

Module 2 Mechanics of Machining

Lesson

7

Use of chip breaker in machining

Instructional Objectives

At the end of this lesson the students would be able to

- (i) identify the need and purposes of chip breaking
- (ii) illustrate the various principles of chip breaking
- (iii) design simple chip breakers
- (iv) demonstrate configuration and working principle of some common type chip breakers
- (v) state the overall effects of chip breaking.

(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.

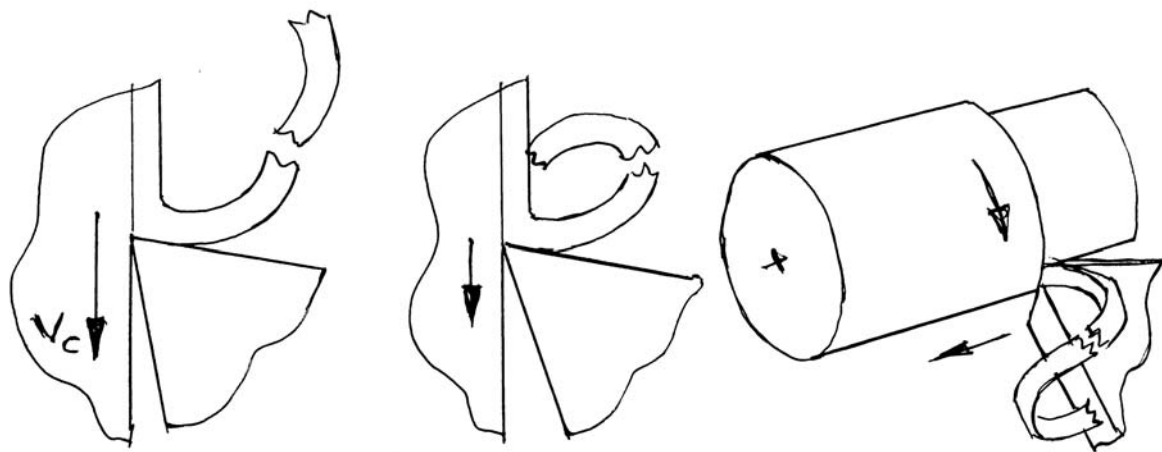
(a) Self breaking of chips

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. 7.1 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.

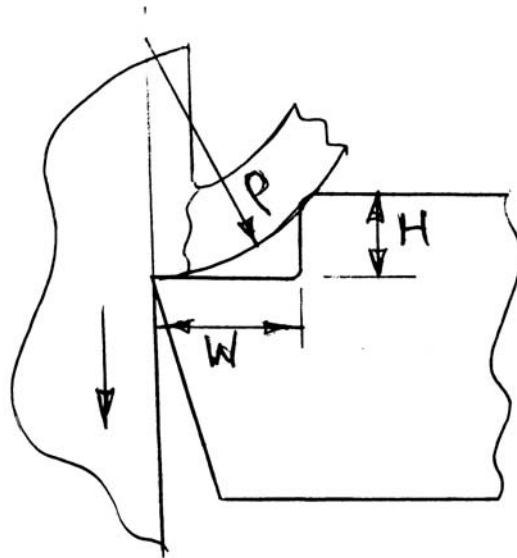
Chip breakers are basically of two types :

- 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.



