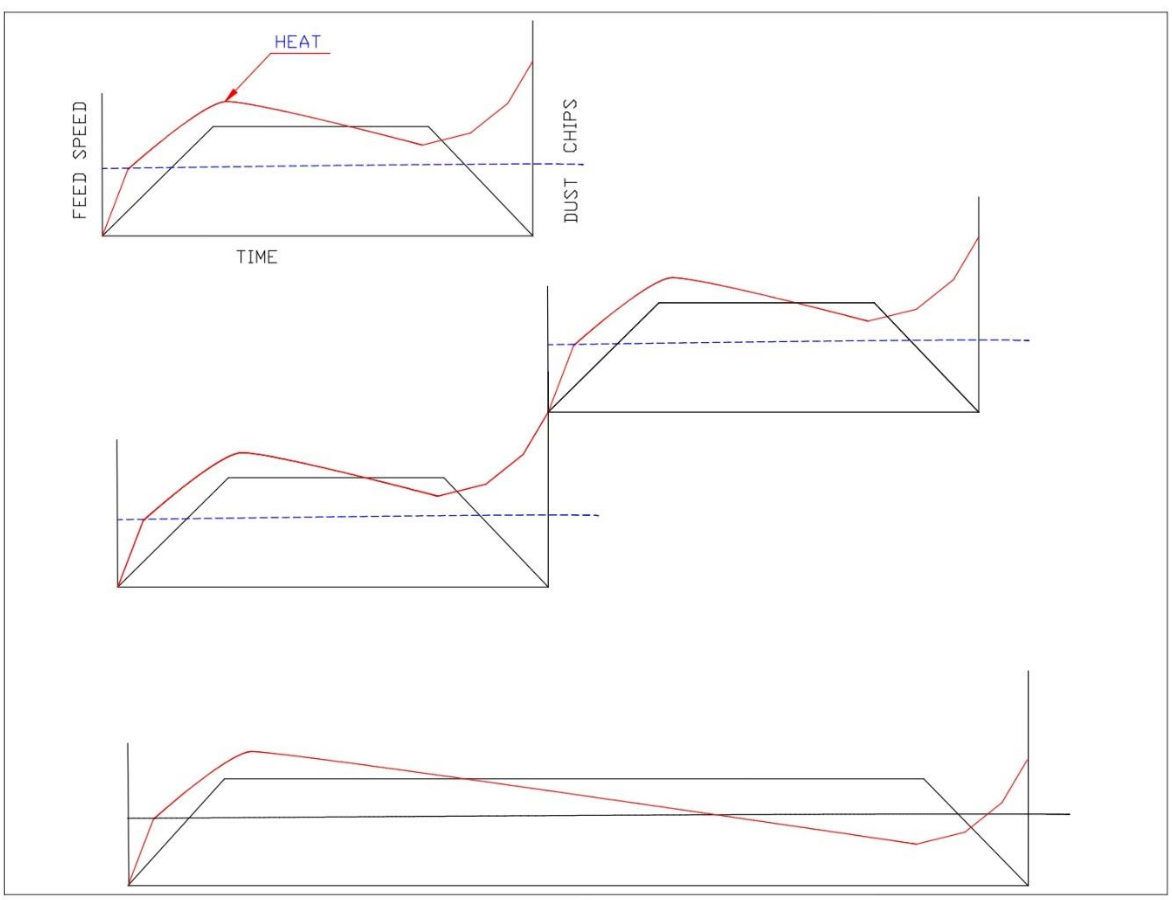
MAKE CHIPS NOT DUST

In metal working and woodworking, chips or shavings carry heat away from the cutting tool. Dust will not carry heat away, and thus, the cutting tool heats up. This will result in shorter tool life at a minimum and, very likely, poor cut quality. This is the opposite of 'conventional wisdom' that says, "high speeds and fine cuts will give the smoothest finish". As a rule of thumb, the thicker the chip, the more heat is removed. There are two reasons for this: first, the greater mass of the thicker chip can carry more heat energy with it; and, second, thicker chips means fewer cuts need to be made for the same amount of material removed, thus generating less heat from friction.

