Manufacturing Processes
UTA026

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THEORY OF CHIP FORMATION

- The cutting tool removes the metal from the workpiece in the form of ***"chips".***

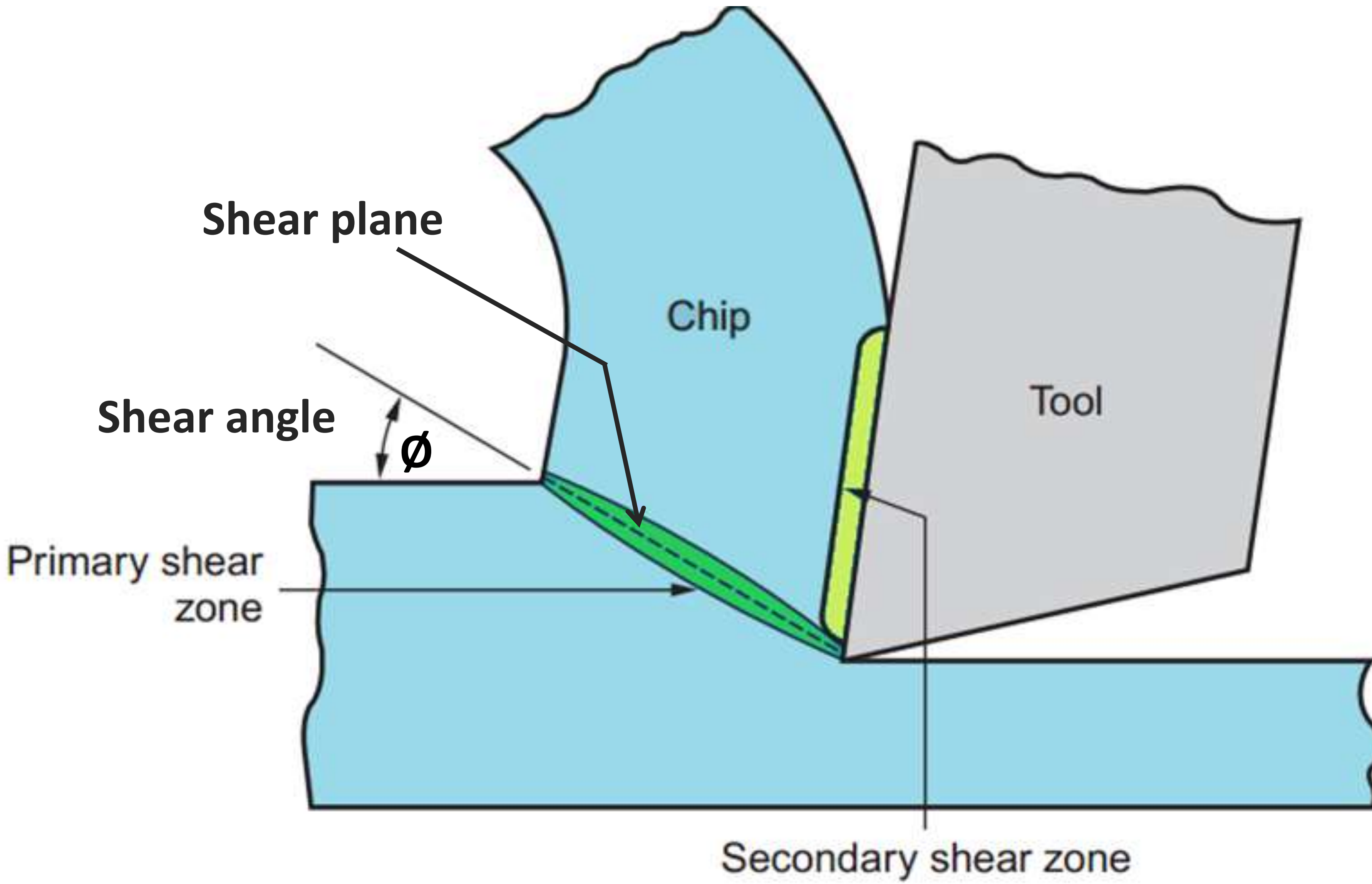
- As the tool advances into the workpiece, the metal in front of the tool is ***compressed*** and when the ***compression limit*** of the metal has been ***exceeded***, it is separated from the workpiece and ***flows plastically*** in the form of chip.

THEORY OF CHIP FORMATION

- The plastic flow of the metal takes place in a localised region called ***shear plane***, which extends from the cutting edge obliquely upto the uncut surface in front of the tool.

Or in other words

- The chip is formed by shear deformation (***primary shear***) along a plane called the ***shear plane***, which is oriented at an ***angle Ø*** with the surface of the work.


Shear plane
Chip
Tool
Shear angle
ø
Primary shear zone
Secondary shear zone

THEORY OF CHIP FORMATION

- ***Another shearing*** action occurs in the chip after it has been formed.

- This additional shear is referred to as <u>***secondary shear***</u> to distinguish it from primary shear.