$W = \text{width}, \quad H = \text{height}, \quad \beta = \text{shear angle}$

Fig. 7.2 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. 7.4

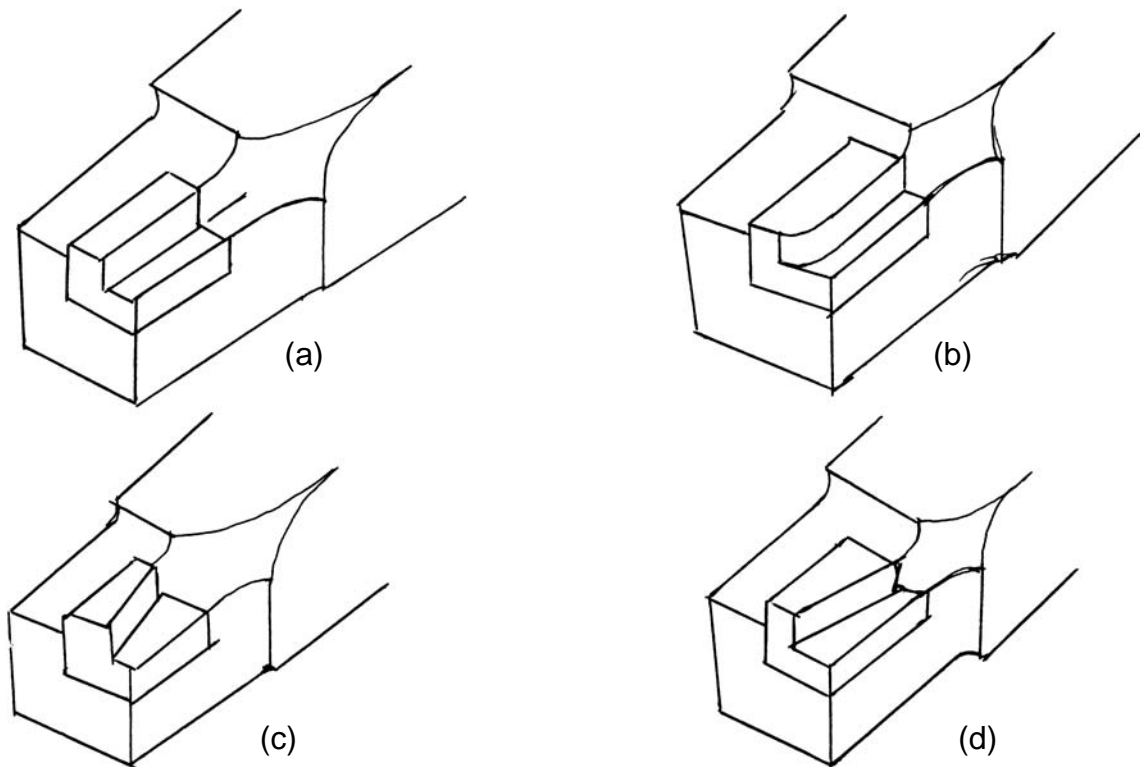
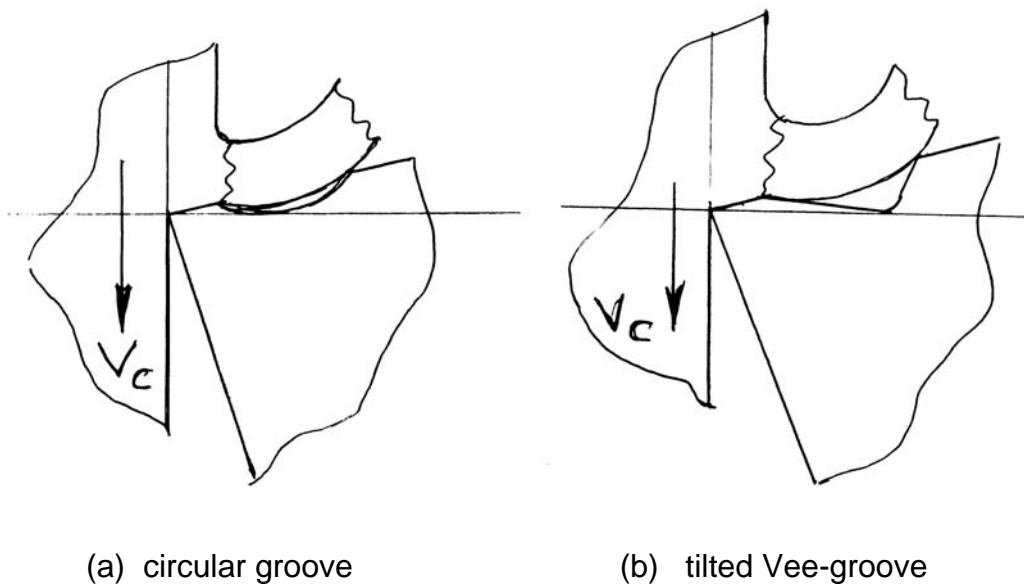


Fig. 7.3 Step type in-built chip breaker (a) parallel step (b) parallel and radiused (c) positive angular (d) negative angular



(a) circular groove

(b) tilted Vee-groove

Fig. 7.4 Groove type in-built chip breaker

The unique characteristics of in-built chip breakers are :

