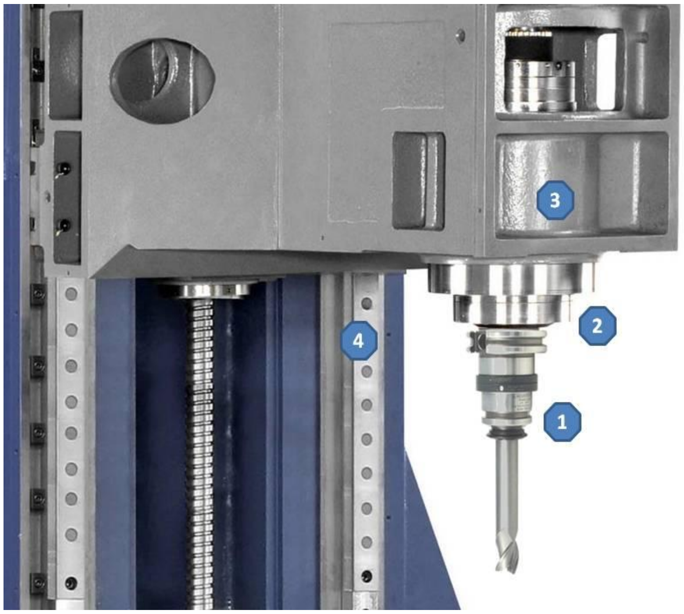
What is MACHINING DYNAMICS?

Machining Dynamics is the science of vibration and frequencies created at the tool point during machining.



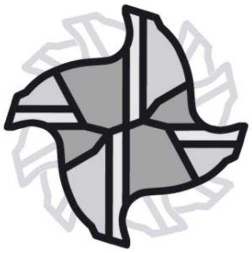
The cutting tool is part of a dynamic cutting system. (1) the endmill is mounted into collet in a toolholder, (2) the toolholder is held in a spindle, (3) the spindle is rotating on bearings and is mounted in a headstock, (4) the headstock is moving up and down on guideways. In order for each of these connections to function there must be some amount of clearance or "play". Without it tools wouldn't fit into toolholders, spindles would not rotate on their bearings and guideways would not slide. With this "play", when force is applied to the tool tip it will "give" or deflect.

Force is applied when a tooth of the endmill makes contact with the workpiece. The force causes the endmill to deflect. The amount of the deflection is determined by the depth of cut.

When the tooth releases from the cut the endmill rebounds in the opposite direction and then continues to vibrate back and forth until it is fully dissipated. The rate and duration of this vibration is the tool point's natural frequency.

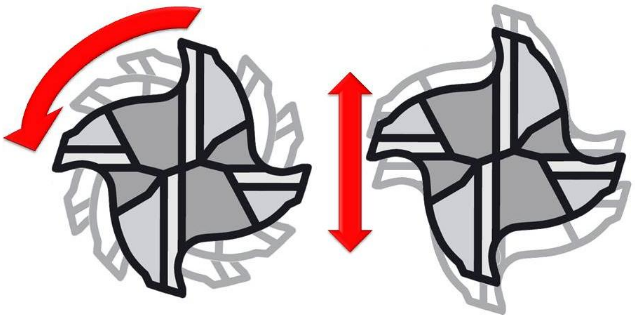
"For every action there is an equal and opposite reaction"
Sir Isaac Newton

A way to visualize a natural frequency is to hang a ruler over the edge of a table and flick the end with your finger. The ruler will vibrate at its natural frequency.

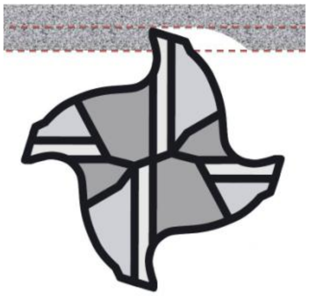


Problem is the vibration is not allowed to fully dissipate. Because the endmill has multiple teeth and is rotating fast, the next tooth impacts the workpiece and the process starts all over again. For example a four flute tool, running at 15,000 RPM, will have 1000 impacts per second.

So you now have a back and forth vibration with multiple, rotating tooth impacts.



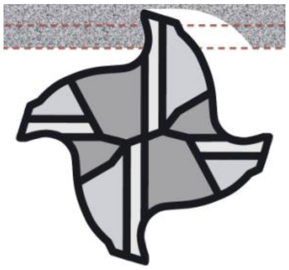
If the back and forth vibration, the tool point's natural frequency, is timed properly with the tooth

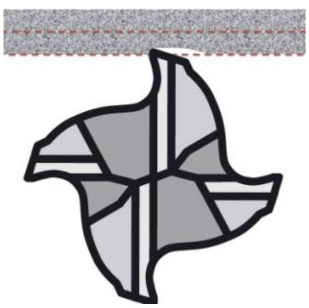


passing (rotational) frequency, each tooth of the endmill will impact the workpiece at the same instantaneous chip thickness. The cut will be smooth, tool life maximized, the finish superior and the part is accurate.

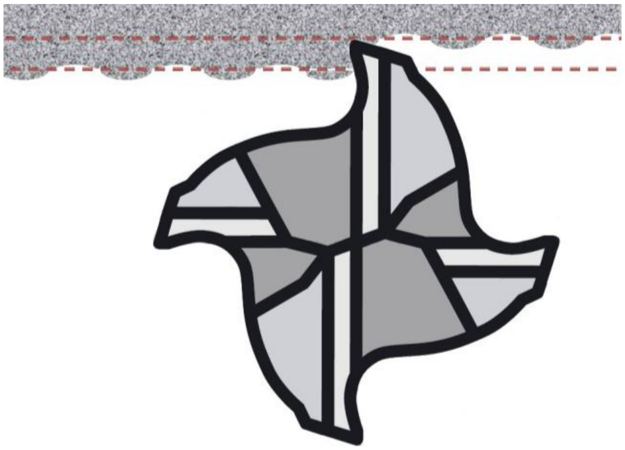
HOWEVER…

…if the timing is off and the next tooth arrives too late, the chip thickness is larger, It is cutting oversize, perhaps scrapping the part. Tool life will be far less (this tooth will fail sooner than the rest), the finish will deteriorate. It is also generating more force that will cause the tool to deflect even more, impacting up the next tooth.





If the next tooth arrives too early the tooth is undercutting leaving more stock for the next tooth. That will lead to the over-cutting problems described above.



Because the unequal cuts leave a wavy surface, each subsequent pass creates even greater chip thickness variations. This can lead to chatter and it will only get worse. This is what is called "regenerative chatter".

You can overcome the effects of Machining Dynamics by either slowing the spindle speed down enough so that the vibration from one tooth is dissipated before the next tooth comes through or by taking so light a cut that the deflection is miniscule. Machining time will be 5 to 10X longer.

It is important to note that ANY change to ANY component of the cutting system (endmill, toolholder, spindle, machine tool and workpiece) will change the tool point frequency and, therefore, the performance of the system. Changes include:

- **Cutter Length**
- **Cutter Diameter**
- **Endmill Projection**
- **Number of Teeth**
- **Spacing of Teeth (Variable Pitch)**
- **Helix Angle**
- **Toolholder Type**
- **Toolholder Gripping Force**
- **Weight or Mass of Toolholder**
- **Run-out**
- **Imbalance**
- **Spindle Drawbar Force**
- **Spindle Bearing Preload**

And too many more to list