- ***Secondary shear results*** from ***friction*** between the chip and the tool as the chip slides along the ***rake face*** of the tool.

THEORY OF CHIP FORMATION

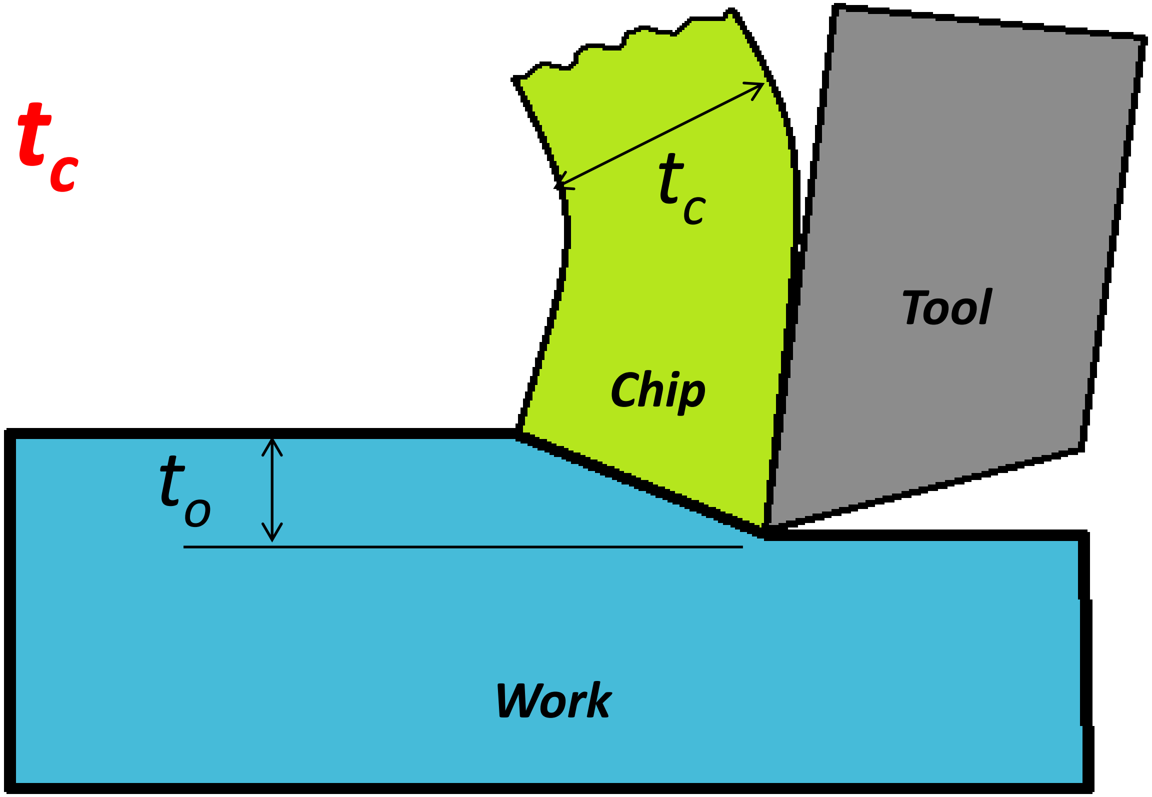
- During cutting, the cutting edge of the tool is positioned a certain distance below the original work surface.

- This corresponds to the ***thickness*** of the chip ***before*** the ***chip formation*** = t_o.

- ***As the chip is formed*** along the shear plane, its ***thickness increases*** to = t_c.

THEORY OF CHIP FORMATION

$t_o < t_c$



THEORY OF CHIP FORMATION

- The ratio of t_o to t_c is called the ***chip thickness ratio*** (or simply the chip ratio) ***r***.

$$\boxed{r = \frac{t_o}{t_c}}$$

- Since the chip thickness after cutting is always greater than the corresponding thickness before cutting, the chip ratio will ***always be less than 1***.

TYPES OF CHIPS

- Chip is a small piece of material removed in the course of chopping, cutting, or breaking something, esp. a hard material such as wood , stone or metal.

- In a metal cutting operation chips are separated from the workpiece to impart the required size and shape to the workpiece.

TYPES OF CHIPS

- The chips that are formed during metal cutting operations can be classified into three types:

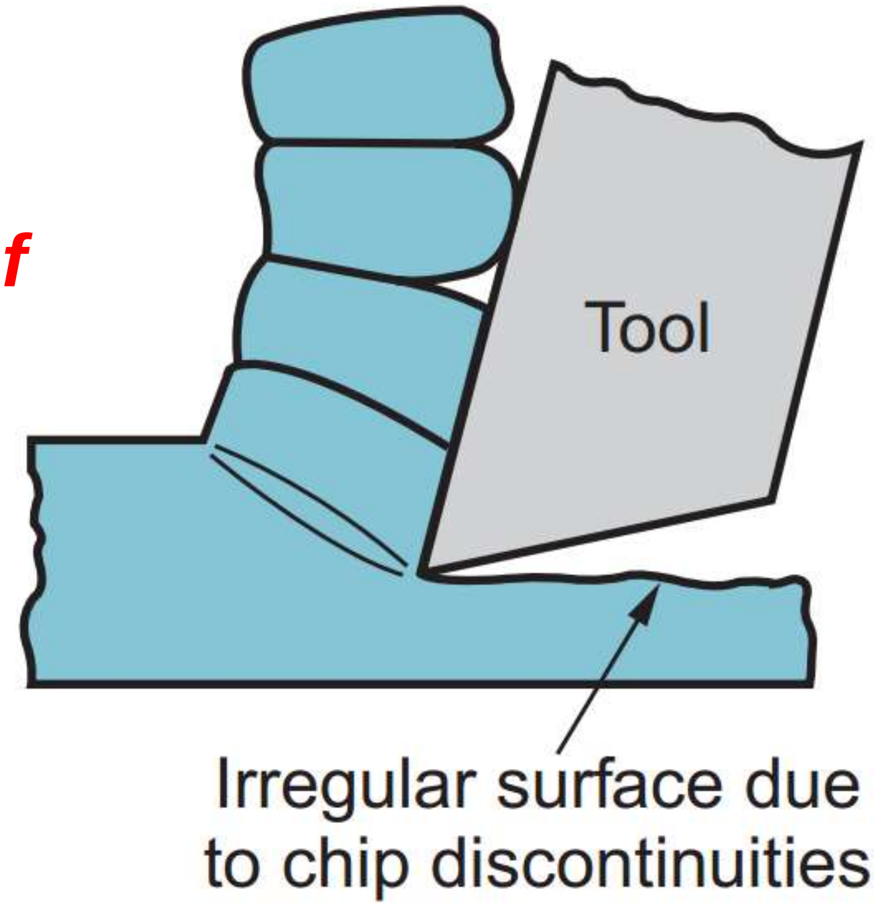
1. Discontinuous or segmental chips

2. Continuous chips

3. Continuous chips with built-up edge.

1. DISCONTINOUS CHIP

- ***Brittle work materials***
- ***Low cutting speeds***
- ***Large feed and depth of cut***
- ***High tool-chip friction***
- ***Low or Negative rake angle***



1. DISCONTINOUS CHIP

- When brittle materials like cast iron are cut, the deformed material gets fractured very easily and thus the chip produced is in the form of ***discontinuous segments.***

- In this type the deformed material instead of flowing continuously gets ***ruptured periodically.***

1. DISCONTINOUS CHIP

- Also they generally ***provide better surface finish*** (for ***brittle material only***).

- Discontinuous chips are ***easier from the chip disposal view point.***

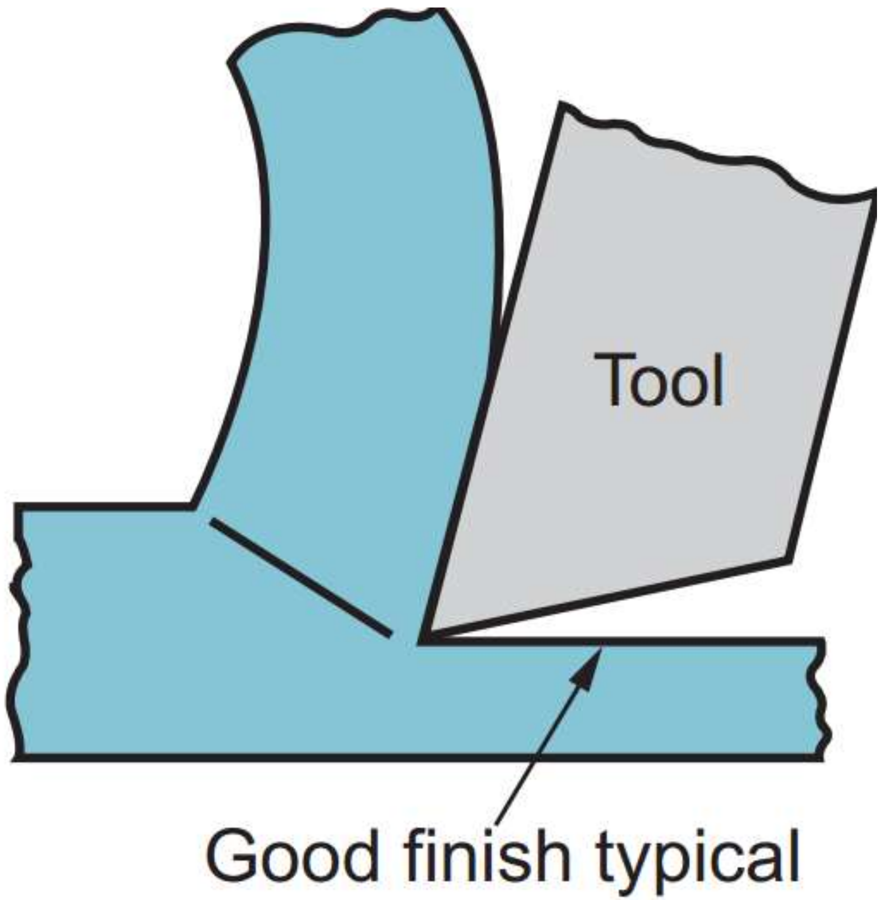
- However, in case of ***ductile materials*** they cause ***poor surface finish*** and low tool life.

