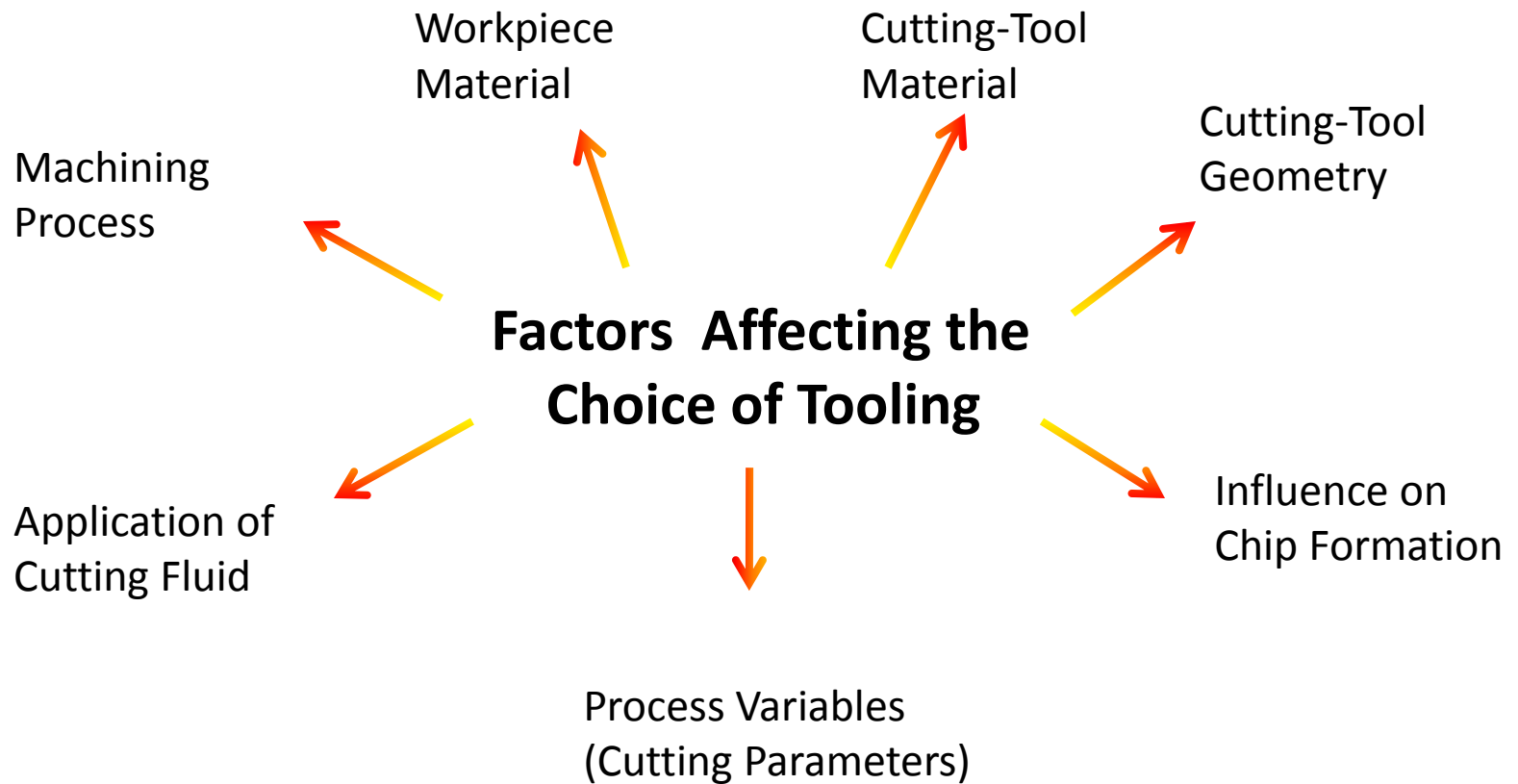


The background of the slide features a collection of various machine tools, primarily drill bits and a reamer, arranged vertically. The tools are shown in a grayscale, high-contrast style, highlighting their metallic surfaces and complex geometries. The central tool is a large, double-flute drill bit, while the tool to its right is a reamer with many fine, closely spaced flutes. Other smaller drill bits are visible on the left and right sides.

Machine Tooling

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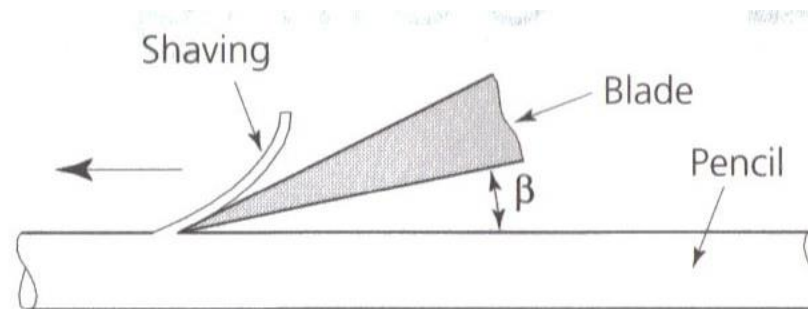
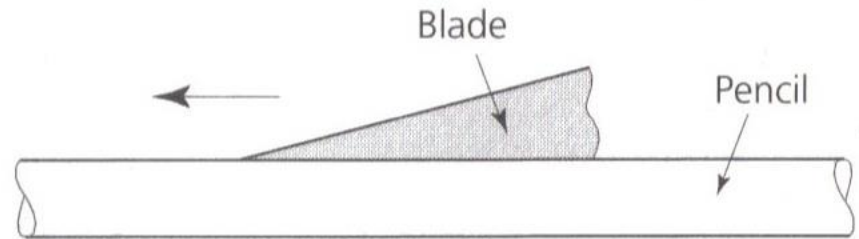
Cutting Tool Geometry

