How chips are formed - (basic concepts)

The ways in which the metallic chip is formed and flows, have been in the past one hundred years of uninterrupted and in-depth studies conducted by many investigators.
All the many factors that affect in some way on the chip formation were examined and classified. We started from very low cutting speed (about 1 m/min) to reach cutting speeds that even today, especially for steel, is unusual (about 2000 m/min).
Ingenious systems have been developed for measuring the temperature in the contact zone between chip and tool, such as for example, special substances that take a different color for each temperature, or has used the property of the thermoelectric couple formed by the workpiece and 'tool.
They finally adopted special equipment at very high speed film that have allowed us to follow very clearly entire process of chip formation.
Will not be here a report of all the experiences, among other things virtually impossible, but we will only briefly mention a few, to give an idea of the phenomenon, also in order to resolve specific practical problems associated with chip formation

Types of chips
The various types of chips can be classified into three categories:

- *discontinuous chips*
- *segmented chips*
- *fluent chips*

The discontinuous chip is a small basic chip which separation from the workpiece is before it has begun the formation of the following.
This type of chip is obtained with considerable feed per revolution (about 4 mm / rev) with very low cutting speed and with not too ductile materials.
With such feed and cutting speeds so low, there is the possibility of a plastic flow of the material stopped from the face cutting tool and the material belonging to the piece that it can continue its movement.

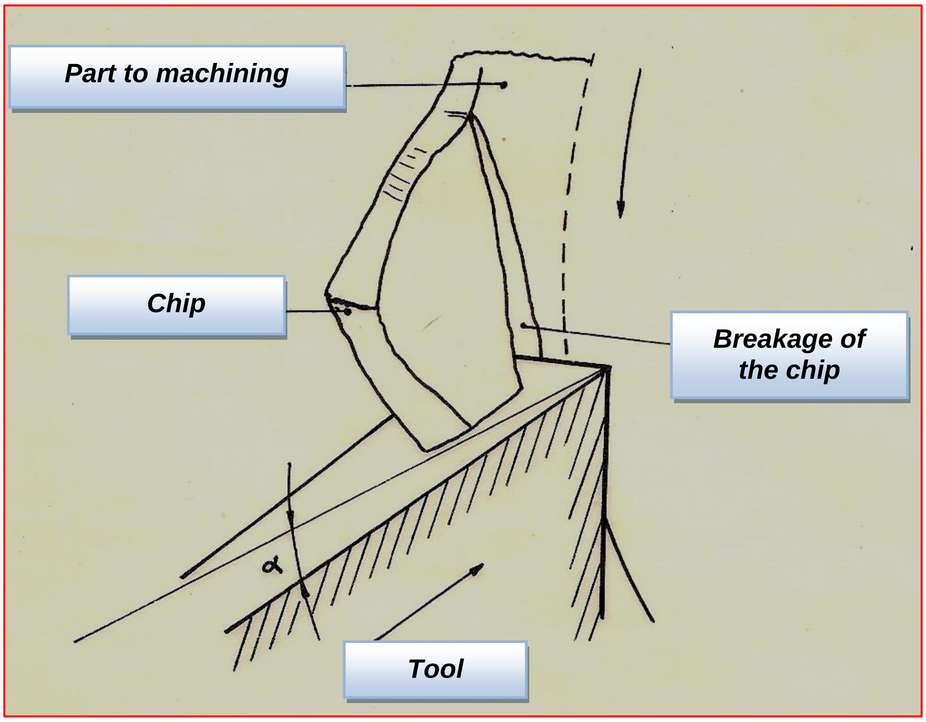

Figure N°1- *Discontinuous chip formation*

This creates a break which starts from the tool and expands until it reaches the periphery of the workpiece where determines the separation of the chip.
This separation occurs before the tool has started producing a new chip.
Note that if the rake angle was increased, the main cutting edge has the possibility to start its action on another chip before the crack becomes large enough to completely detached the first chip.
This would happen even if the feed per revolution was reduced.

