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Gun motion changes follow production changes

by Nick Liberto

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Gun motion changes follow production changes

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A few years ago, you installed an oscillator or reciprocator on your line. The device and the other application equipment worked as expected—for a while. But lately you have had problems: Finishing quality has decreased, and equipment doesn't seem to be working right. To be specific, these are the problems you are seeing:

- *Poor film thickness control*
- *Uncoated areas*
- *Increased manual touch-up*
- *Premature gun wear*
- *Excessive overspray*

If you are like most finishers, you don't suspect that the oscillator or reciprocator is the source of these problems. After all, it is functioning the way it always has. That's just the problem: It is the same, but your production needs have changed. You are probably coating parts with different shapes and dimensions than you were when the gun motion device was installed, and your line speed has probably increased too.

What you need to do is adjust your gun motion device to accommodate these changes. This article will give you the information you need to do this. It starts with a brief overview of the operation of oscillators and reciprocators, the most common gun motion devices used in typical powder coating lines. It then presents the calculations you need to make oscillator and reciprocator adjustments.

Though different in design, and intended to fill different coating requirements, oscillators and reciprocators share a common feature: They move the spray gun(s) in one plane to coat a larger area than a fixed spray gun can. Consequently, their use reduces the number of guns needed to coat an area and creates a more efficient and economical application system.

Oscillator operation

Oscillators are unique among gun motion devices because their stroke and speed are fixed when they are manufactured. Users can adjust the stroke and speed of some oscillators but not while the device is running.

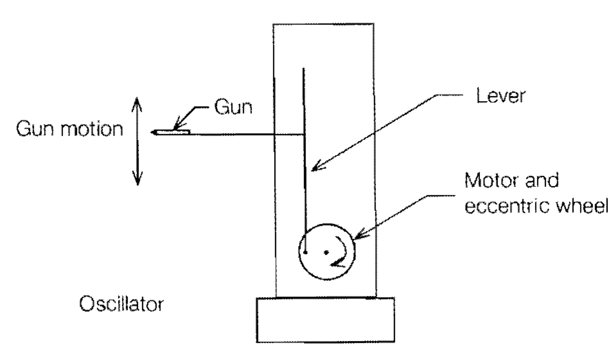
The main components of oscillators are an eccentric wheel and a lever. As Figure 1 illustrates, a motor rotates the eccentric wheel. The lever, attached to the wheel at some distance from the center, translates the rotary motion to a vertical motion. Stroke length is determined by the lever's position at the point it is attached to the eccentric wheel and by the wheel's diameter. Stroke length can be adjusted by locating the lever at different points on the wheel radius. Speed is dictated by the motor and gear reduction devices used in the design. Sometimes clutches, adjustable belt sheaves, or both, are used to provide speed adjustment. Oscillators are available for $2,000 to $8,000.

In recent years, the basic design has been modified to provide similar motion at a reduced cost. Called a Waggler, the new device is designed to move guns by attaching the eccentric wheel to a hinged (pinned) gun mount instead of a moving gun carriage. The hinged gun mount provides an arc-shaped motion at the gun. The length of the arc, and therefore the length of the gun stroke, is limited by the optimum target distance (distance between the gun tip and part) that the gun requires to coat the part effectively. This is because as the arc increases, so does the target distance to the part. Wagglers are available for $2,000 to $4,000.

As long as a finishing operation has enough guns to coat parts of various sizes and maintains a fixed conveyor speed for all parts, either device will fulfill most application needs. If this is not the case, however, reciprocators should be used.

FIGURE 1

Oscillator operation



Reciprocator operation

Reciprocators (Figure 2) use various levels of electronic sophistication to control stroke and speed. In these devices, the mechanical link between the motor and guns is fixed. Therefore, speed and stroke control must be adjusted electrically. These adjustments are sometimes made to the unit itself and sometimes to the control panel. For instance, stroke adjustment can be made by moving electrical limit switches in the unit or by adjusting an electronic feedback loop variable in the control panel. The manufacturer's design determines which is used.

Speed control depends on the type of motor used. In reciprocators that use DC motors, speed is controlled by varying the voltage at the motor. In contrast, units with AC motors use variable speed control circuits. Both speed control systems can be adjusted during operation. This gives reciprocators flexibility over oscillators in coating operations that require different stroke lengths and speeds to coat parts of different sizes.

Reciprocators are useful in powder applications where changes in line speed and part size must be accommodated with fewer spray guns. Their basic design has not been improved in recent years. In fact, the only change has been a cost reduction: Reciprocators now cost $3,000 to $12,000.

