Use of chip breaker in machining

(i) Need and purpose of chip-breaking

Continuous machining like turning of ductile metals, unlike brittle metals like grey cast iron, produce continuous chips, which leads to their handling and disposal problems. The problems become acute when ductile but strong metals like steels are machined at high cutting velocity for high MRR by flat rake face type carbide or ceramic inserts. The sharp edged hot continuous chip that comes out at very high speed

- becomes dangerous to the operator and the other people working in the vicinity
- may impair the finished surface by entangling with the rotating job
- creates difficulties in chip disposal.

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.

Chip breaking is done in proper way also for the additional purpose of improving machinability by reducing the chip-tool contact area, cutting forces and crater wear of the cutting tool..

(ii) Principles of chip-breaking

In respect of convenience and safety, closed coil type chips of short length and 'coma' shaped broken-to-half turn chips are ideal in machining of ductile metals and alloys at high speed.

The principles and methods of chip breaking are generally classified as follows :

- Self breaking

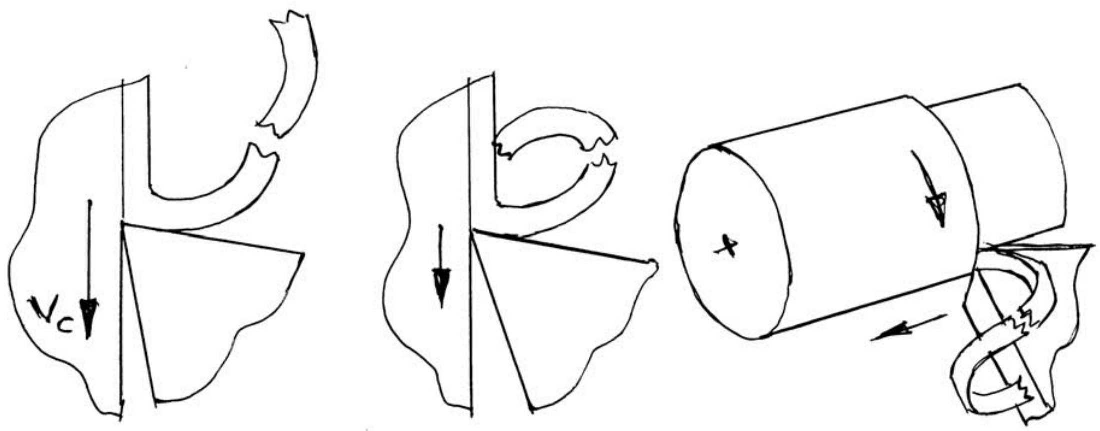
  This is accomplished without using a separate chip-breaker either as an attachment or an additional geometrical modification of the tool.
- Forced chip breaking by additional tool geometrical features or devices.

(a) Self breaking of chips

Ductile chips usually become curled or tend to curl (like clock spring) even in machining by tools with flat rake surface due to unequal speed of flow of the chip at

its free and generated (rubbed) surfaces and unequal temperature and cooling rate at those two surfaces. With the increase in cutting velocity and rake angle (positive) the radius of curvature increases, which is more dangerous. In case of oblique cutting due to presence of inclination angle, restricted cutting effect etc. the curled chips deviate laterally resulting helical coiling of the chips.
The curled chips may self break :

- By natural fracturing of the strain hardened outgoing chip after sufficient cooling and spring back as indicated in Fig.7.1 (a). This kind of chip breaking is generally observed under the condition close to that which favours formation of jointed or segmented chips
- By striking against the cutting surface of the job, as shown in Fig. 7.1 (b), mostly under pure orthogonal cutting
- By striking against the tool flank after each half to full turn as indicated in Fig. 7.1 (c).



(a) natural (b) striking on job (c) striking at tool flank

Fig. *Principles of self breaking of chips.*

The possibility and pattern of self chip-breaking depend upon the work material, tool material and tool geometry (γ, λ, φ and r), levels of the process parameters (V_C and s_o) and the machining environment (cutting fluid application) which are generally selected keeping in view the overall machinability.

(b) Forced chip-breaking

The hot continuous chip becomes hard and brittle at a distance from its origin due to work hardening and cooling. If the running chip does not become enough curled and work hardened, it may not break. In that case the running chip is forced to bend or closely curl so that it breaks into pieces at regular intervals. Such broken chips are of regular size and shape depending upon the configuration of the chip breaker.