1. DISCONTINOUS CHIP

- A discontinuous chip comes off as small chunks or particles. When we get this chip it may indicate:
  - ***brittle work material***
  - ***small or negative rake angles***
  - ***large feed, depth of cut and low cutting speed***

2. CONTINUOUS CHIP

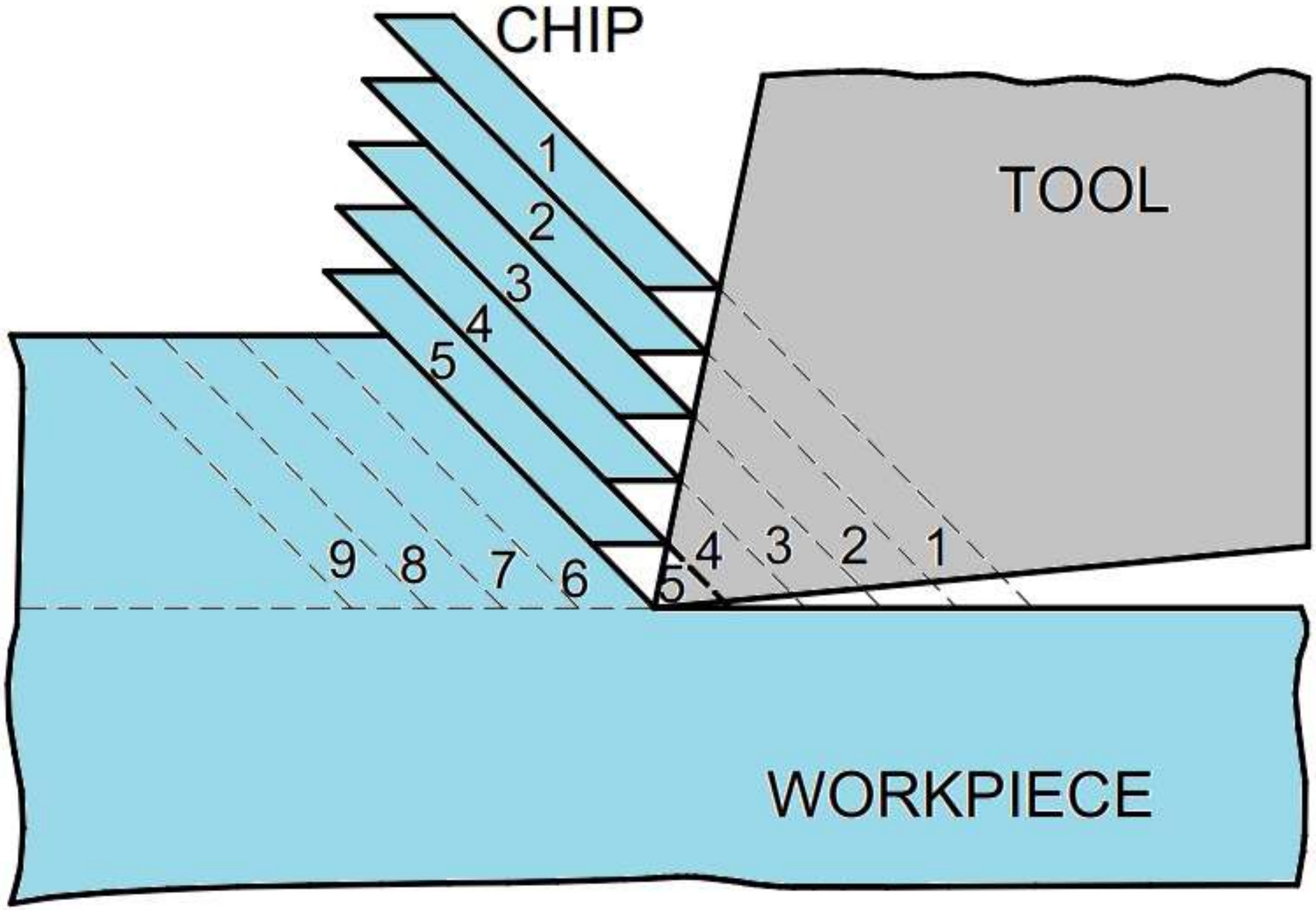
- *Ductile work materials*
- *High cutting speeds*
- *Small feeds and depths*
- *Sharp cutting edge*
- *Low tool-chip friction*
- *High or Positive rake angle*



2. CONTINUOUS CHIP

- Continuous chips are normally produced when machining steel or ***ductile metals*** at ***high cutting speeds.***
- The continuous chip which is like a ribbon flows along the rake face.
- Continuous chip is possible because of the ductility of metal.

