Calculating Conveyor Speed

A relatively simple formula adds up to PCB processing success.

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f you're an engineer, you've probably experienced the following scenario: You and the engineering vice president of your company are inspecting a new conveyorized process. He or she turns to you and asks, "If we increase the conveyor speed by 2 feet per minute, how many more panels per hour can we get through the line ?" You whip out your calculator and begin to cogitate: "Feet per minute, panels per inch, days per hour . . ." By the time you figure it all out, you've already blown your chances for promotion!

Relating Productivity

As an engineer (or anyone else responsible for a conveyorized process), you're frequently required to translate conveyor speed into productivity. The problem is that conveyor speed is expressed in feet per minute (fpm) and productivity in panels per hour. How do the two relate ?

Without delving too deeply into the applicable algebra, the formula that depicts this relationship is as follows:

$$\frac{P = 7 2 0 * C}{w + d}$$
(1)

where

P = production in panels per hour

C = conveyor speed in fpm

W = panel width in inches

D = distance between panels in inches.

The metric version, for the 95% of the world that still uses this arcane system, doesn't look any cleaner:

$$P = \frac{60,000 * C}{w + d}$$
(2)

where

- P = production in panels per hour
- C = conveyor speed in meters per minute
- w = panel width in millimeters
- d = distance between panels in millimeters.

So, for example, if you had a conveyor speed of 6 fpm, a panel size of 18", and 2" between panels, your production rate would be 216 panels per hour. (Keep in mind that this is an ideal, or maximum, rate.)

If you're feeding pieces (or panels side by side), then Equation 1, the conveyor formula, fails. But imagine that you're feeding columns of pieces (or panels). In this case, calculate the productivity of each column and multiply by the number of columns. The resulting formula would look like this:

$$p = -n .7 \frac{2 \ 0 \ * \ C}{w \ + \ d}$$
(3)

Suppose, for example, you're feeding 8" square boards, spaced 1" apart, two at a time on a conveyor moving 4 fpm. Your production rate would be 640 boards per hour.

Variations on the Theme

Despite its advantages, applying the conveyor formula to numerous different board sizes can be tedious. Another approach is to assume that you're feeding the pieces about as efficiently as you would if they were still in panel form, and to assume that the time for each production lot is therefore about the same. (This scenario is also based on the assumption that each production lot has about the same number of panels.) Obviously, your estimate will only be as accurate as your assumptions are valid.

If you're specifying a new piece of equipment, you may have a productivity figure in mind and need to

calculate the necessary conveyor speed. To do this, solve the conveyor formula for "C", as in:

$$C = P * (w + d) / 720$$
 (4)

The Distance Factor

The distance between panels is the most interesting factor in the conveyor formula. For one thing, it affects productivity. In our first example, a conveyor speed of 6 fpm, a panel size of 18", and a distance between panels of 2" yielded a productivity rate of 216 panels per hour. Suppose you could reduce the distance between panels to 1". This would boost the productivity level to 227 panels per hour, a net gain of 11 panels per hour.

Ideal productivity can be calculated and the effects of down time predicted.

Another feature of "d" is that it changes to accommodate different conveyor speeds. Suppose the conveyor in the first example feeds onto a faster conveyor (i.e., one moving at a speed of 9 fpm). In this case, "d" would increase from 2" to 12". How can you calculate this figure on your own? Solve for "d":

$$\mathbf{d} = (720 * C/P) \cdot \mathbf{w}$$
(5)

An Untrue Truism?

One truism regarding conveyorized processes that's not necessarily true is that a slower conveyor should not follow a faster one because the panels they're carrying will overlap. In fact, this configuration can be used if you regulate the flow of panels onto your first conveyor to match the capacity of your slowest conveyor. How? If your line is manually fed, a practical solution is to begin your series of processes with a short loading conveyor that runs at the same speed as the slowest conveyor. In this case, the operator would be unable to feed panels too quickly for the slowest conveyor to accept them.

If your line is automatically fed, time the feeder to correspond to your slowest conveyor. You can set the feeder by trial and error, or you can calculate the time per panel using the following formula:

$$T = 5 * (w + d) / C$$
 (6)

where

T = time per panel in seconds.

In our first example, T was equal to 16.67 seconds per panel.

Equation 6 has yet another use. Suppose an interval

of down time occurs after a certain quantity of panels moves through the line. If, for instance, five minutes (300 seconds) is spent restocking the feeder every 100 panels, "T" increases by 3 seconds per panel.

How does this affect productivity? The process time of 16.67 seconds per panel plus the feeder restocking time of 3 seconds per panel equals a total time per panel of 19.67 seconds. Since

$$P = 3,600/T,$$
 (7)

a productivity drop from 216 to 183 panels per hour can be calculated.

Don't Underestimate Delays

While we're on the subject of time, be aware of the impact that delaying the panels has on productivity. Say your postage stamp laminator holds a panel for 3 seconds before beginning lamination. If the preceding process runs at 6 fpm, then there must be 3.6" of space between the panels to prevent them from overlapping as they enter the laminator:

$$d = 0.2 * t * C$$
 (8)

where

d = required distance between panels in inches

t = time of delay in seconds

C = conveyor speed in fpm.

Unless you can compensate by increasing the previous conveyor speed to achieve the desired value for "d," this mandated distance between panels decreases productivity. In the case of the automatic laminator, this may be practical. (Use Equation 4.) But suppose you have a tunnel oven that cycles every 45 seconds. How do you guarantee that the panels won't overlap as they wait to be cycled in (and off the conveyor) ? If your infeed conveyor runs at a modest 4 fpm, you have to leave 36 between panels. Increasing the incoming conveyor speed to compensate might be impractical; you may need a staging conveyor of some type.

Final Words on the Formula

So what does it all mean? The productivity of a conveyorized process need not be a vague concept. Ideal productivity can be calculated and the effects of routine down time predicted. Variants of the conveyor formula can also help in designing series of conveyorized processes or fully automated lines. And, last but not least, these relatively simple numbers can save you from some potentially awkward moments over the conveyor line with your engineering vice president!

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