Basic Principles

A Practical Example

Variables

- Blade angle
- Blade sharpness



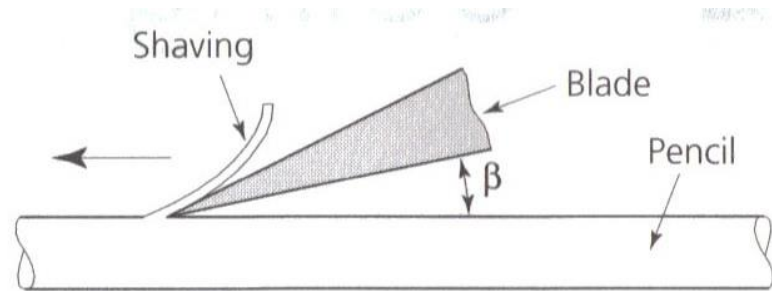
Clearance Angle

Clearance = **Beta β**

Reasons for minimising β

To Prevent the tool biting (digging in)

To Prevent tool 'chatter'



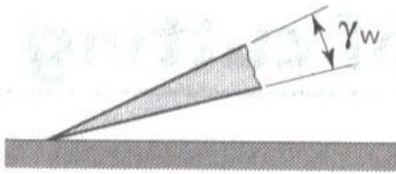
β must be large enough to penetrate the workpiece

β will vary (typically between 5° & 7°) depending on the type of operation and the material being cut

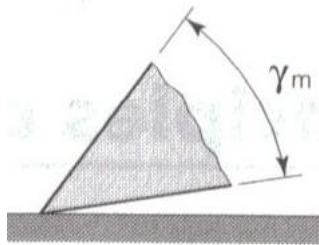
Wedge or Tool Angle

Wedge or Tool Angle = Gamma γ

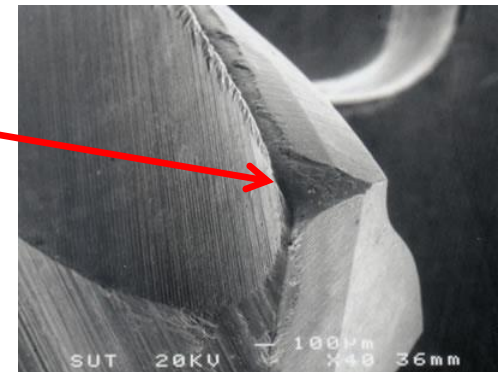
- What would happen if we used a knife to cut a copper or steel shaft?
- To cut harder materials we must create a cutting edge with a less acute angle



Approximate wedge angle for cutting wood (γ_w)



Approximate wedge angle for cutting steel (γ_m)



Larger γ angles =

- Stronger tool geometry
- Increases heat transfer from cutter/workpiece interface
- Prolongs tool life
- Increases the force required to penetrate the workpiece