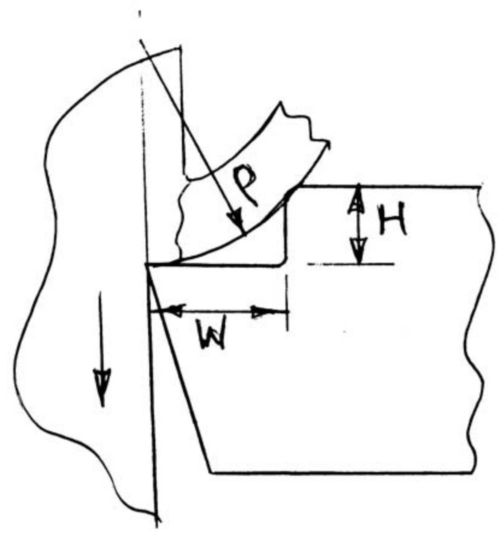
Chip breakers are basically of two types :

- In-built type
- Clamped or attachment type

In-built breakers are in the form of step or groove at the rake surface near the cutting edges of the tools. Such chip breakers are provided either

- Δ after their manufacture – in case of HSS tools like drills, milling cutters, broaches etc and brazed type carbide inserts
- Δ during their manufacture by powder metallurgical process – e.g., throw away type inserts of carbides, ceramics and cermets.

The basic principle of forced chip breaking is schematically shown in Fig. 7.2 when the strain hardened and brittle running chip strikes the heel, the cantilever chip gets forcibly bent and then breaks.



W = width, H = height, β = shear angle

Fig. *Principle of forced chip breaking.*

Fig. 7.3 schematically shows some commonly used step type chip breakers :

- Parallel step
- Angular step; positive and negative type
- Parallel step with nose radius – for heavy cuts.

Groove type in-built chip breaker may be of

- Circular groove   or
- Tilted Vee groove

as schematically shown in Fig.

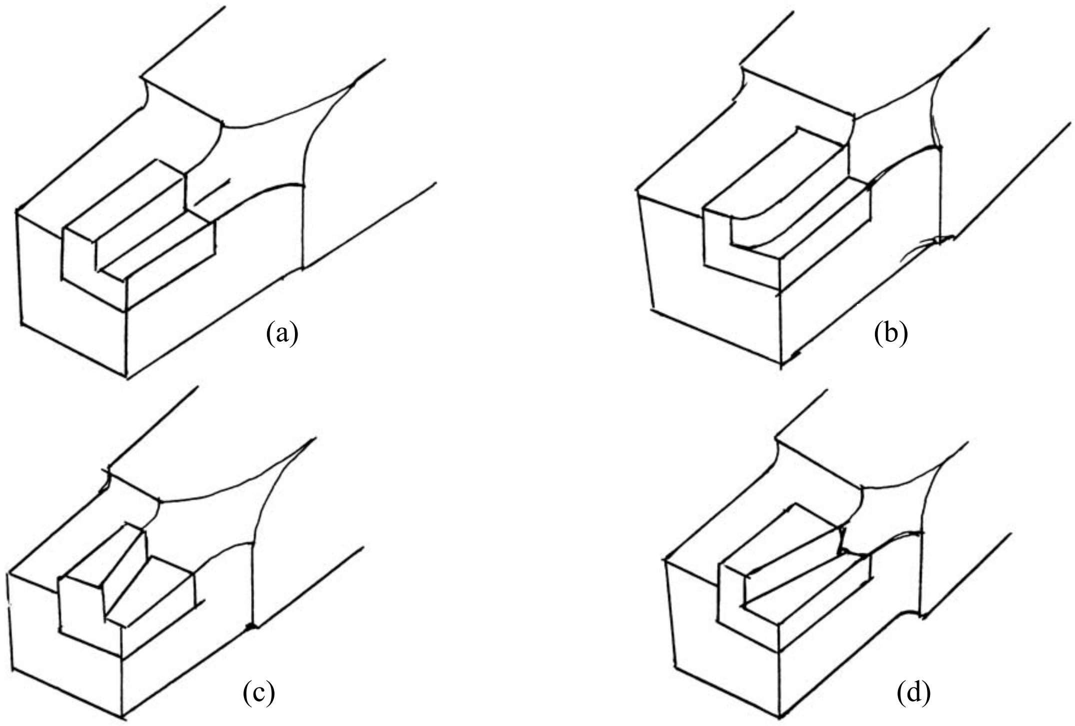
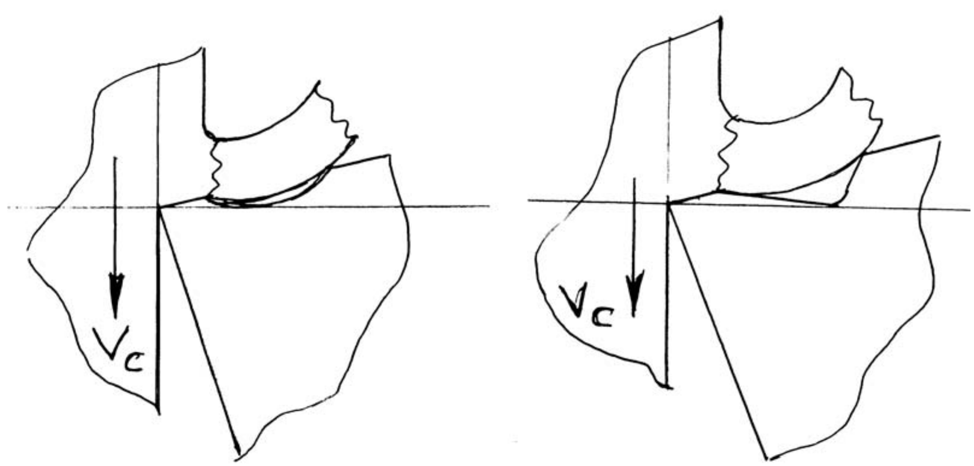


