(2) – Basic of milling

Direction of axial forces

The milling cutters with straight teeth have the disadvantage that each edge begins to cut the material on its entire length creating very strong efforts with a discontinuities of the load on the tool.
It follows that the cutter receives shocks that cause vibration dangerous to the quality of the machined surface.
For this reason it is almost always necessary to reduce the cutting speed and feed , and so the milling time will be longer.
The cutters with helical cutting edges eliminate these problems primarily because the edges come into contact with the workpiece more gradually to avoid rapid changes in cutting forces on the edges.
The total forces become more uniform, almost constant, and the vibrations disappear with a big advantage for the machined surfaces.
Another benefit adopting the helical cutting edge with a strong inclination is to reduce the maximum width of the cutting edge in contact with the piece getting more teeth that work simultaneously to improve the continuity of the cut.
The axial force generated by the helical cutting edge milling cutters imposes a limit on the value of the angle of the helix in relation to the direction of cut, the direction of the helix, and the type of cutter.
The angle of the helix, may vary within a very wide range, ie from 15-20° to 45-50° depending on the characteristics of the cutter.
The milling cutters with high helix angle (45-50°) are called high-performance cutters because they are suitable for a high volume of chip removed per unit of time without causing shock or vibration.
Due to the high axial force, however, these cutters can be utilized in a rational manner only on machines with high power and with spindles in perfect condition and suitable to absorb the strong axial forces without problems.
On machines no longer in perfect condition and efficiency, with backlash on the spindles or with limited power, the choice of the cutter must be given to those with helix angle not exceeding 20°, which allows continuous cutting action , and generate low axial force that are absorbed without dangerous consequences.
In milling the cutting force find a reaction to the piece that is reflected on the cutter in the normal direction to the cutting edge.
If the edges are helical, the force admits three components as shown in figure N° 1.

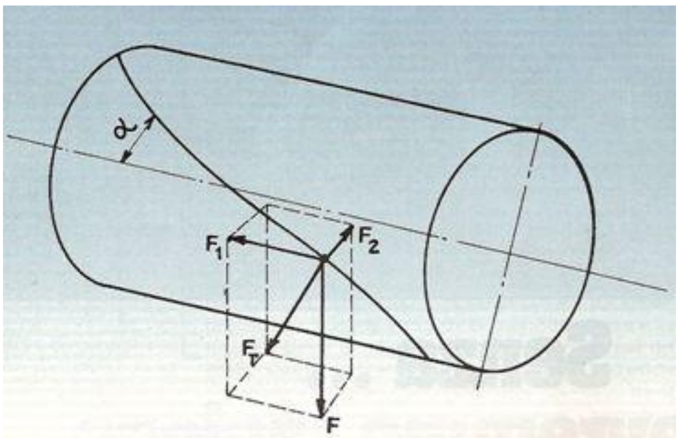

Fig.N°1- *Direction of the forces in the helical milling cutters*

F_1 opposes the rotation of the cutter, F_2 acts axially pushing the spindle to its seat or trying to remove it from the seat depending on the direction of the helix, and the direction of cutting, finally F_3 is parallel to the feed but in the opposite direction.

The value of the axial force depends primarily on the working condition , such as material, the cutting depth, the width of the milling, feed rate etc.. and then the inclination of the helix. If F is the force component that opposes the rotation of the cutter and F1 the axial force you can write:

$$F_1 = F\ tg.\alpha. \quad \text{where } \alpha \text{ is the helix angle.}$$

In the figures N°2 are shown the axial force, which may occur in practice.
The axial force should always be directed towards the seat of the spindle and to prevent the milling cutter spindle is unlocked from its seat and that generate dangerous vibrations.
From the figures we can see that in order to have an axial force directed against the seat of the spindle, the direction of the cutting force and the direction of the helix must be contrary.
If the total force FT is very strong and, because of a very high helix angle, results a strong axial component, for example, when milling large surfaces, it is appropriate to use two cutters coupled with a opposite direction of the helix so that the opposed forces will compensate.
For cylindrical milling cutters with frontal cutting edges the direction of the axial force becomes more important because it can verify the unlocking of the cutter from the seat.
In this case it is necessary to use the threaded tapered shanks with , to allow secure locking with a threaded rod.
In this type of cutter must also consider the influence that has the helix angle on the rake angle of the frontal cutting edges and the ability to properly discharge the chips detached by these cutting edges .
From the figures we see that if the directions of the helix and the cut are opposed it has an unfavorable condition for the discharge on the chips, but the force is directed against the seat of the spindle.
If the direction of helix are the same the cutting action is facilitated, but the pressure would tend to detach the cutter from the seat. It would be good in these cases to block the cutter with a threaded rod, especially if the helix angle is very high.