Rake Angle

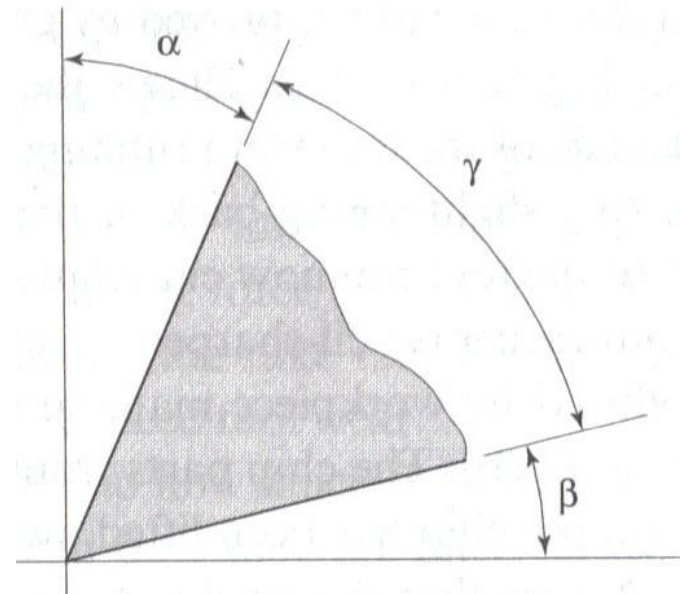
Rake angle = **Alpha α**

α controls the geometry of chip formation

α controls the cutting action of the tool

Rake angle α is given by the formula:-

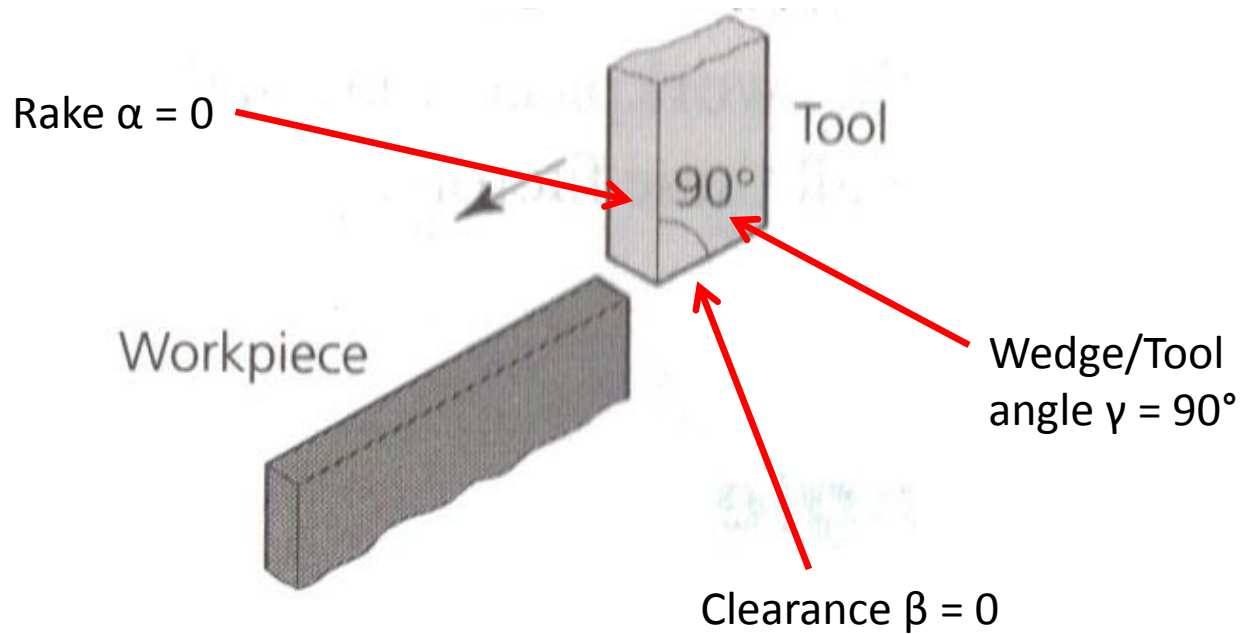
$$\alpha = 90^\circ - (\beta + \gamma)$$