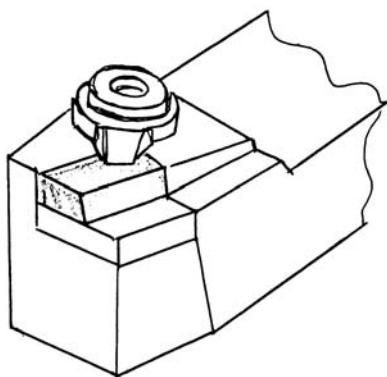
- The outer end of the step or groove acts as the heel that forcibly bend and fracture the running chip
- Simple in configuration, easy manufacture and inexpensive
- The geometry of the chip-breaking features are fixed once made (i.e., cannot be controlled)
- Effective only for fixed range of speed and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

(c) clamped type chip-breaker

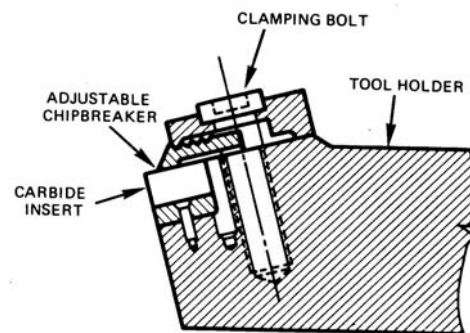
Clamped type chip breakers work basically in the principle of stepped type chip-breaker but have the provision of varying the width of the step and / or the angle of the heel.

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

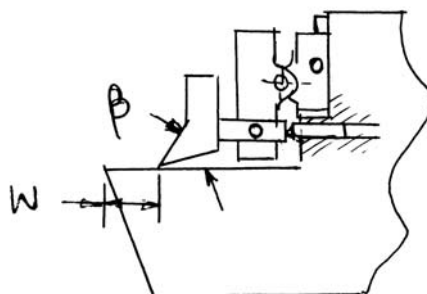
- With fixed distance and angle of the additional strip – effective only for a limited domain of parametric combination
- With variable width (W) only – little versatile
- With variable width (W), height (H) and angle (β) – quite versatile but less rugged and more expensive.



(a) fixed geometry



(b) variable width



(c) variable width and angle

Fig. 7.5 Clamped type chip breakers.

(iii) Design principle of simple step type chip breaker.

- **Parallel step type in-built chip breaker**

In machining like turning of ductile material the chip first leaves the hot plastic zone and then comes out as an elastic cantilever beam. The chip breaker (heel) forcibly bends the chip to shorter radius of curvature and raises the strain, resulting chip breaking as shown in Fig. 7.2.

Lot of study had been done on chip breaking and the results, briefly shown in Fig. 7.6 indicates that for a given value of uncut chip thickness, a_1 , the chip effectively breaks when the radius of curvature (ρ) is brought to or slightly below some critical value.

From Fig. 7.2,

$$W^2 = (2\rho - H).H \quad (7.1)$$

where,

W = width of the step

H = height of the step

ρ = radius of curvature of the chip

Example : Design step type integrated chip breaker for plain turning of a mild steel rod at feed $s_0 = 0.24$ mm/rev. with a tool whose PCEA (ϕ) = 60°

Solution :

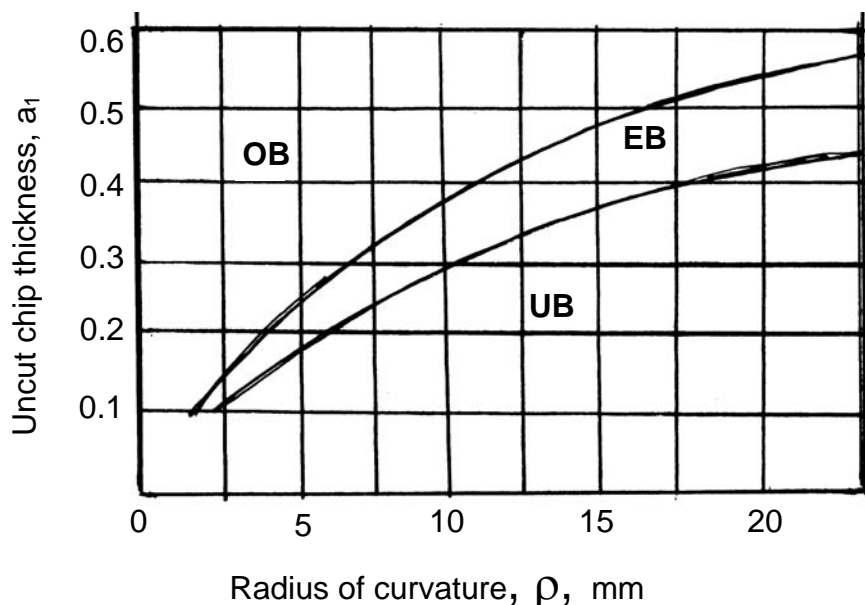
Here, $a_1 = s_0 \sin \phi = 0.24 \times \sin 60^\circ = 0.2$ mm