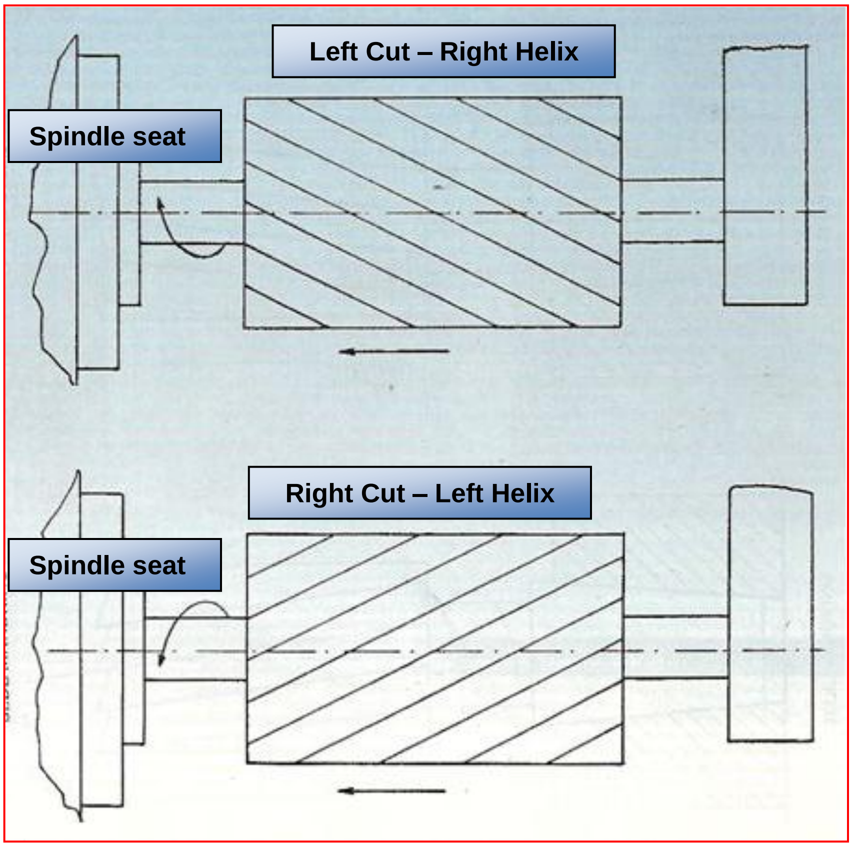

Figure N°2a- *Direction of axial force toward seat of spindle*

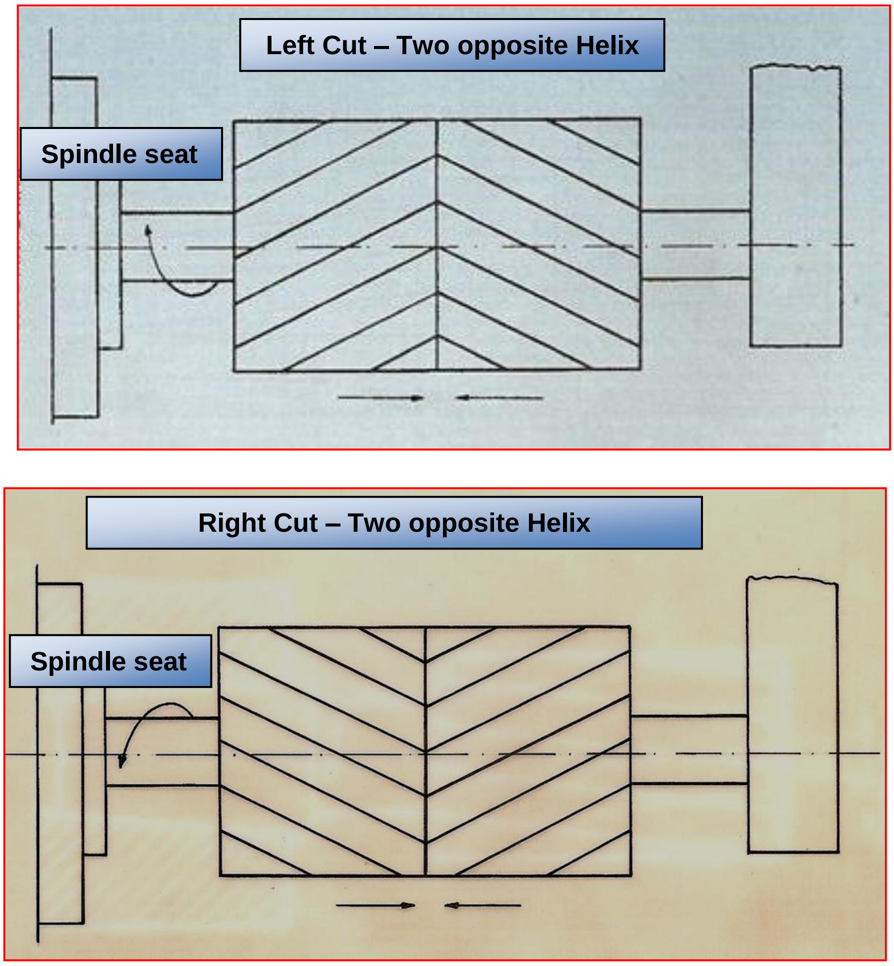

Figure N°2b – *Axial forces cancel each other*