Another factor which must be considered is the quality of the cut. Cut quality is affected by other factors, such as: the physical characteristics of the material being cut, the geometry of the cutting tool and direction of cut (conventional vs. climb cutting). Here we will only concern ourselves with chip size, also known as 'chip load'.

In cutting along a path on the CNC router, the cutting tool will experience a varying chip load, because of the varying travel, or 'feed', speed of the router spindle. In cutting a path, the spindle will start at zero inches per minute, accelerate to the programmed feed speed, and then decelerate back to zero in preparation for a change in direction. The shorter the straight line or arc that the router is cutting, the faster this all happens. For a small, complex pattern the feed speed will rarely get to the programmed value. Thus, the chip load will vary on a continuum from zero to maximum chip load, and thus produce dust as well as chips. The percentage of time that the cutter is producing dust will determine, to a large extent, the amount of heat buildup it experiences.

As the diagrams below show, multiple short cuts will lead to heat buildup, while longer cuts will give chips a longer time to carry heat away from the cutter.



The task then becomes to minimize dust production while maintaining quality of cut. The position of the ‘dust to chips’ line depends on spindle speed and feed rate. A slower spindle speed or a faster feed rate will lower that line.

The maximum practical feed rate is limited by size/complexity of the cut path, power of the spindle, size of router bit, and by the maximum feed rate that a particular CNC router can produce. In non-production scenarios a reasonable value for feed rate is 50% of the maximum for the machine. Faster feed rates put greater force on the router bit (especially problematic for small diameter bits) and a greater load on the spindle (especially with larger diameter bits). The longer acceleration/deceleration times as well as the shorter times between can cause a greater heat buildup in the stepper motors that drive the gantry.

As will be seen from calculations of chip load, spindle speeds at 50% of the maximum for the spindle are rarely needed. The following formula is used to calculate chip load aka cuts per inch:

$$\frac{\text{FEED SPEED}}{\text{SPINDLE SPEED * \# FLUTES}} \qquad \text{Example: } \frac{\text{100 in/min}}{\text{12,000 rpm * 2 flutes}} = 100/24{,}000 = .004'' * .25 = .001''$$

The ‘dust to chips’ line is somewhere around .001” thick chips, which would be 25%of the programmed speed in this example.
100 inches per minute is very fast for small and complex patterns. For spindle speed, I rarely go below 9,000 rpm. The spindle has less power at lower rpm’s and can heat up. For smaller parts, 50 in/min is a better feed speed, but this would raise the line to about 40% of programmed feed rate, and thus, give more time for heat to build up..

$$\frac{\text{FEED SPEED}}{\text{SPINDLE SPEED * \# FLUTES}} \qquad \text{Example: } \frac{\text{50 in/min}}{\text{9,000 rpm * 2 flutes}} = 50/18{,}000 = .0028'' \quad * .4 = .0011''$$

So we see that there is no perfect solution. When quality of cut is factored in, I end up using 40 in/min and 10,000 rpm as my normal starting point. With a 2-flute bit this gives a .002” chip thickness. If I try to exceed .004” chip thickness, the quality of cut suffers.

For ‘production’ work, such as cutting cabinet parts out of particle board or MDF 4’X8’ sheets, I would use 150 in/min and 15,000 spindle speed with a 3/8” 3-flute bit. With a 7.5 hp or larger spindle, I would be cutting through a ¾” sheet in one pass.

$$\frac{\text{FEED SPEED}}{\text{SPINDLE SPEED * \# FLUTES}} \qquad \text{Example: } \frac{\text{150 in/min}}{\text{15,000 rpm * 3 flutes}} = 150/45{,}000 = .003'' \quad \text{Chip Thickness}$$

With a larger spindle 500 in/min would be possible. And a really powerful router could run at 1500 in/min with a spindle speed of 24,000. Obviously, quality of cut is not the primary factor here.

The goal of making chips instead of dust is to minimize heat buildup in the router bit while maintaining an acceptable quality of cut and not overworking the machine itself. That being said, bits get dull and turn dark or blue on the end. Then we throw them away and use a new one. If you are making dust, then be sure to have extra bits on hand.