2. CONTINUOUS CHIP



2. CONTINUOUS CHIP

- It can be assumed that each layer of metal flows along the slip plane till it is stopped by work hardening.
- Each of these layers get welded to the previous ones because of the high temperature, thus forming a continuous chip.

2. CONTINUOUS CHIP

- Some ideal conditions that promote continuous chips in metal cutting are:
  - ***sharp cutting edge,***
  - ***small chip thickness (fine feed),***
  - ***large rake angle,***
  - ***high cutting speed,***
  - ***ductile work materials and***
  - ***less friction between chip tool interface through efficient lubrication.***

2. CONTINUOUS CHIP

- This is the most desirable form of chip since the surface finish obtained is good and cutting is smooth.

- It also helps in having higher tool life and lower power consumption.

- ***However, long continuous chips (as in turning) can cause <u>problems</u> with regard to chip disposal.***

2. CONTINUOUS CHIP

- These chips also ***cause a hazard*** to
  - ***the machine operator and***
  - ***the workpart finish,***
  - ***and they interfere with automatic operation of the turning process.***

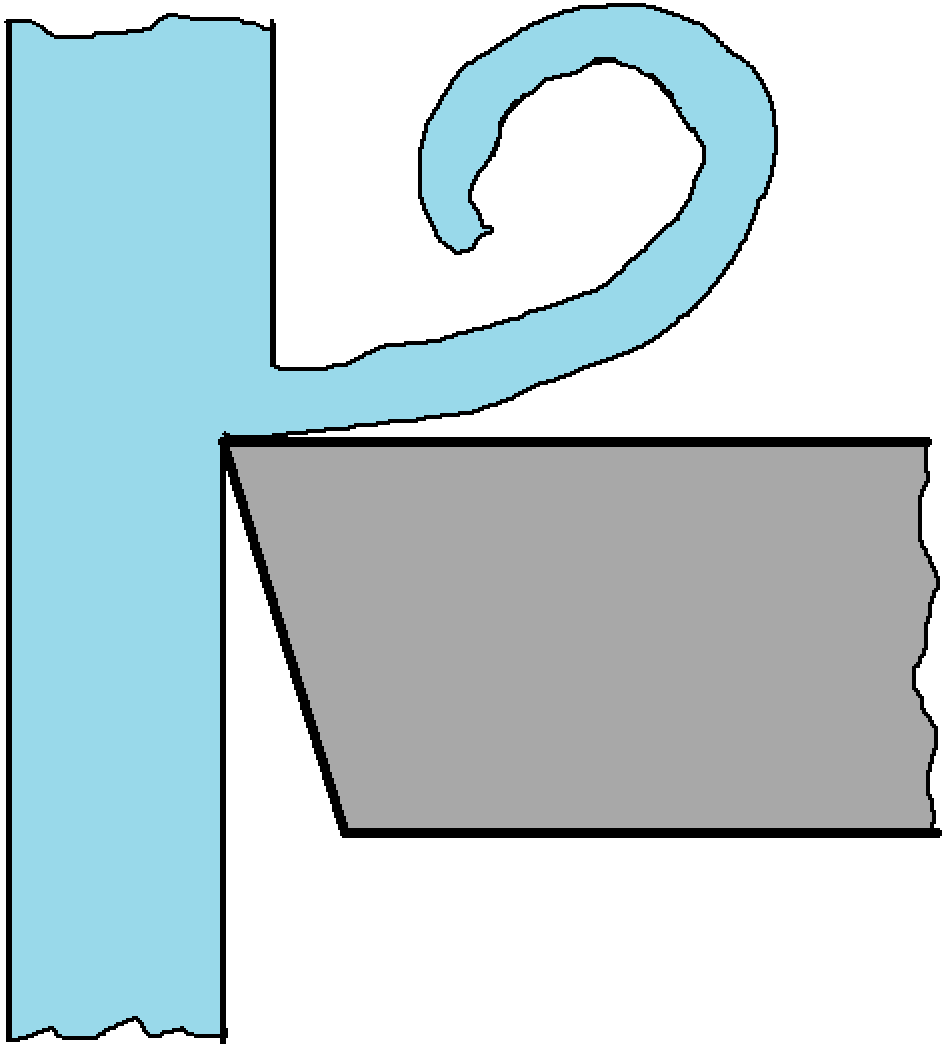
2. CONTINUOUS CHIP

- Therefore it is ***essentially needed to break such continuous chips*** into small regular pieces for
  - ***safety of the working people***
  - ***prevention of damage of the product***
  - ***easy collection and disposal of chips.***