System design calculations

When your powder system was designed, the manufacturer used certain equations to determine how much spray equipment the application required. You need to review these equations to understand the effects production changes have on gun motion application. These are the equations you will need to use to modify your oscillator or reciprocator:

- Theoretical coverage
- Application coverage
- Gun calculation based on coverage
- W pattern
- Gun calculation based on W pattern

Determining the number of guns needed, based on coverage. The theoretical coverage of a particular powder is defined as the "capacity of a given mass of that powder to coat, in the cured state, an area of substrate to a determined film thickness."[1] This calculation determines the coating capacity of the powder used in an application under conditions of 100 percent first-pass transfer efficiency (see Table 1).

Since 100 percent first-pass transfer efficiency does not exist in the real world, you must consider the calculation for application coverage. This requires that you estimate the application efficiency of your system in coating a specific part. For example, if you are coating flat, solid (no openings) sheet stock, you can estimate that first-pass transfer efficiency will be relatively high—let's say 75 percent. If, however, you are coating a similar size product that has large openings—a window frame, for example—then you will estimate that first-pass transfer efficiency will be low, perhaps 40 percent. The more realistic you are in determining application efficiency, the more realistic the gun motion design will be.

The next step is to determine how many spray guns you need to coat the part, considering powder coverage only. For this, you will use the formula for gun calculation based on coverage, dividing the area of the parts coated per hour by the gun output at a given application coverage. You will need to estimate the gun output, basing your estimate not only on how much the spray gun can pump out, but on how much it can pump out and still charge the powder effectively without prematurely wearing out.

The answers to these calculations tell you only how many spray guns are required to coat the part, taking only coverage into account. Typically, this number of spray guns is on the low side for a proper application. That is because this calculation gives you only part of the picture: Although gun output allows you to coat the part, the spray pattern size limits how much of the part the powder can reach. To find out how much of the part the powder can reach, you must calculate how many guns are required, based either on gun position or W pattern.

In a fixed gun application, spray pattern size determines how many spray guns are required to coat a particular part. To find out how many guns are needed, divide the part height by the spray pattern diameter. You may discover that you

FIGURE 2

Reciprocator operation

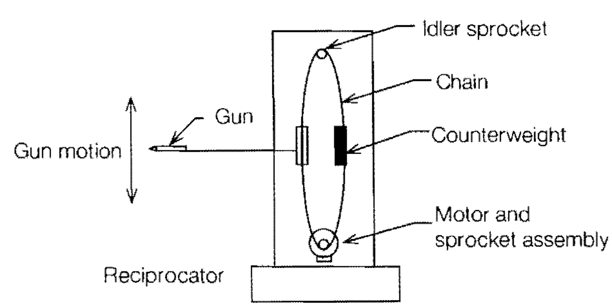


TABLE 1

Number of guns needed, based on coverage

$$\text{Theoretical coverage} = \frac{(192)\ (\text{percent solids})}{(\text{specific gravity})\ (\text{film thickness in mils})}$$

$$\text{Application coverage} = (\text{theoretical coverage})\ (\text{application efficiency})$$

$$\text{Number of guns} = \frac{(\text{number of parts/hour})\ (\text{area of part})}{(\text{application coverage})\ (\text{gun output in pounds/hour})},$$

$$\text{where number of parts/hour} = \frac{\text{conveyor speed (fpm)}}{\text{part spacing (feet)}} \times 60$$

need more guns than you can afford. If so, you may need a gun motion device.

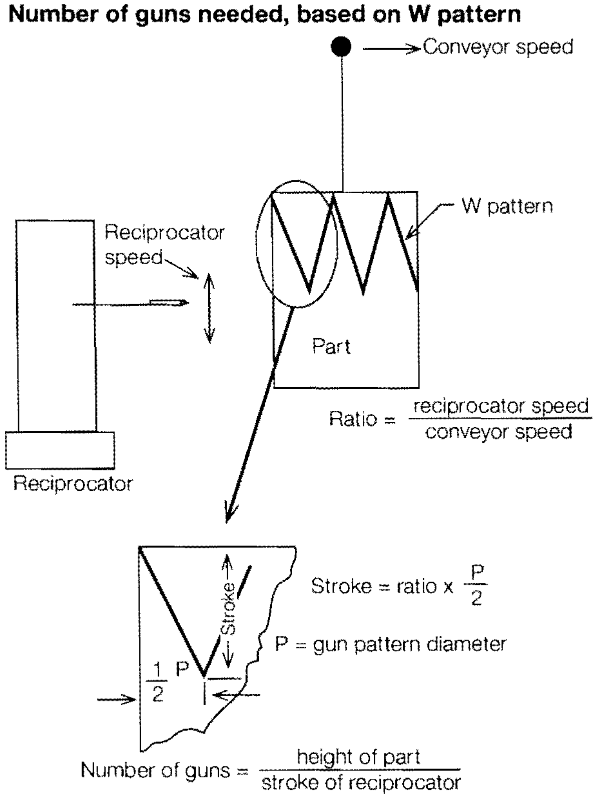
Determining the number of guns needed, based on W pattern. Gun motion devices create a phenomenon called W pattern, named for the shape that the spray pattern creates on the moving part. You must take W pattern into account when determining how many spray guns are required to coat the part. To do this, you first need to calculate the ratio between the speed of the conveyor and the speed of the reciprocator, as shown in Figure 3.