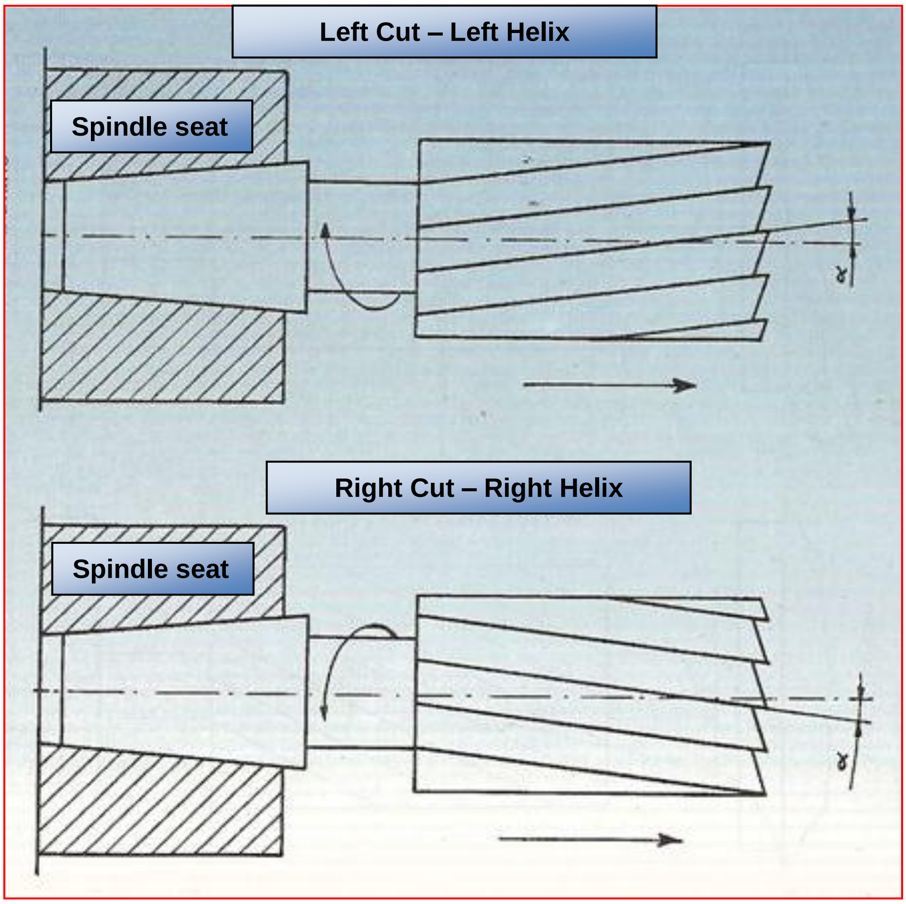

Figure N°2c- *Axial force opposite to spindle seat*

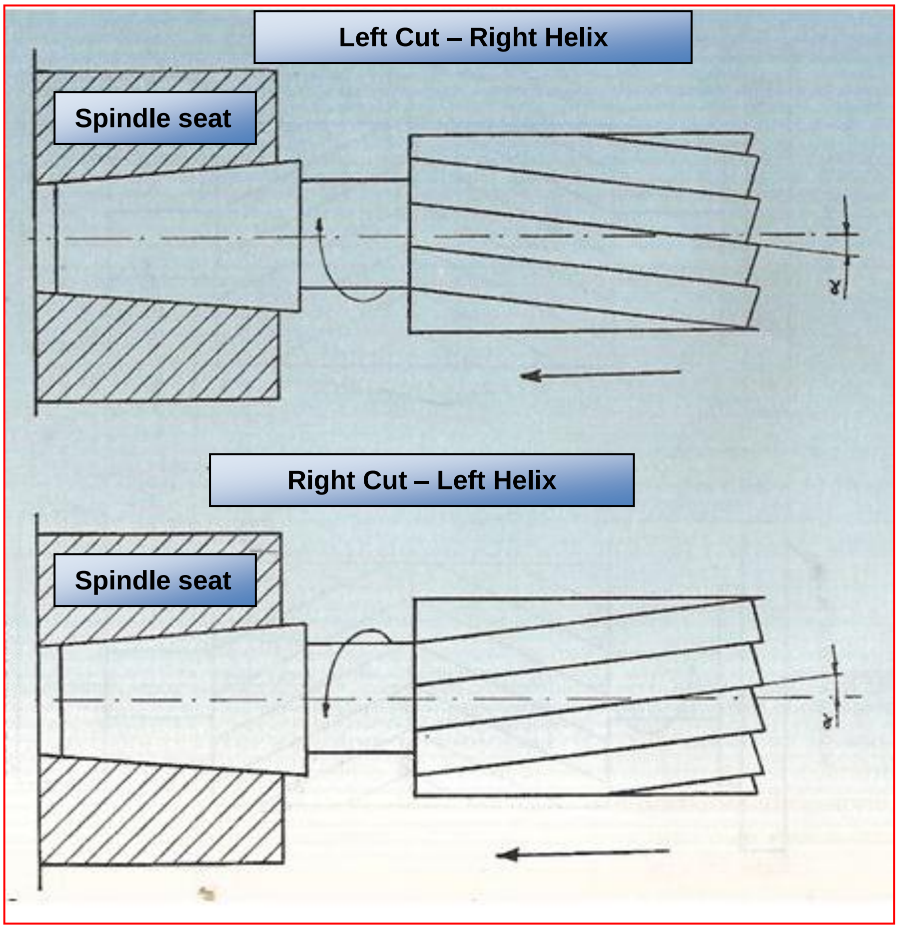

Figure N°2d- *Axial force to spindle seat*