2. CONTINUOUS CHIP
(Chip Breakers)

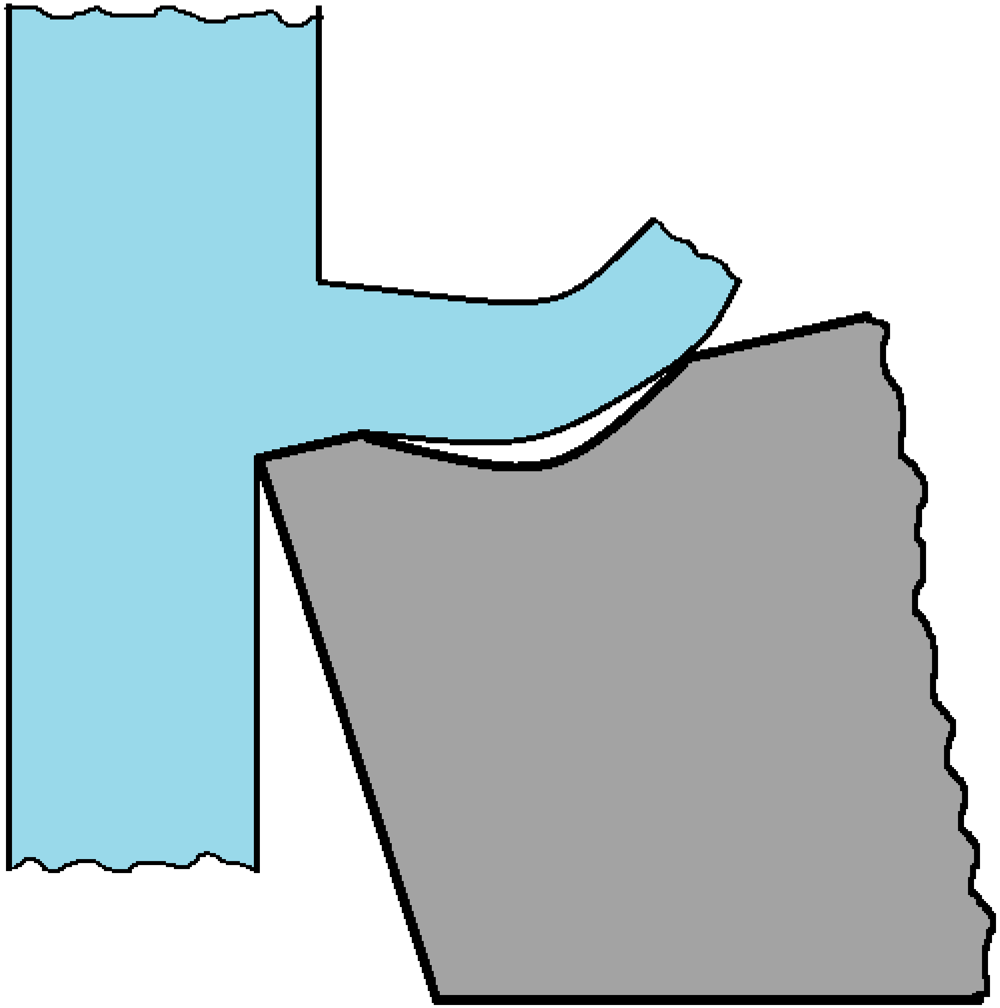
- To help in this direction various forms of ***chip breakers*** are frequently used with single-point tools
  - ***to force the chips to curl more tightly*** than they would naturally do, ***thus*** causing them to be ***broken*** into small pieces so that they can be ***easily disposed off.***
- They work on the principle that ***"If you decrease the radius of chip enough you can break the chip."***

Chip Curl



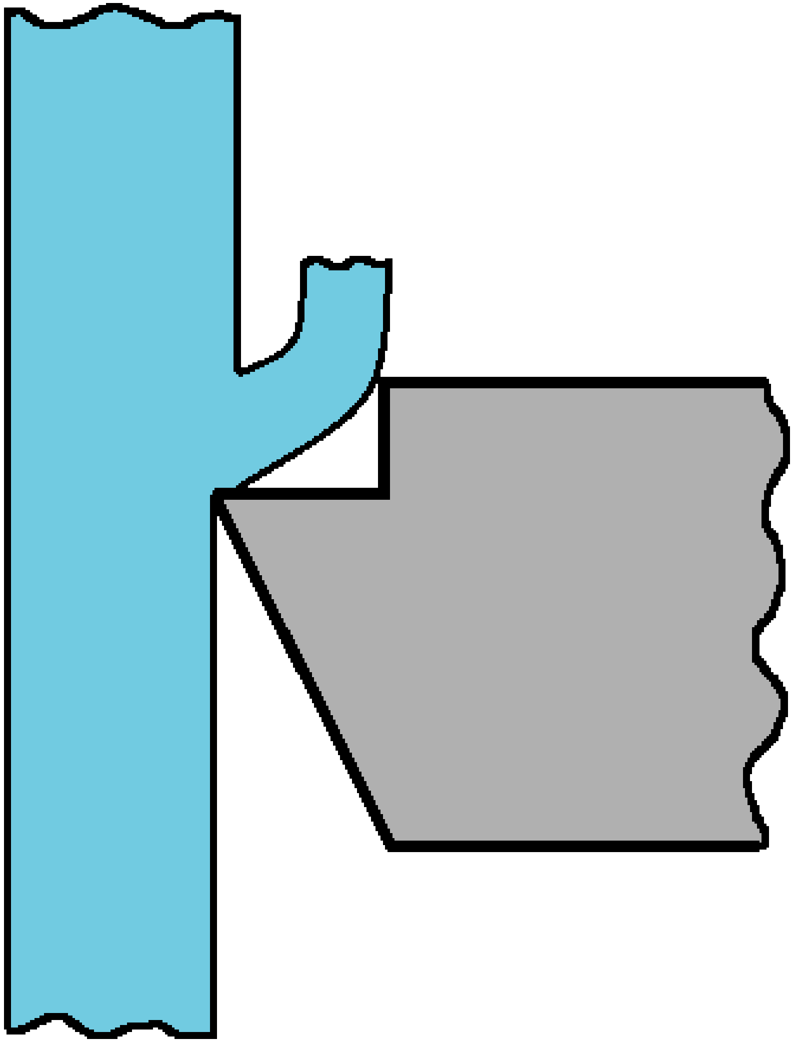
- A single point cutting tool (without a chip breaker) showing a long chip curl