Conveyor speed is usually a fixed, known quantity, based on the production output of the system. Reciprocator speed, in contrast, can be whatever you want, within the design limits of the unit. (The only other factor to consider is how fast the gun can move and still have effective dwell time on the part. If the gun moves too fast, the powder will not be in the electrostatic field long enough to absorb a sufficient charge.) Therefore, when choosing a reciprocator speed, you can make the calculation easier if you choose a speed that is evenly divisible by the conveyor speed. For example, for a 15 fpm conveyor speed, choose a reciprocator speed of 90 fpm.

You will use this ratio to calculate the maximum reciprocator stroke you can set without creating an undesirable W pattern. The reciprocator stroke is a function of the spray pattern diameter and this ratio. Divide the stroke dimensions into the part height to determine how many guns are required to coat the part at a given conveyor and reciprocator speed.

FIGURE 3

Number of guns needed, based on W pattern



An example of determining initial reciprocator speed

You now know that you need a certain number of guns based on your calculations for application coverage, and another number based on your calculations for W pattern. The one to use is the bigger of the two. In most cases, this will be the W pattern answer. To better illustrate this, let's look at an example.

The parameters for this example system are as follows:

- Powder specific gravity = 1.2
- Powder percent solids = 96 percent
- Film thickness desired = 1.5 mils
- Product to be coated = flat sheet steel
- Part size = 4 ft high X 3 ft wide
- Part hanging centers = 4 ft
- Conveyor speed = 15 fpm

You calculate the theoretical coverage to be 102.4 sq ft/lb, as shown in Table 2. Since this is a relatively simple part (no hidden areas or Faraday cages), first-pass transfer efficiency will be high; you assume 75 percent. That yields an application coverage of 76.8 sq ft/lb. Through calculation, you determine that 225 parts per hour will go through the system.

Before you continue, you must determine whether you will calculate the number of guns needed based on the number of guns on one side or both sides of the part. You decide to look at one side only, then double the answer to get the total number of guns required for the system. If, however, you want to look at both sides of the part, you need to calculate the part area to reflect this.

The gun output, which is available from the manufacturer, states that the powder output is up to 80 lb/hr. You decide to use 40 lb/hr for this calculation. Gun calculation based on coverage shows that you require only one gun per side to coat this part with this powder at this line speed. Now you need to determine how you will coat the part. If you use fixed guns with a 6-inch pattern, then the number of guns

TABLE 2

Example using initial design:
Number of guns needed, based on coverage

Theoretical coverage:

$$C_t = \frac{(192)\ (96\%)}{(1.2)\ (1.5)} = 102.4 \text{ sq ft/lb}$$

Application coverage:

$$C_a = (102.4)\ (75\%) = 76.8 \text{ sq ft/lb}$$

Number of guns:

$$\text{Number of parts/hour} = \frac{15}{4} \times 60 = 225$$

$$\text{Number of guns} = \frac{(225)\ (12)}{(76.8)\ (40)} = 1 \text{ gun/side}$$

needed to coat the part is eight guns per side. This will require a much larger spray booth than is desirable, not to mention a hefty budget for guns. Given this, you need to look to reciprocation to provide gun motion to coat the part.

The first thing you need to find out is what reciprocator speed you will use to coat the part. Your manufacturer's product specs say that the reciprocator will run between 15 to 120 fpm. From experience, you know that a gun traveling at 120 fpm will not have enough dwell time to obtain first-pass transfer efficiency of 75 percent. A reciprocator speed of 90 fpm will, however. As Table 3 indicates, using this reciprocator speed, you calculate that the ratio between conveyor speed and reciprocator speed is 6. This yields a reciprocator stroke of 18 inches. Therefore, three guns per side are needed to coat the 4-foot-high part, bringing the number of guns needed in the system to six.