The relationship between α and β & γ

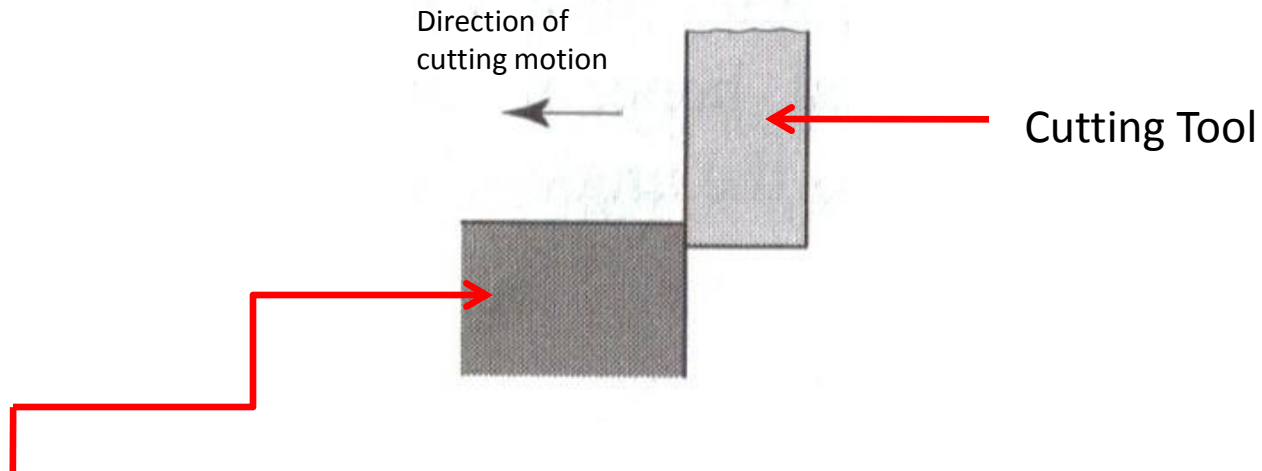
An Example

The effect of trying to cut without clearance β



An Example

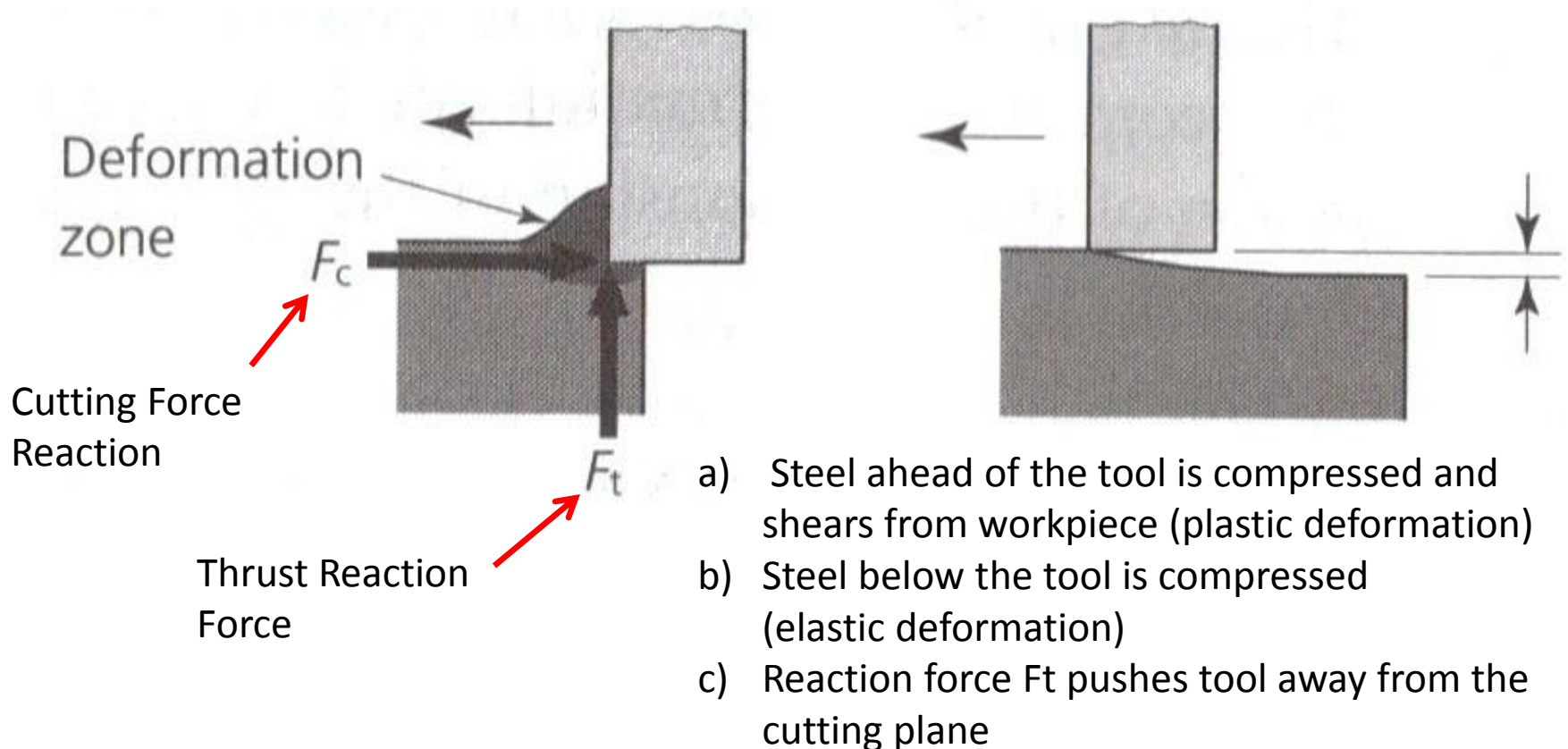
The effect of trying to cut without clearance β



Workpiece Material – Low Carbon (Mild) Steel low strength, ductile material

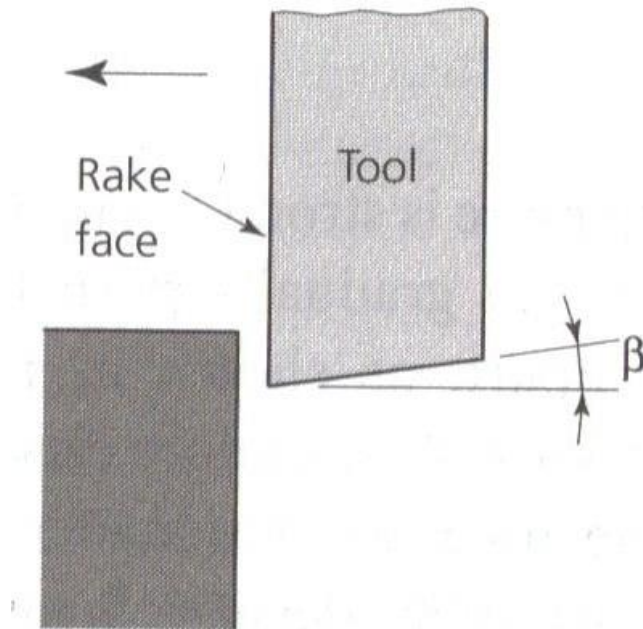
An Example

The effect of trying to cut without clearance β



An Example

Introduction of a clearance angle (approx 7°)

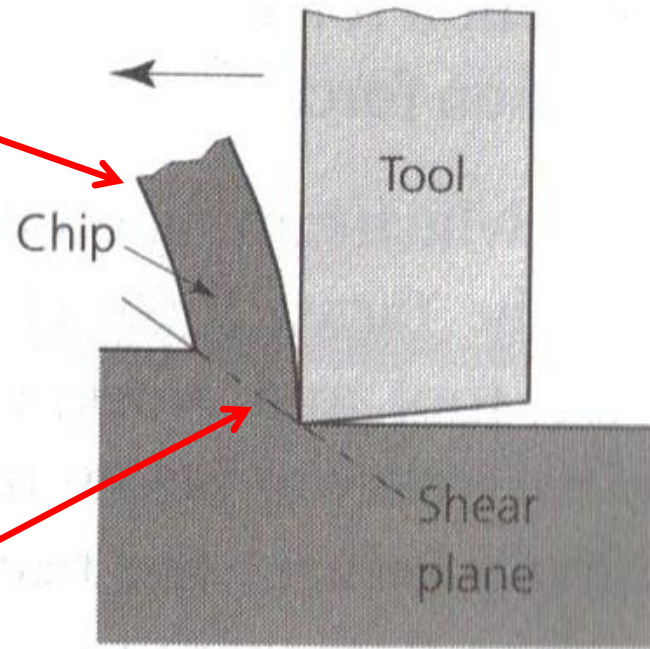


- Tool edge is able to 'bite' into the work
- β prevents the tool from rubbing the freshly cut surface
- Ft from the deformed zone will be behind the cutting point of the tool
- Tool can cut freely without lifting off the workpiece