From the graph (a_1 vs ρ),

For $a_1 = 0.2$ mm, the value of ρ is taken 5 for effective chip breaking

Assuming $H = 2$

$$W = \sqrt{(2 \times 5 - 2) \cdot 2} = 4.0 \text{ mm} \quad \text{Ans.}$$



OB – over breaking, EB – effective breaking, UB – under breaking

Fig. 7.6 Critical radius of curvature for chip breaking.

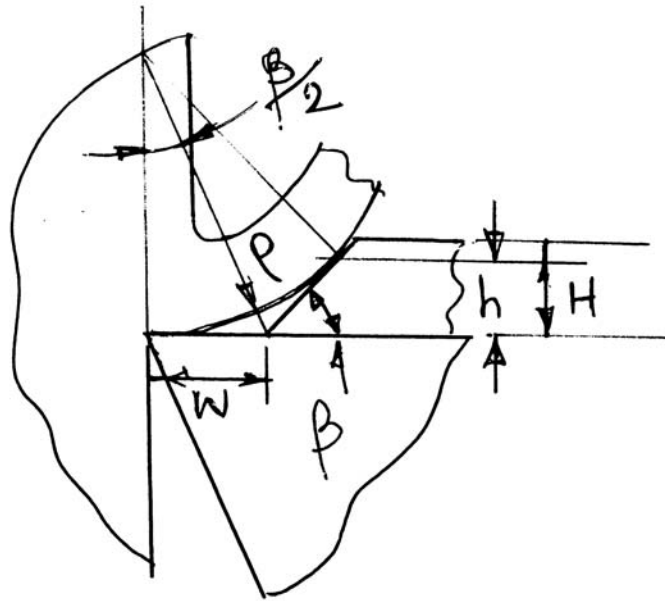


Fig. 7.7 Design of clamped type chip breaker.

- **Clamped type chip breaker**

From the geometry of Fig. 7.7,

$$W = \rho \tan \frac{\beta}{2} \quad (7.2)$$

and $h = W \sin \beta \quad (7.3)$

where, β = angle of the chip-breaking strip

H is taken 1 ~ 2 mm greater than h.

For the same condition of previous problem, i.e., $a_1 = 0.2$ mm and $\rho_c = 5$ mm and assuming $\beta = 60^\circ$ (varies from 45° to 90°)

$$W = 5 \times \tan 30^\circ \cong 3 \text{ mm}, \quad h = 3 \times \sin 60^\circ = 2.5 \text{ mm}$$

$$\therefore H = 2.5 + 1.0 = 3.5 \text{ mm} \quad \text{Ans.}$$

Previous researchers prepared a chart recommending the dimensions of step type chip breaker for different conditions under the following assumptions :

- ideally plastic chip, i.e., no work hardening
- chip flows straight if chip breaker does not exist
- plane sections remain plane
- heel of breaker exerts bending force on chip.

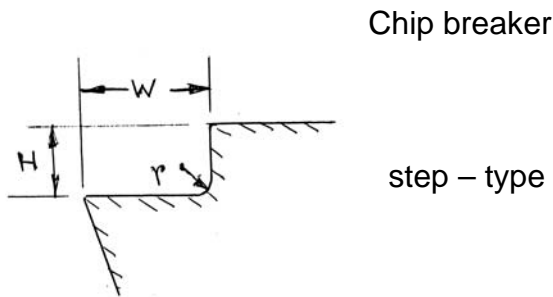


Table 1 In-built chip breaker design

Depth of cut	Feed	0.15 ~ 0.3 mm	0.3 ~ 0.4 mm	0.4 ~ 0.6 mm	0.6 ~ 1.0 mm	> 1.0 mm
	r	0.25 ~ 0.6	1.0 ~ 2.0	1.0 ~ 2.0	1.0 ~ 2.0	1.0 ~ 2.0
	H	0.25	0.4	0.5	0.75	0.75
0.4 ~ 1.2 mm	W	1.6	2.0	2.8	3.2	-
1.6 ~ 6.4 mm	W	2.4	3.2	4.0	5.0	5.0
2.0 ~ 12.8 mm	W	3.2	4.0	5.0	5.0	5.0
3.6 ~ 20 mm	W	4.0	5.0	5.0	5.0	5.0
> 20 mm	W	5.0	5.0	5.0	5.0	6.4