An example of adjusting reciprocation when production requirements change

Now your application needs have changed. The part you are now coating is larger and more complex, and your production rate has increased the line speed. Let's look at how these changes affect the system. For this example, we will examine a situation in which production has increased dramatically. This scenario may seem unlikely because the other system components (washer, dry-off oven, cure oven) would probably require modification to accommodate the new line speed. I feel, however, that this example shows the full effect of large production changes on powder system design. The new coating parameters are as follows:

- Powder specific gravity = 1.2
- Powder percent solids = 96 percent
- Film thickness desired = 1.5 mils
- Product to be coated = steel boxes
- Part size = 5 ft high X 4 ft wide X 1 ft deep
- Part hanging centers = 6 ft
- Conveyor speed = 25 fpm

The theoretical coverage will remain unchanged at 102.4 sq ft/lb (see Table 4). Because the new part is more complex than the old (it has hidden areas and Faraday cages), first-pass transfer efficiency will be lower; you will assume 55 percent. That yields an application coverage of 56.32 sq ft/lb. You calculate that 250 parts per hour will go through the system. Also, you decide that you will look at one side only, then double the answer to determine the total number of guns needed for the system. Gun output remains 40 lb/hr.

Gun calculation based on coverage shows that you require four guns per side to coat this part with this powder at this line speed. Now, as before, you must decide how you will coat the part. If you use fixed guns with a 6-inch pattern, then 10 guns per side are required to coat this box, plus additional guns for the top and bottom. Assuming the sides will be coated by electrostatic wrap, two guns will be needed for the top and two for the bottom, bringing the total to 24 guns. Obviously, you will require a much larger spray booth than you have at your facility and a much bigger budget for guns.

You now must look at the effects these changes have made on reciprocation. You need to decide if the reciprocator speed should be increased to coat the new part. The manufacturer's specs say the unit will run between 15 to 120 fpm. Based on your experience, you select a reciprocator speed of 100 fpm. As shown in Table 5, using this speed, you determine that the ratio between conveyor speed and reciprocator speed is 4. This yields a reciprocator stroke of 12 inches. Therefore, five guns per side are needed to coat the new part, along with two guns for the top and two for the bottom. This brings the total number of guns to 14.

TABLE 4

Example using changed design:
Number of guns needed, based on coverage

Theoretical coverage:

$$C_t = \frac{(192)\ (96\%)}{(1.2)\ (1.5)} = 102.4 \text{ sq ft/lb}$$

Application coverage:

$$C_a = (102.4)\ (55\%) = 56.32 \text{ sq ft/lb}$$

Number of guns:

$$\text{Number of parts/hour} = \frac{25}{6} \times 60 = 250$$

$$\text{Number of guns} = \frac{(250)\ (29)}{(56.32)\ (40)} = 4 \text{ guns/side}$$

TABLE 3

Example using initial design:
Number of guns needed, based on W pattern

$$\text{Ratio} = \frac{90}{15} = 6$$

$$\text{Reciprocator stroke} = 6 \times \frac{6}{2} = 18 \text{ in}$$

$$\text{Number of guns} = \frac{48}{18} = 3 \text{ guns/side}$$

TABLE 5

Example using changed design:
Number of guns needed, based on W pattern

$$\text{Ratio} = \frac{100}{25} = 4$$

$$\text{Reciprocator stroke} = 4 \times \frac{6}{2} = 12 \text{ in}$$

$$\text{Number of guns} = \frac{48}{12} = 5 \text{ guns/side}$$

Summary

This example shows that coating this part, which has dramatically different production requirements than the old one did, will require an increase in reciprocation speed and additional guns. If these changes are not made when the new part is introduced, the results will be all or some of the following:

- Poor film thickness control across the entire part surface: This condition is caused by the W pattern becoming too wide for the powder gun spray pattern. When this is the case, you will also find that the new part cannot be coated adequately without the addition of fixed guns.

- Uncoated areas on the part: If the W pattern gets too wide for the powder gun spray pattern, some areas of the part will not be coated at all.

- Unrealistic amounts of manual reinforcement required to coat the part: Often, the first response to production changes of this sort is to increase the amount of manual touch-up. This is done in an effort to coat the areas that the automatic guns on the motion device used to coat but aren't coating anymore. This only makes coverage worse, however, because the quality of manual touch-up is usually inconsistent. Also, touch-up quality is often further compromised when line speed is increased because operators are unable to keep up with the line.

- Prematurely worn out guns created by excessive powder output: The second response to increased production is to increase gun output in an attempt to coat more area in a given amount of time. This takes its toll on spray gun life.

- Creation of excessive amounts of overspray as a result of low transfer efficiency: This happens when gun output is increased beyond the optimum first-pass transfer efficiency, proving that more is not always better. If so much overspray is produced that the recovery system cannot handle it efficiently, it will end up as scrap rather than as reclaimed powder. This isn't just inefficient, it's expensive. **PC**

Endnotes

1. *Technical brief #8.* (Alexandria, Va.: Powder Coating Institute, 1989).

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