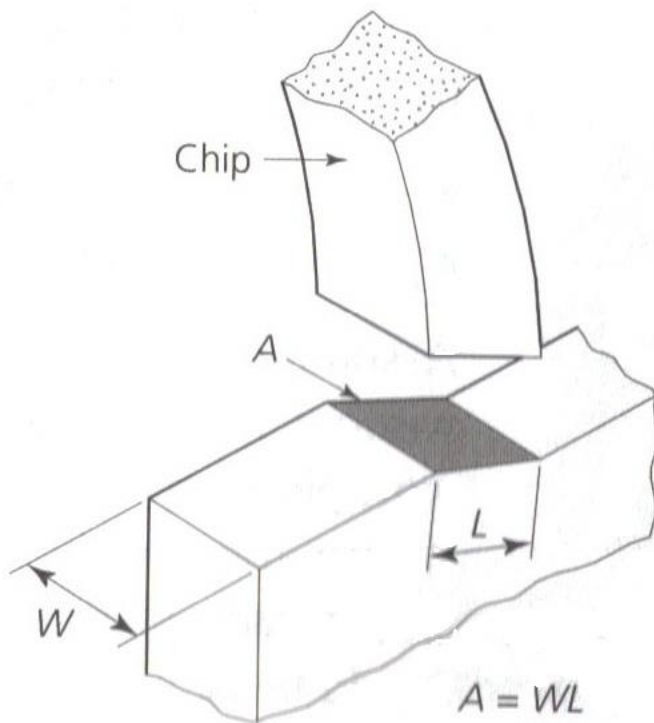
An Example

A 'chip' is produced by the shearing action

The 'chip' parts from the workpiece along the shear plane

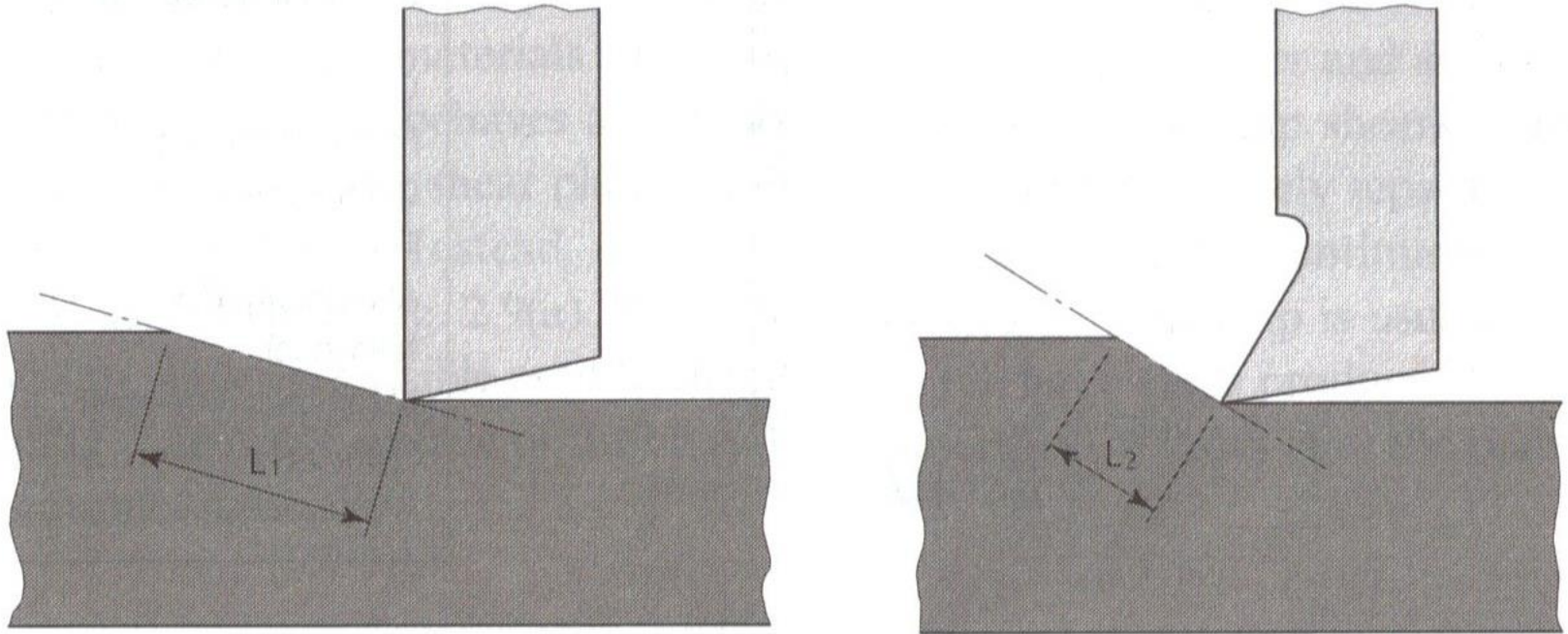


An Example



- Lifting the 'chip' away we can see the area in shear (AIS)
- $AIS = \text{Width of Cut (W)} \times \text{Length of Shear Plane (L)}$
- Smaller AIS = Smaller F_c (cutter reaction force)
- Smaller F_c = Greater Cutting Efficiency
- A reduction in width (W) would reduce the Material Removal Rate (MRR)
- The most effective way of reducing the AIS is by reducing the length (L)