Groove-type :
CHIP BREAKER



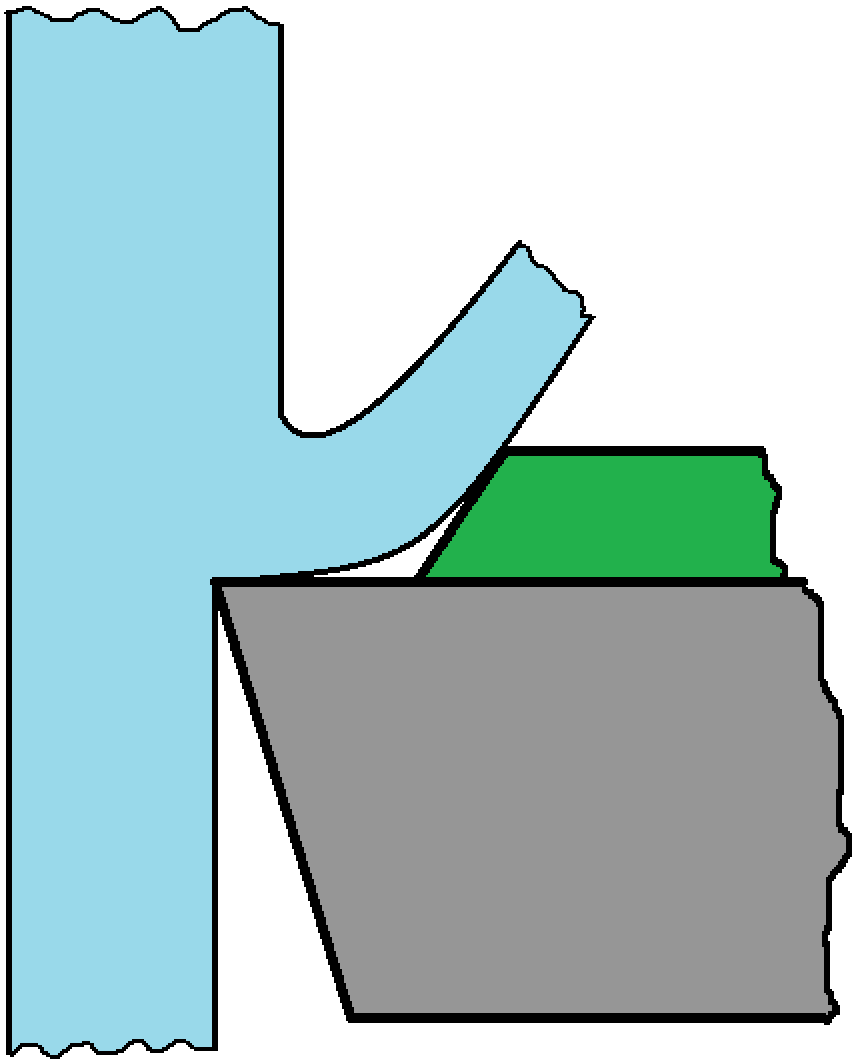
- Groove-type chip breaker designed into the cutting tool itself.

Integrated Obstruction Type : CHIP BREAKER



- Integrated Obstruction-type chip breakers are in the form of step made as an integral part on the rake face of the tool.