Fig. *Step type in-built chip breaker (a) parallel step (b) parallel and radiused (c) positive angular (d) negative angular*



(a) circular groove (b) tilted Vee-groove

Fig. *Groove type in-built chip breaker*

The unique characteristics of in-built chip breakers are :

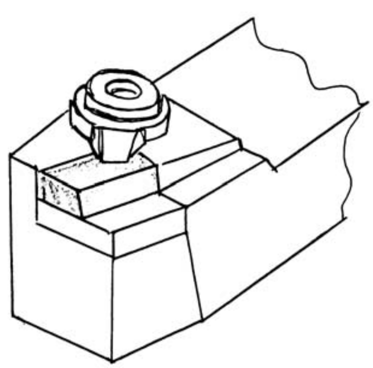
- The outer end of the step or groove acts as the heel that forcibly bend and fracture the running chip
- Simple in configuration, easy manufacture and inexpensive
- The geometry of the chip-breaking features are fixed once made (i.e., cannot be controlled)
- Effective only for fixed range of speed and feed for any given tool-work combination.

(c) clamped type chip-breaker

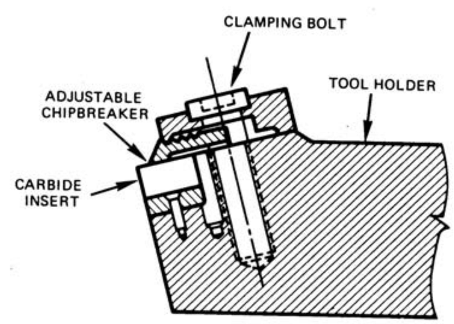
Clamped type chip breakers work basically in the principle of stepped type chip-breaker but have the provision of varying the width of the step and / or the angle of the heel.

Fig. 7.5 schematically shows three such chip breakers of common use :

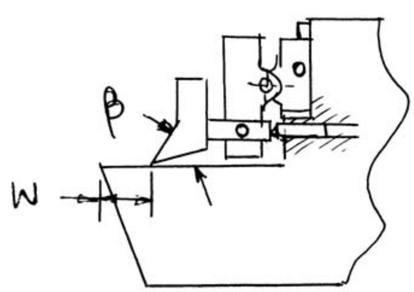
- With fixed distance and angle of the additional strip – effective only for a limited domain of parametric combination
- With variable width (W) only – little versatile
- With variable width (W), height (H) and angle (β) – quite versatile but less rugged and more expensive.