(iv) Configuration and working principle of some chip breakers in practice

In-built type chip breakers once made are of fixed geometry and hence are effectively applicable for particular situations or materials but are very simple in construction and easy to handle. While designing the overall geometry of the tool inserts, several factors, in addition to chip-breaking, need to be considered, such as ;

- imparting mechanical strength to the cutting edge by its rounding and / or bevelling
- reduction of cutting forces having favourable (positive) rake
- controlled contact (chip-tool) cutting effect for lesser friction and wear
- better heat dissipation

Incorporation of all such aspects through integrated tool geometry require proper design and manufacture which fortunately have become now-a-days, quite easy and fast due to advent of CAD and processes like EDM, ECM etc. for manufacturing complex shaped die and punch. In-built type chip breakers with integrated tool geometry have been much popular and are getting widely used.

Fig. 7.8 shows the typical form of the modern cutting tool inserts with in-built chip-breaker. The curved portion BC is the edge radiusing, CD is the land with negative rake, DEF is the groove with positive rake and the point F acts as the heel to break the chip by fracturing. The actual length and angle of those features and their apportionment are decided and some special features are further incorporated to that geometry (Fig. 7.8) depending upon the operations like bulk machining or finishing and the characteristics of the work materials.

The configurations of some industrially used uncoated and coated carbide tool inserts with compound rake including chip-breaking feature are typically shown in Fig. 7.9. [Cutting Tools for Productive Machining – T.A.Sadanivan and D. Sarathy, WIDIA (I) Ltd.]

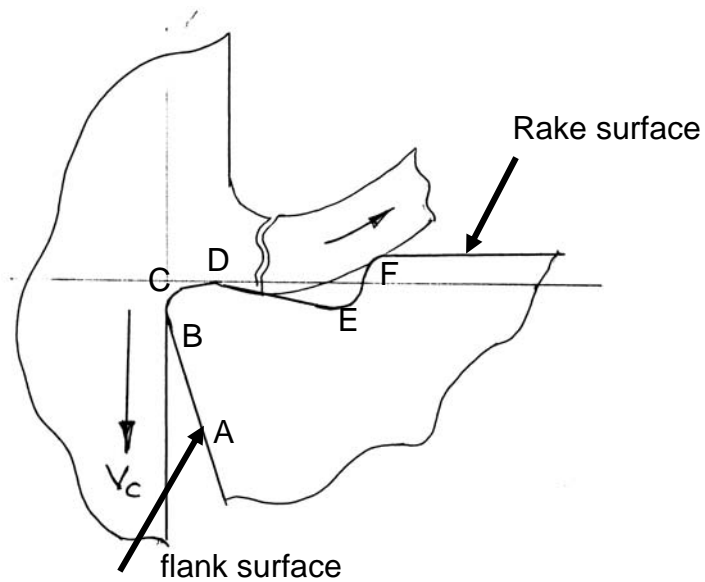


Fig. 7.8 Schematic view of the typical form of inserts (cutting edge) with integrated chip-breaker.