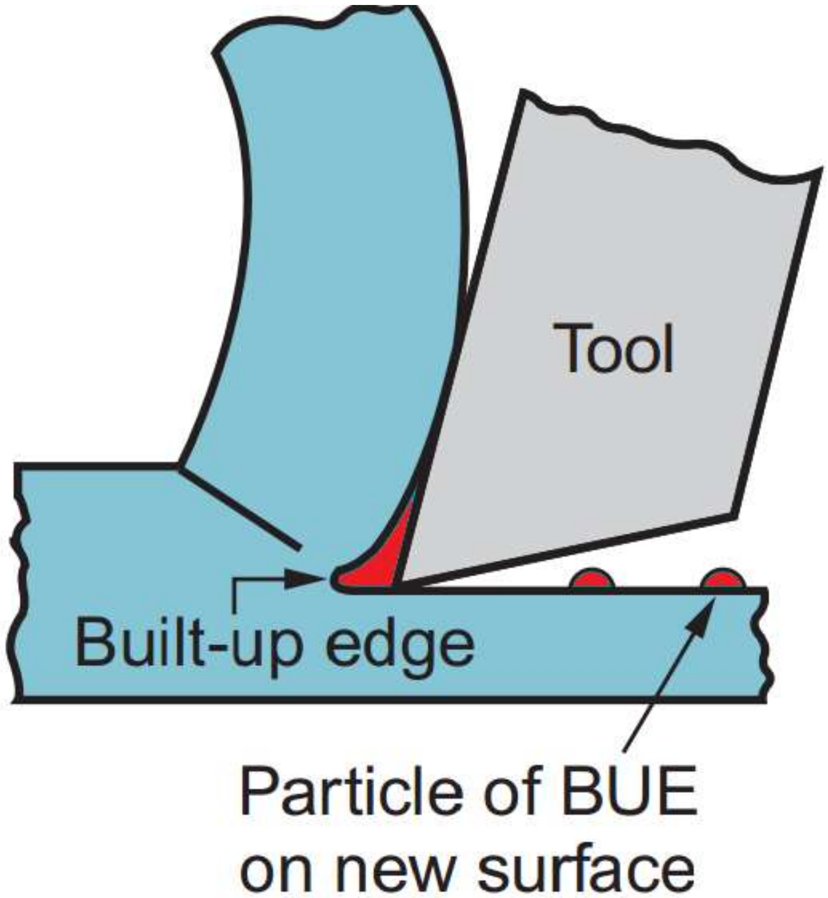
Clamped On Obstruction Type : CHIP BREAKER



- Clamped on obstruction-type chip breaker designed as an additional device on the rake face of the tool.

3. CONTINUOUS CHIP WITH BUILT-UP EDGE

- ***Ductile materials***
- ***Low-to-medium cutting speeds***
- ***Tool-chip friction causes portions of chip to adhere to rake face***
- ***BUE forms, then breaks off, cyclically***



3. CONTINUOUS CHIP WITH BUILT-UP EDGE

- When machining ductile materials at low-to-medium cutting speeds, friction between tool and chip tends to cause portions of the work material to adhere to the rake face of the tool near the cutting edge.
- This formation is called a built-up edge (BUE).
- The formation of a BUE is cyclical; it forms and grows, then becomes unstable and breaks off.

3. CONTINUOUS CHIP WITH BUILT-UP EDGE

- Much of the detached BUE is carried away with the chip, sometimes taking portions of the tool rake face with it, which reduces the life of the cutting tool.
- Portions of the detached BUE that are not carried off with the chip become imbedded in the newly created work surface, causing the surface to become rough.

3. PREVENTION OF BUILT-UP EDGE CHIP FORMATION

- The formation of a built-up edge is also referred to as chip welding.
- Since chip welding has a considerable adverse effect on tool life, power consumption, and surface finish, every attempt must be made to prevent it occurring.

3. PREVENTION OF BUILT-UP EDGE CHIP FORMATION

- This is largely achieved by reversing the conditions that cause chip welding in the first place.
- Prevention is mainly done by
  - ***Reduction of friction***
  - ***Reducing the pressure***
  - ***Preventing metal to metal contact***
  - ***Reducing the temperature***

3. PREVENTION OF BUILT-UP EDGE CHIP FORMATION

- ***Reduction of friction***
  - This can be achieved by increasing the rake angle, using a cutting fluid that is an extreme pressure lubricant as well as a coolant, and polishing the rake face.
- ***Reducing the pressure***
  - This can be achieved by increasing the rake angle. Remember this also weakens the tool and there is a limit to how far the rake angle can be increased for any given workpiece material.
  - Reducing the rate of feed will also help.

3. PREVENTION OF BUILT-UP EDGE CHIP FORMATION

- ***Preventing metal to metal contact***
  - This can be achieved by the use of a lubricant containing an extreme pressure additive. Such additives are usually sulphur or chlorine compounds. These additives tend to build up a non-metallic film on the surfaces of the tool and the chip. Since metal is not then in contact with metal chip welding cannot take place.

3. PREVENTION OF BUILT-UP EDGE CHIP FORMATION

- ***Reducing the temperature***
  - This can also be achieved by any of the above solutions. The temperature can also be achieved by reducing the spindle speed but this reduces the rate of metal removal.

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