The segmented chip is therefore obtained decreasing the feed or increasing the rake angle, or even increasing the cutting speed, because in the latter case there is a certain action of plastic flow between the first chip detached and the next one in formation , enough to not allow the crack to get to the periphery of the workpiece.
Segmented chip therefore means a joined chip, but that the part that slides against the cutting face of the tool have the cracks are more or less deep.
By decreasing the value of feed per revolution or further increasing the cutting speed or by increasing the rake angle, depth and spacing of cracks decreases until annulled, leading to the fluently chip.

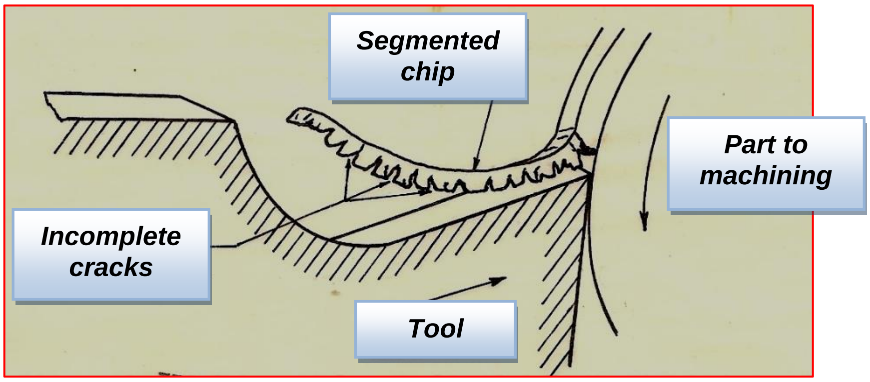

Figure N°2 – *Formation of segmented chip*

The fluent chip can be considered a continuous ribbon and uniform without cracking.
This type of chip is still difficult to find with low values of cutting speed unless you decrease the feed lot and execute a curved groove on the cutting edge so as to greatly increase the rake angle and facilitate rolling up of the chip itself.
These chips are very common with high cutting speeds typical of modern machines and carbide tools especially if coated with TiN.
In these cases occurs a phenomenon that allows to have fluent chips with negative rake angles, in fact, with angles of this kind the main cutting edge no longer appears as a wedge into the material, but the chip is removed by compression.
In this way it is a significant slipping between each element of plastic chip with a high heat generation which tends to make more plastic the material being processed.
And for this reason that over a certain cutting speed, the specific resistance of the material being cut decreases from 30 to 35%.
The chip will be continuous, but consists of items that are slipped one over another and due to their increased plasticity remained united.
The part that slides against the cutting face looks shiny, but you can not say the same of the other side.