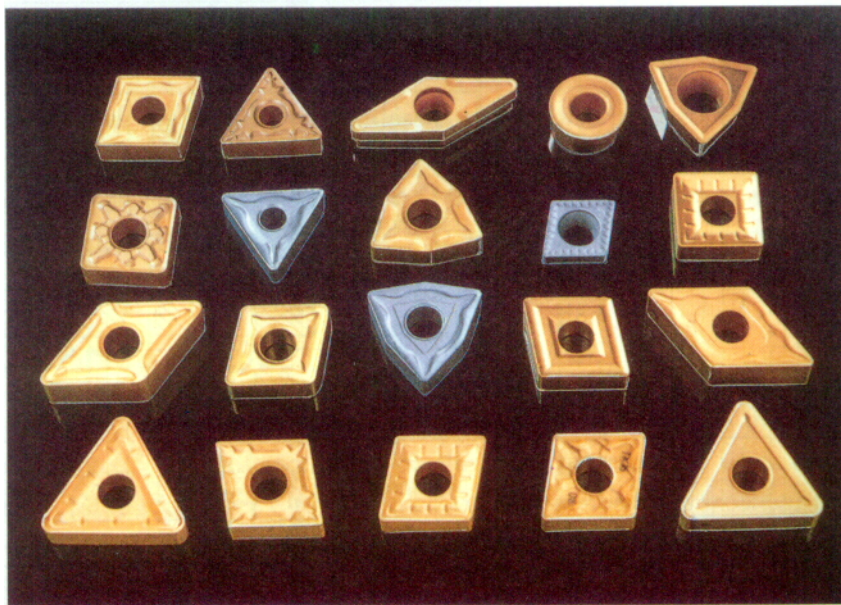


Fig. 7.9 Various groove type inserts

Throw away type indexable tool inserts are also widely used for drilling, milling, broaching etc. where the inserts of suitable geometry are mechanically clamped in

the steel shank of the tools. The geometry of some of those uncoated and coated carbide inserts also essentially incorporates the chip-breaking feature.

Chip breakers in solid HSS tools

Despite advent of several modern cutting tool materials, HSS is still used for its excellent TRS (transverse rupture strength) and toughness, formability, grindability and low cost.

The cutting tools made of solid HSS blanks, such as form tools, twist drills, slab milling cutters, broaches etc, are also often used with suitable chip breakers for breaking the long or wide continuous chips.

The handling of wide and long chips often become difficult particularly while drilling large diameter and deep holes. Grooves, either on the rake faces or on the flanks as shown in Fig. 7.10 help break the chips both along the length and breadth in drilling ductile metals. The locations of the grooves are offset in the two cutting edges.

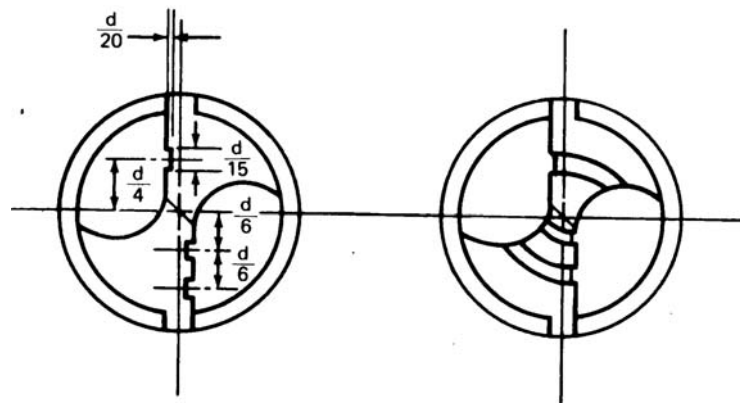
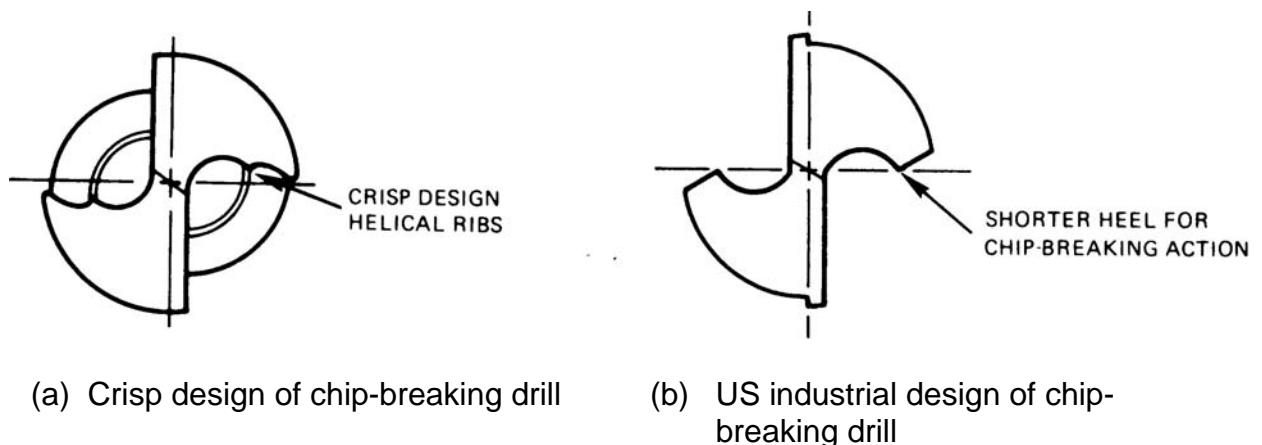


Fig. 7.10 Chip breaking grooves.