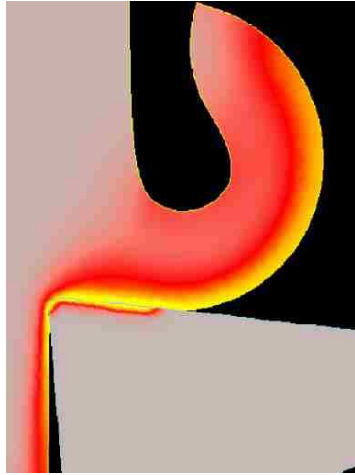
An Example



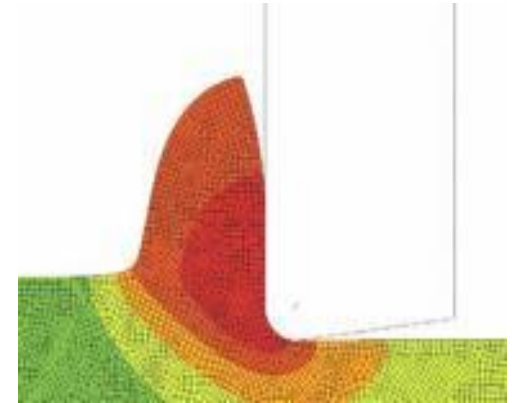
- By inclining the rake away from the perpendicular we give the tool a positive rake angle
- A positive rake angle reduces the length of the shear plane $L_1 \rightarrow L_2$
- Positive rake reduces AIS $\rightarrow$ reducing F_c
- Positive rake allows the chip to flow freely at less of an angle $\rightarrow$ reducing F_c
- Positive rake $\rightarrow$ reduction in $F_c \rightarrow$ extended tool life

Chip Formation

Chip Formation



Characteristics of the
workpiece material



Discontinuous chip

Geometry of the
cutting tool

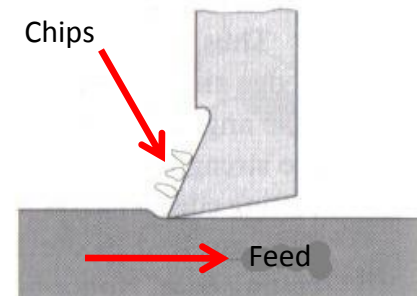
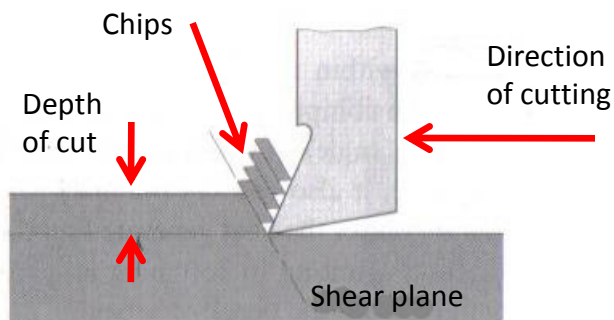
Chip formation

Continuous chip

Continuous chip
with BUE

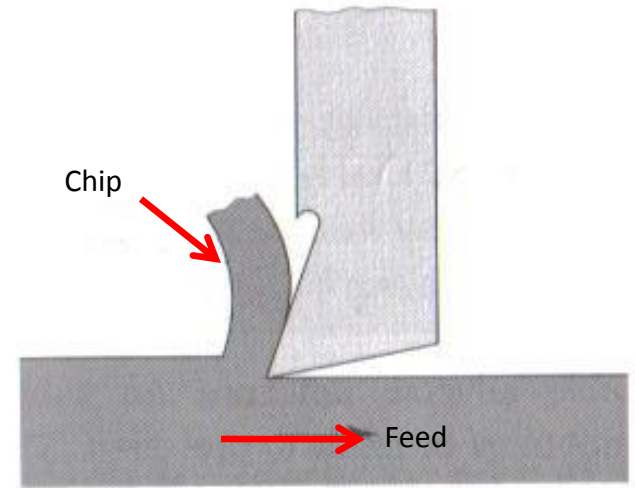
Discontinuous Chip Formation

- In forming the chip, the workpiece material is severely strained
- Brittle, non-ductile materials may fracture along the shear planes in the primary deformation zone producing discontinuous or granular chips
- Associated with non-ductile materials e.g.
 - Gray Cast Iron
 - Free-Cutting Brass
 - Thermosetting Plastics