(a) fixed geometry



(b) variable width



(c) variable width and angle

Fig. *Clamped type chip breakers.*

(i) Failure of cutting tools

Smooth, safe and economic machining necessitate

- prevention of premature and catastrophic failure of the cutting tools
- reduction of rate of wear of tool to prolong its life

To accomplish the aforesaid objectives one should first know why and how the cutting tools fail.

Cutting tools generally fail by :

i) Mechanical breakage due to excessive forces and shocks. Such kind of tool failure is random and catastrophic in nature and hence are extremely detrimental.

ii) Quick dulling by plastic deformation due to intensive stresses and temperature. This type of failure also occurs rapidly and are quite detrimental and unwanted.

iii) Gradual wear of the cutting tool at its flanks and rake surface.

The first two modes of tool failure are very harmful not only for the tool but also for the job and the machine tool. Hence these kinds of tool failure need to be prevented by using suitable tool materials and geometry depending upon the work material and cutting condition. But failure by gradual wear, which is inevitable, cannot be prevented but can be slowed down only to enhance the service life of the tool.

The cutting tool is withdrawn immediately after it fails or, if possible, just before it totally fails. For that one must understand that the tool has failed or is going to fail shortly.

It is understood or considered that the tool has failed or about to fail by one or more of the following conditions :

(a) In R&D laboratories

- total breakage of the tool or tool tip(s)
- massive fracture at the cutting edge(s)
- excessive increase in cutting forces and/or vibration
- average wear (flank or crater) reaches its specified limit(s)

(b) In machining industries

- excessive (beyond limit) current or power consumption
- excessive vibration and/or abnormal sound (chatter)
- total breakage of the tool
- dimensional deviation beyond tolerance
- rapid worsening of surface finish
- adverse chip formation.

(ii) Mechanisms and pattern (geometry) of cutting tool wear

For the purpose of controlling tool wear one must understand the various mechanisms of wear, that the cutting tool undergoes under different conditions.
The common mechanisms of cutting tool wear are :

i) Mechanical wear
- thermally insensitive type; like abrasion, chipping and delamination
- thermally sensitive type; like adhesion, fracturing, flaking etc.

ii) Thermochemical wear
- macro-diffusion by mass dissolution
- micro-diffusion by atomic migration

iii) Chemical wear

iv) Galvanic wear

In diffusion wear the material from the tool at its rubbing surfaces, particularly at the rake surface gradually diffuses into the flowing chips either in bulk or atom by atom when the tool material has chemical affinity or solid solubility towards the work material. The rate of such tool wear increases with the increase in temperature at the cutting zone.
Diffusion wear becomes predominant when the cutting temperature becomes very high due to high cutting velocity and high strength of the work material.
Chemical wear, leading to damages like grooving wear may occur if the tool material is not enough chemically stable against the work material and/or the atmospheric gases.
Galvanic wear, based on electrochemical dissolution, seldom occurs when both the work tool materials are electrically conductive, cutting zone temperature is high and the cutting fluid acts as an electrolyte.
The usual pattern or geometry of wear of turning and face milling inserts are typically shown in Fig. respectively.

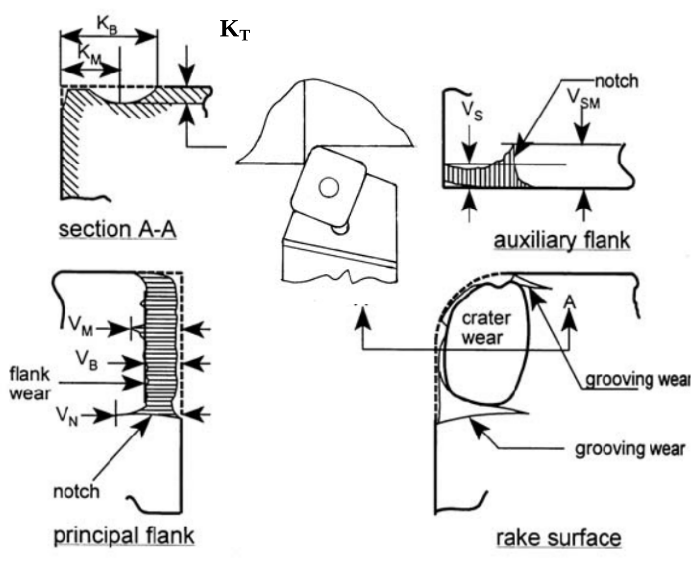


Fig. *Geometry and major features of wear of turning tools*