Fig. 7.11 schematically shows another principle of chip-breaking when the drilling chips are forced to tighter curling followed by breaking of the strain hardened chips into pieces.



(a) Crisp design of chip-breaking drill

(b) US industrial design of chip-breaking drill

Fig. 7.11 Designs of chip-breaking drill

Plain milling and end milling inherently produces discontinuous 'coma' shaped chips of favourably shorter length. But the chips become very wide while milling wide surfaces and may offer problem of chip disposal. To reduce this problem, the milling cutters are provided with small peripheral grooves on the cutting edges as shown in Fig. 7.12. Such in-built type chip breakers break the wide chips into a number of chips of much shorter width. Similar groove type chip-breakers are also often provided along the teeth of broaches, for breaking the chips to shorter width and ease of disposal.

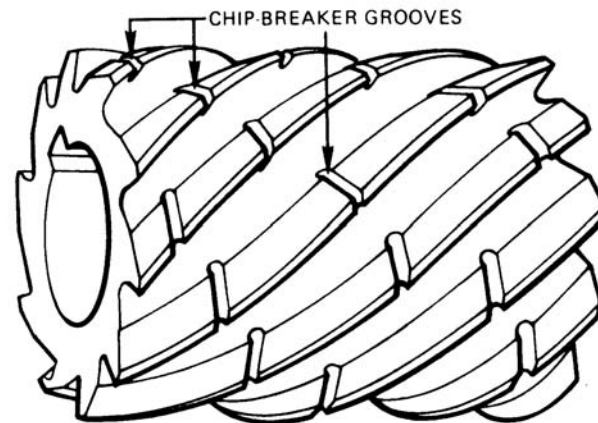


Fig. 7.12 Chip breaking grooves on a plain helical milling cutter.

Dynamic chip breaker

Dynamic turning is a special technique, where the cutting tool is deliberately vibrated along the direction of feed as indicated in Fig. 7.13 at suitable frequency and amplitude. Such additional controlled tool oscillation caused by mechanical, hydraulic or electro-magnetic (solenoid) shaker improves surface finish. This also reduces the cutting forces and enhances the tool life due to more effective cooling and lubrication at the chip tool and work tool interfaces for intermittent break of the tool-work contact. Such technique, if further slightly adjusted, can also help breaking the chips. When the two surfaces of the chip will be waved by phase difference of about 90° , the chip will either break immediately or will come out in the form of bids, which will also break with slight bending or pressure as indicated in Fig. 7.13. This technique of chip breaking can also be accomplished in dynamic drilling and dynamic boring.

Fig. 7.14 schematically shows another possible dynamic chip-breaking device suitable for radially fed type lathe operations, e.g., facing, grooving and parting.

(v) Overall effects of chip breaking

- Favourable effects
 - safety of the operator(s) from the hot, sharp continuous chip flowing out at high speed
 - convenience of collection and disposal of chips

- chances of damage of the finished surface by entangling or rubbing with the chip is eliminated
- more effective cutting fluid action due to shorter and varying chip tool contact length.
- Unfavourable effects
 - chances of harmful vibration due to frequent chip breaking and hitting at the heel or flank of the tool bit
 - more heat and stress concentration near the sharp cutting edge and hence chances of its rapid failure.
 - Surface finish may deteriorate