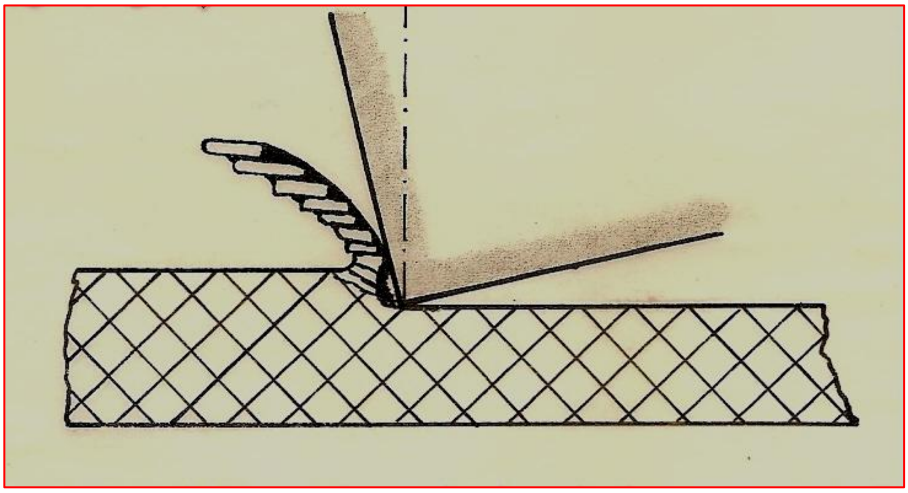

Figure N°3- *How the chip is formed with negative rake angle*

<u>Built-up edge</u>

With the rake angles higher than normal and cutting speeds not too high, both with high-speed steel tools than with carbide, it has, during the chip formation, the generation of so-called built-up edge that in many cases has a damaging action and in some others can increase tool life.
In modern tools the formation of built-up edge is a very rare phenomenon, because of the coatings which the tool is subject.
If the built-up edge to remain welded permanently on the cutting edge, it would have some kind of action to protect and serve to increase the tool life itself, but this does not happen because it is formed and detach many times over the course of a normal turning operation at intervals of fractions of a second.
When you are not completely detach, a fraction fleeing attached to the chip or to part machined and that is quickly replaced with another little bit of material.
The built-up edge is therefore a piece of material that is welded on the tool and this phenomenon is the easier the greater the chemical affinity between tool and workpiece.
With reference to figure N°4, in the first phase we can observe the fragments **a** and **a’** just detached from the cutting edge and fleeing with the chip and the workpiece,:
Immediately, there are the formation of another built-up edge that in the second phase becomes larger; in the third stage begins the action of separation of the two sections and fourth stage is almost complete.

