Ball Nose End Mills

Some information are necessary about this type of end mills, specially for calculate the effective cutting speed and the roughness of the surface of the workpiece after milling operation.

We must consider that i fan End mill with ball nose is working with vertical axis, in the central point, means in the point placed in the axis, the cutting speed is zero, therefore we must avoid this condition.
Any way if the end mill is working with vertical axis, the maximum cutting speed must be calculate not in accordance with the nominal diameter **d**, but with the effective maximum working diameter $\mathbf{d_{eff}}$, this diameter depends both of nominal diameter and the axial depth of cutting $\mathbf{a_p}$.
In accordance with the figure N°1, the formula that is used to calculate the effective working diameter is the following:
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$$d_{eff} = 2 \cdot \sqrt{d \cdot a_p - a_p^2}$$

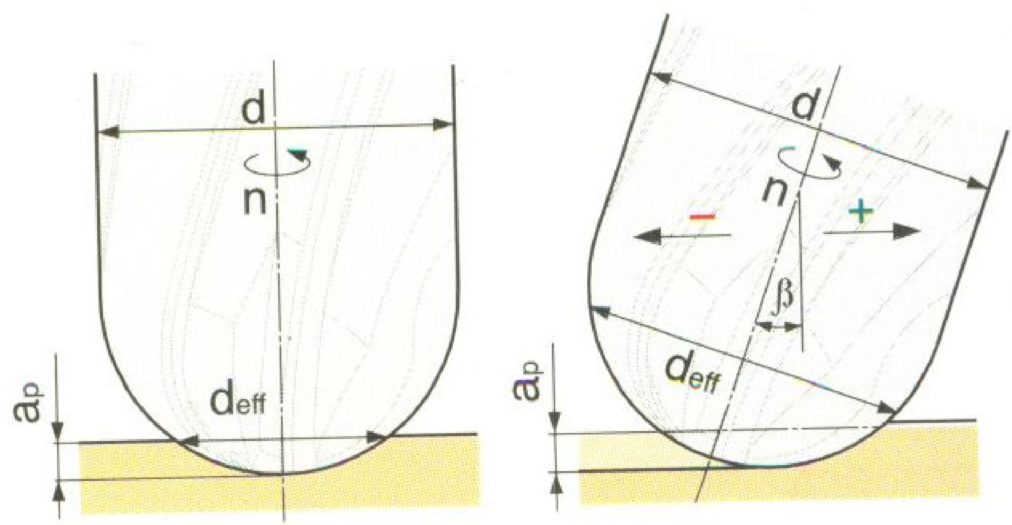


Figura N°1

In the same figure N°1 we can see that the end mill have the axis inclined with an angle β out of the normal of the working surface the maximum effective working diameter will be:

$$d_{eff} = d \cdot sen\left[\beta \pm \arccos\left(\frac{d - 2 \cdot a_p}{d}\right)\right]$$

And therefore the effective maximum cutting speed must be calculated by :

$$V_{ceff} = \frac{2 \cdot \Pi \cdot n}{1000} \cdot \sqrt{d \cdot a_p - a_p^2} \qquad \text{with} \quad \beta = 0$$

$$V_{ceff} = \frac{\Pi \cdot n \cdot d}{1000} \cdot sen\left[\beta \pm \arccos\left(\frac{d - 2 \cdot a_p}{d}\right)\right] \quad \text{with } \beta \neq 0$$

If a ball nose end mill travels a flat surface and every stroke it's shifted by a value a b_r (feed pitch), it's possible to calculate the theoretical roughness of the surface.
In accordance with the figure N°2 we have:
If $b_r \geq d_{eff}$ will be $R_{th} = a_p$ and if $b_r < d_{eff}$ will be $R_{th} < a_p$ with:

$$R_{th} = \frac{d - \sqrt{d^2 - b_r^2}}{2}$$

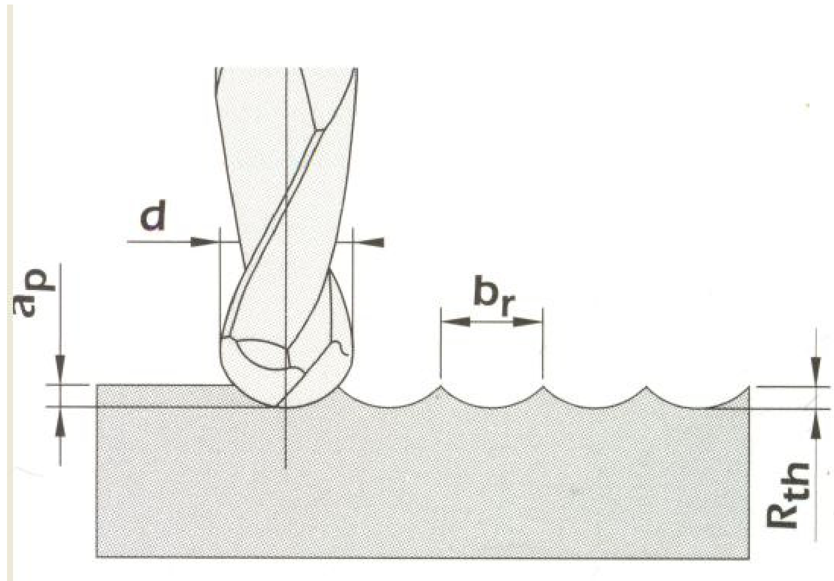


Figura N°2

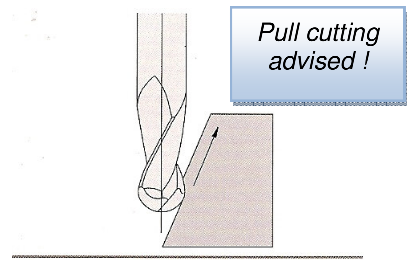
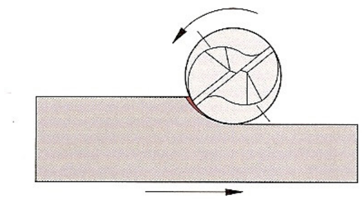
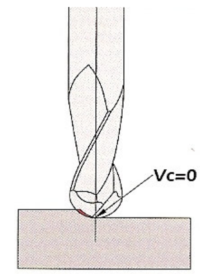
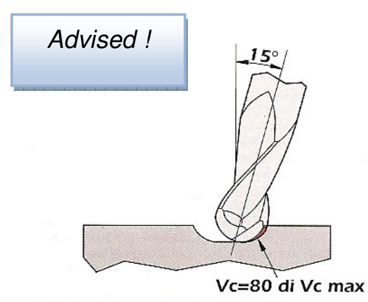
In the following tab. N°1 you can find the most common formulae used to calculate the working parameters.

Tab. N°1

Parameter	*Formula*
n - Rpm (Revolution per minute)	$n = \frac{V_c \cdot 1000}{d \cdot \pi}$
V_c – Cutting speed (m/min)	$V_c = \frac{d \cdot \pi \cdot n}{1000}$
f - Feed per revolution (mm)	$f = f_z \cdot z$
f_z - Feed per tooth (mm)	$f_z = \frac{V_f}{z \cdot n}$
V_f – Feed rate (mm/min)	$V_f = f_z \cdot z \cdot n$

In the following table N°2 are shown the useful suggestion for a correct use of this kind of end mills.

Tab. N°2

It's recommended that pull cutting be used as much as possible. *The bigger section of chip correspond to the optimum cutting speed*	
Concordant milling gives a better quality result that discordant milling: better surface roughness, less noise, and longer tool life.	
If possible the tools should be slightly tilted in the feed direction to avoid any working in the central part of the tool where the cutting speed is equal to zero.	
The better tilt is at 15° in the feed direction and allow the mill to work to a cutting speed equal to 80% of the maximum theoretical one in reference to the nominal diameter of the cutter itself.	
Do not carry out vertical movements of immersion in the piece, we recommend spiral or ramp movements.