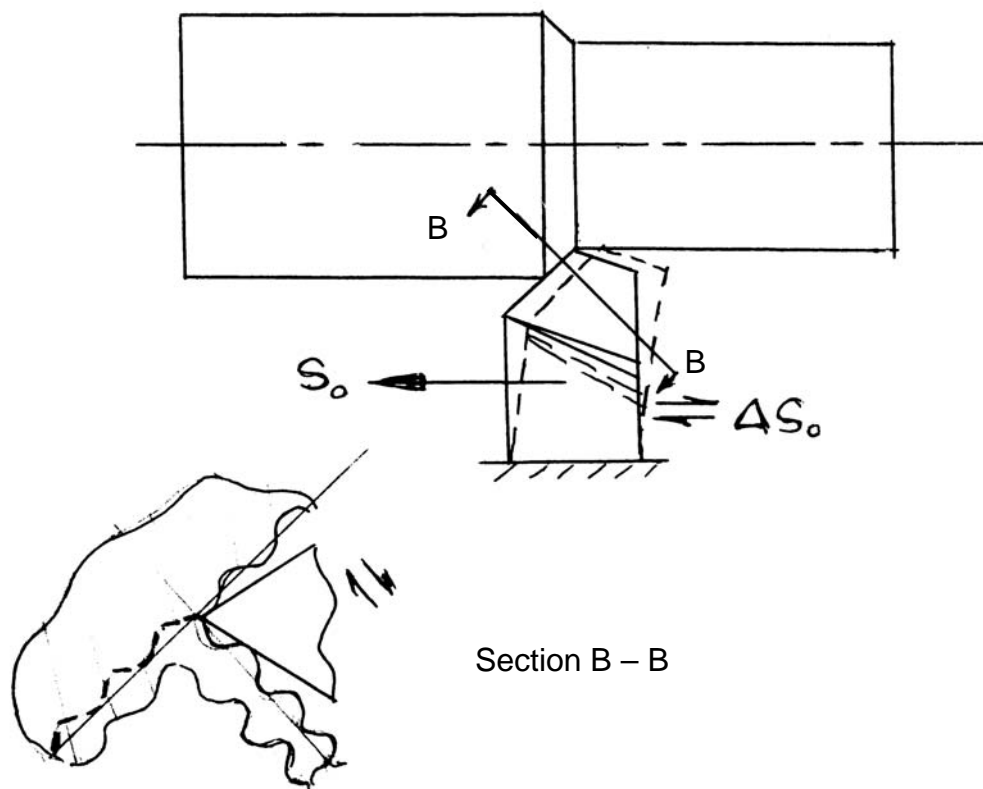


Fig. 7.13 Self chip breaking in dynamic turning.

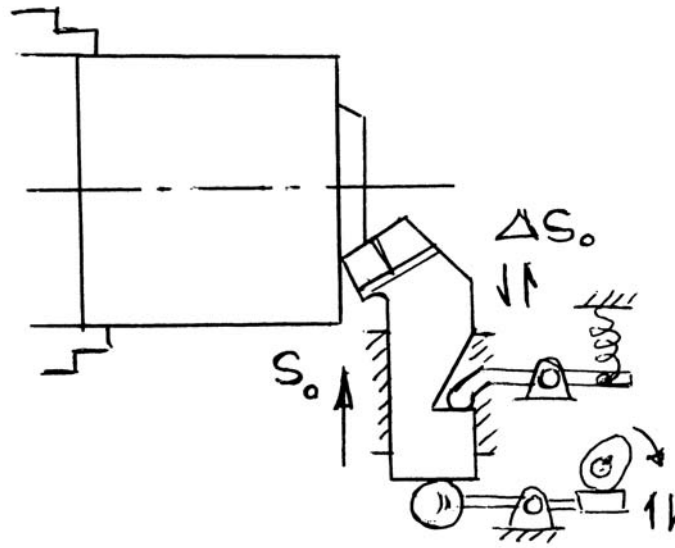


Fig. 7.14 Dynamic chip breaking in radial operations in lathe.

Exercise – 7

- Q. 1 What factors are considered while designing the rake surface / cutting edge of carbide turning inserts ?
- Q. 2 In which direction is the cutting tool vibrated and why in dynamic turning ?
- Q. 3 Why are step type integrated chip breakers made angular ?
- Q. 4 When is forced chip breaking necessary and why ?

Answers of the questions given in Exercise – 7

Ans. to Q. 1

- enhance thermal and mechanical strength at the sharp edge
- reduction of the cutting forces
- more effective cutting fluid action
- chip-breaking

Ans. to Q. 2

The tool is vibrated in feed direction only

- vibration in transverse direction will enhance surface roughness
- vibration in tangential direction is less effective and more difficult also.

Ans. to Q. 3

To produce close curling of chips which is safe and easy to collect and dispose.

Positive angle – shifts the coil away from the job

Negative angle – shifts the chip away from the operator

Ans. to Q. 4

When chips continuously form and come out very hot, sharp and at quite high speed – under the condition :

- soft ductile work material
- flat rake surface with positive or near zero rake

for

- safety and convenience of the operator
- easy collection and disposal of chips.