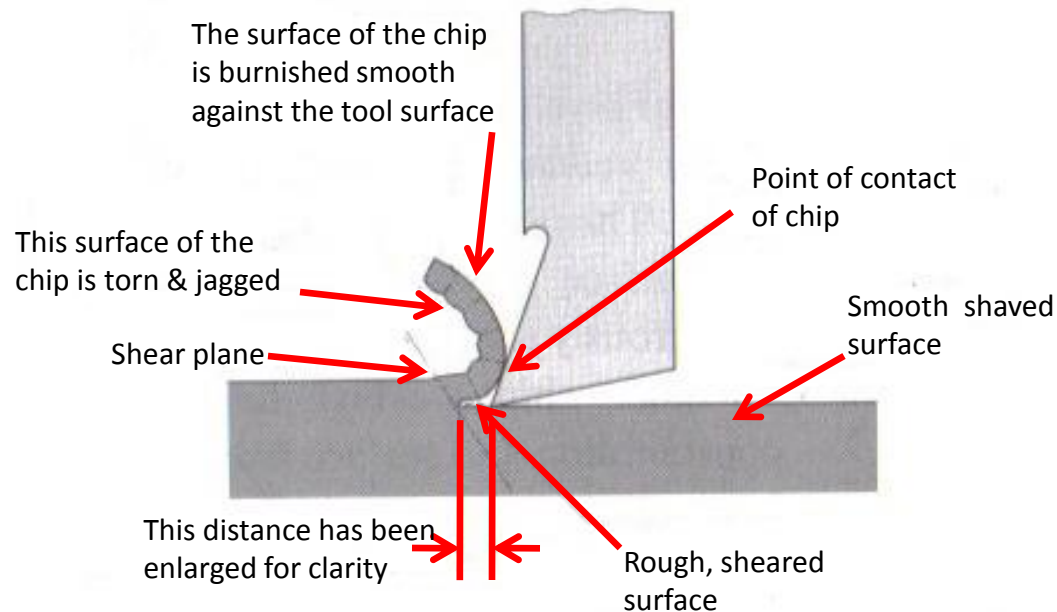
Continuous Chip Formation

- Characterised by a long ribbon-like chip
- Produced by a combination of two factors:
 - Tools with a high positive rake angle
 - Ductile workpiece materials e.g.
 - Low Carbon Steels (mild)
 - Copper
 - Aluminium
- The chip shears from the workpiece material along shear planes
- Plate (chip) separation does not occur completely
- Due to partial separation, a continuous chip is produced



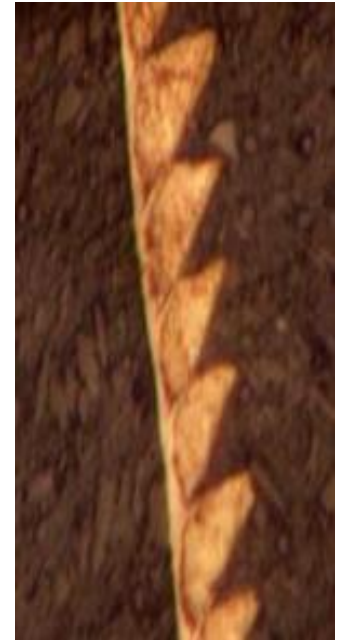
Continuous Chip Formation Cont...

- The inside curvature of the chip is usually rough (due to the slip planes)
- The outer surface of the chip is burnished smooth as it flows over the rake face of the cutting tool



Continuous Chip Formation Cont...

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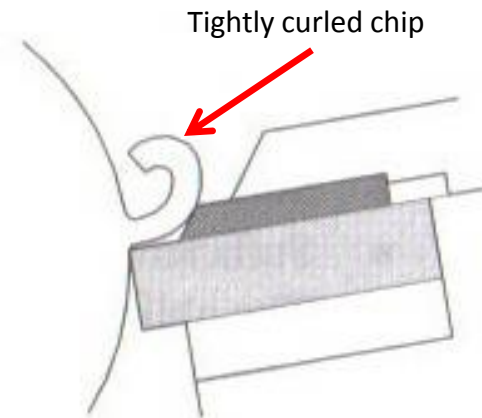
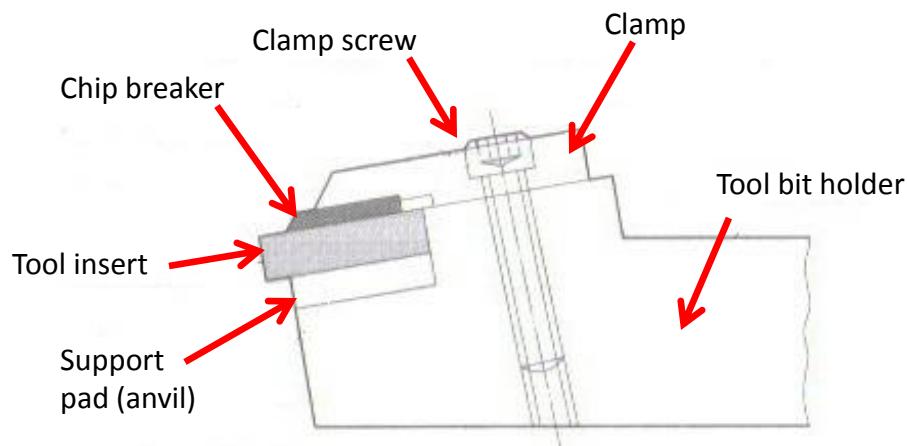


Continuous Chip Formation Cont...

- Continuous chips can have very sharp ragged edges which can present a H&S issue.
- These long ribbon-like chips tend to tangle with the cutter & the workpiece.
- Swarf management is particularly important in high-productivity situations especially when automated cutting processes are being employed such as Computer Numerically Controlled (CNC) machinery.
- To prevent the problems associated with continuous chip formation, some tools actively control the chip formation after it has been sheared from the parent material.