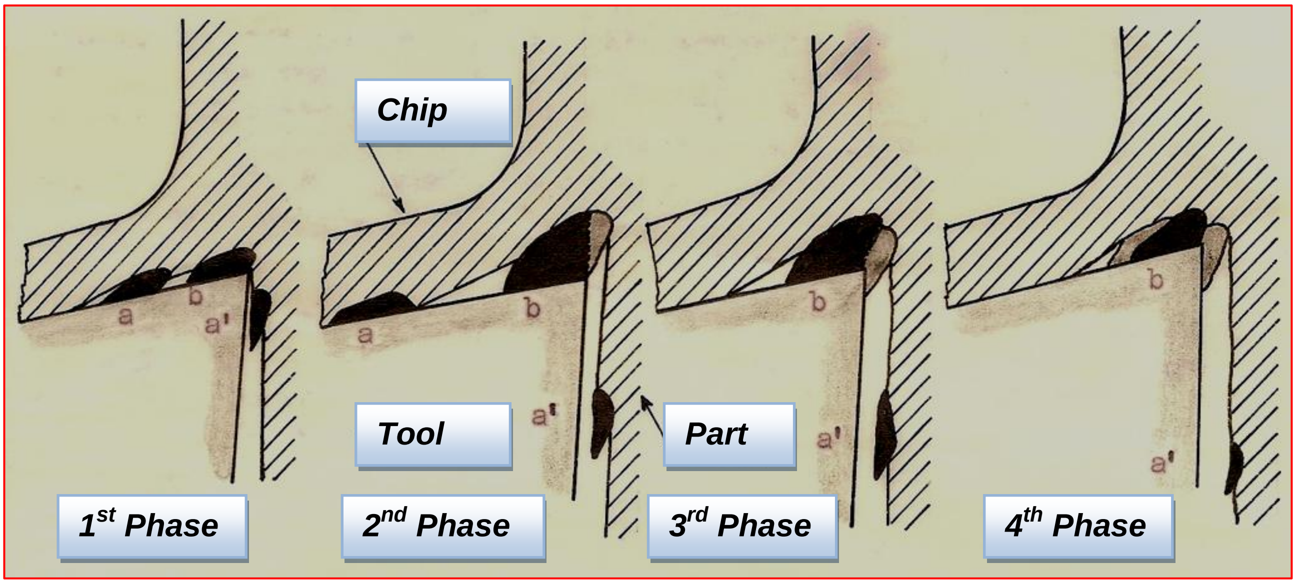

Figure N°4- *How are formed the build-up edge*

This cycle is usually completed in a time ranging from 0.1 to 0.01 seconds.
This continuous change in shape and size of the built up edge causes a remarkable roughness of the machined surface that, especially in finishing operations, is not tolerated.
Secondly, particularly on high speed steel tools, the strong link between tool edge and build-up edge causes, in the moment of separation, the removal of small fragments, and very hard carbides present in the steel of the tool with a consequent increase of wear.
The tantalum present in the sintered carbide has the property to prevent the welding of the build-up edge, it is for this reason that where there is a prevalence of crater wear is preferable to use sintered carbides of group P. Of course, today, with various types of coating (TiN, TiCN, TiAlN, etc..) the phenomenon is very small, but it is still present in many types of tools that are not covered, or those in which the coating film is broken.
A certain protective function of the built up edge is when you work very abrasive materials.
Today in the mass production turning operations are used increasingly carbide tools, especially mechanically fixed inserts. The cutting speed is therefore very high and the tools have very often negative rake angles.
The built up edge is not formed in these cases, because for high cutting speed , and for the little affinity of the materials used to manufacture the tool and the piece (especially if the tool is coated with TiN).
The built up edge formation depends very much on the material being processed, so if you work a cast iron or materials with low plasticity, it almost does not exist, and is facilitated with soft and plastic materials.
In conclusion we can say that it would be desirable in the turning operations the formation of discontinuous chips because they are easy to transport, do not cause obstructions and do not constitute any danger. The speed at which they form, however, are clearly uneconomic for which their formation is achieved only with materials such as cast iron, that at any speed, producing smaller chips.
With steel are formed or chips of segmented type or those fluent type . The first is not a problem because they are subject to a natural break at every single impact against the workpiece or equipment, but gradually you get closer to the chip flowing form is an increasingly serious problem, and this for at least three reasons:

- *Blockages and tangling on the workpiece, on the tool and on the equipment and resulting loss of time for the release.*
- *Risk for the operator.*
- *Difficult of transportability*

It's therefore necessary to break these chips during their formation; for this purpose the most preferred method is to make a step chip breaker near the main cutting edge, so as to force the chip to an abrupt detour that determines the break.
In carbide inserts mechanically fixed, chip breaker, sometimes, is very sophisticated; is obtained directly during sintering.

Minimum chip thickness

If the cutting depth falls below a certain limit the tool refuse the material, compresses it, hardens it and cuts irregularly.
The lower limit depends mainly on the accuracy of re-sharpening, that is, the level of finish of the cutting edge. It 'obvious that a rounded edge will not remove a stock removal smaller than the diameter of the corner rounding. See figure N°5.
You basically have the following minimum values:

- *Highly polished diamond tool: S = 0.008 mm*
- *Carefully honed edge tool with: S = 0.02 mm*
- *Tool finished with fine grinding wheel: S = 0.06 mm*
- *Tool re-sharpening with a coarse grinding wheel: S = 0.16 mm*

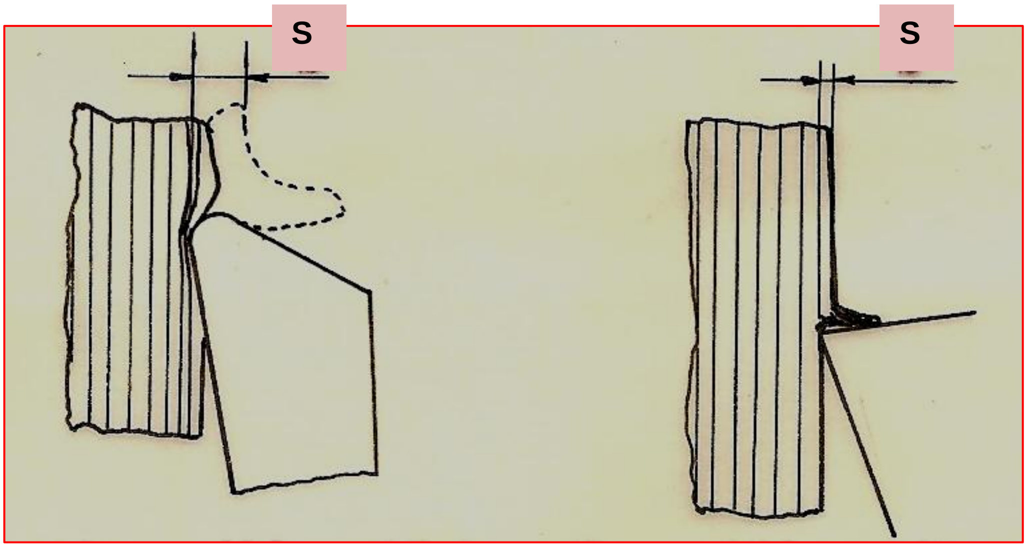

Figure N°5- *Minimum chip thickness*