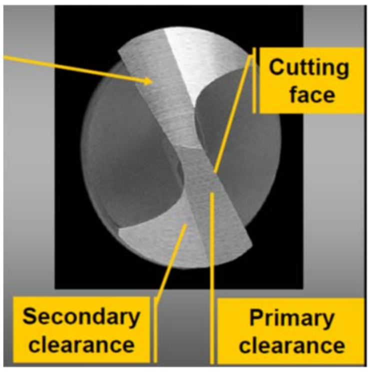
Primary Cause

- Large Axial Thrust force – *Chisel Edge*
- Unequal lips –wobble

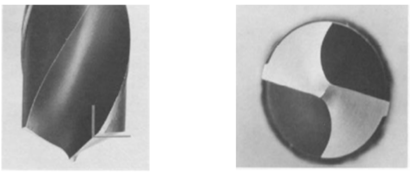
Special Drill Points

- Split point
  - 4 Facet Drill, Crankshaft point
- Spiral Point
  - Spiro Helicoidal relief surface
  - S shaped chisel edge
  - Significant reduction in Thrust force

4 Facet Point - Split Clearance Faces



Spiral Point Geometry



Excellent Self Centering
Burr control