Chip Breakers

- To prevent the problems associated with continuous chip formation, chip breakers are fitted to tools
- Generally, chip breakers force the chip into a tight spiral
- The chip is work-hardened making it brittle
- The chip breaks into short lengths which are safely & easily disposed of

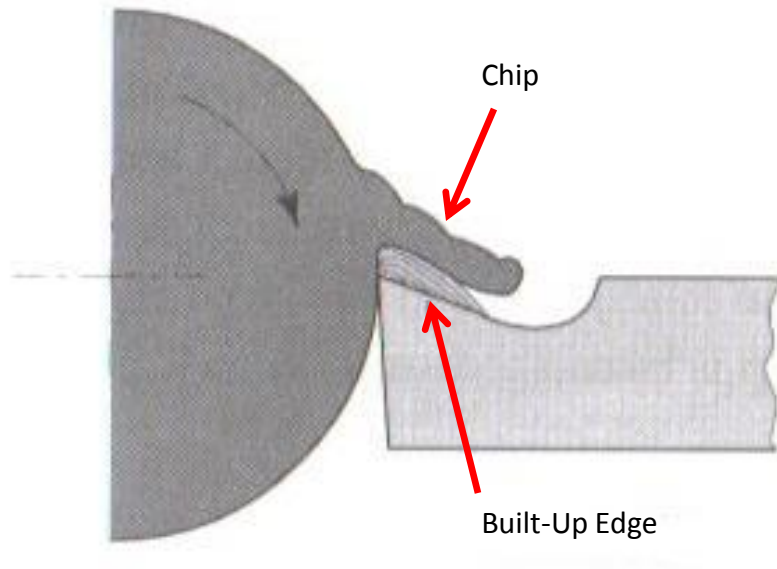


Machining Very Soft & Ductile Materials

- Tearing away from the parent workpiece material just ahead of the cutting tool instead of shearing away cleanly
- The resulting torn surface finish often needs to be cleaned by a finishing tool with a keen edge
- Very fast cutting speeds/feeds are sometimes used to finish soft & ductile materials. Under these conditions, the workpiece material behaves as if it were very much stiffer & harder.



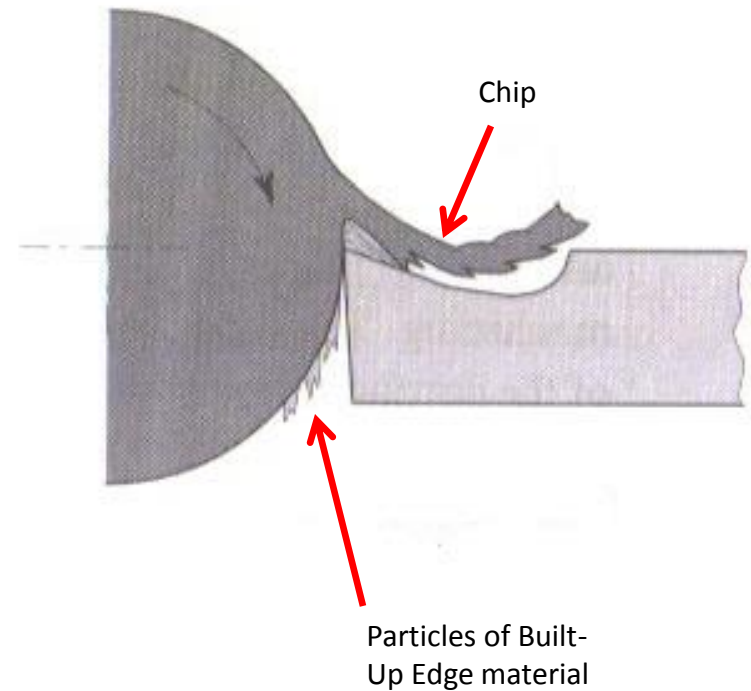
Built-Up Edge (BUE)



- Excessive friction between the chip & the rake face of the tool can occur under certain conditions
- Particles of metal from the chip are pressure welded to the rake face of the tool having the following effects:
 - Rough surface on rake face
 - Cutting edge is masked
 - Tool geometry is changed
- This leads to increased friction & heat at the cutting edge
- Layer upon layer of material is deposited onto the rake face resulting in a BUE

Built-Up Edge (BUE)

- Eventually the amount of built-up material becomes unstable and it breaks down
- Particles of built-up material become welded to the chip & the material (workpiece) leaving:
 - rough workpiece surface finish
 - dangerously jagged chip formations



Built-Up Edge (BUE)

- BUE, caused by chip welding, has a considerable adverse influence on:
 - Tool life
 - Power consumption
 - Surface finish quality,



Every attempt should be made to prevent the formation of a BUE. The table on the following slide identifies some preventative measures.

Prevention of Built-Up Edges on Tooling

Preventative Measure	How this can be Achieved
Reducing Friction	Increasing the rake angle
	Polishing the rake face
	Coating the rake face
	Application of coolant between chip & tool
Reducing Temperature	Reducing friction between chip & tool (see above)
	Using coolant (for heat transfer)
Reducing Pressure	Increasing the rake angle
	Reducing the feed rate
	Using oblique instead of orthogonal cutting
Preventing Metal-to-Metal Contact	High pressure lubricants containing chlorine or sulphur
	Non-metallic cutting tool materials e.g. ceramics