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Lean, Mean Finishing Machines

How effective equipment usage and line management systems can help eliminate—or significantly reduce—the most common sources of waste.

Lean manufacturing is widely bandied about in manufacturing circles today, but what is it and how does it apply to metal finishing?

In its simplest definition, lean manufacturing is a philosophy to reduce and eliminate waste. Although there are differing opinions as to the number of waste sources, there is broad agreement on at least seven types of waste. These are as follows:

1. Overproduction—making more than needed;
2. waiting—work in process inventory sitting or people waiting for materials;
3. transportation—moving material further than needed;
4. non-value-added processing—stand-alone processes;
5. excess inventory—having more than minimally required;
6. defects—scrap and rework costs;
7. and excess motion—people moving more than minimally required.

In traditional manufacturing, specific operations are done in batches. Each process step will place the parts they produce in work-in-process (WIP) inventory, which buffers that stage from the next downstream operation. The inventory buffers make each stage independent of upstream or downstream processes. If stage one in the process experiences downtime, stage two can continue working on its batch of parts.

Cellular manufacturing is a method of designing and organizing workplaces to incorporate lean manufacturing principles. Manual and automatic machine operations are linked to minimize and reduce the seven types of waste. In lean cells, product flows at the demand of the customer. The panacea of many lean practitioners is one-piece flow, also known as single-piece flow. This is the practice of moving one piece at a time through manufacturing operations.

This is all well and good, but how does this apply to metal finishing?

LEAN FINISHING CELL DESIGN

Cellular finishing system design begins with the formation of part families. Part families are typically organized by the size of products—dimensions and weights. For example, a lean cell might be designed to finish a broad range of products for Company XYZ that fit within a nine-in. wide x nine-in. deep x two-ft. high cube and weigh from a few ounces to 10 pounds.

Figure 1: COE lean liquid cell with one part per fixture on eight-in. centers.

The manual and automatic process finish steps are typically linked by a through-process continuous conveyor. Although there are many types of conveyance systems available, most lean finishing cells incorporate either a chain-on-edge (COE) or overhead enclosed track power conveyor (see Figures 1 and 2). The determining factor is usually the part family characteristics. Chain-on-edge conveyors are typically limited to a lower profile part size of not more than 30 inches high (three cubic feet maximum geometrically) and a part weight typically at or below 20 pounds each. Overhead enclosed-track conveyors are used for higher profile (taller) and/or heavier parts.

In our example product family for Company XYZ (nine-in. wide x nine-in. deep x two-ft. high product, up to 10 pounds), a chain-on-edge continuous conveyor is ideal. The chain-on-edge conveyor will be at a comfortable elevation for loading and unloading finished parts (typically 30 in.). Parts are fixtured onto rotator bases and spindles that are usually designed to accommodate a wide range of parts within the product family. These fixtures are affixed to the chain-on-edge conveyor on predetermined space intervals. In our example product family, we will assume that fixtures are installed at a rate of one fixture for every 12 in. of chain-on-edge conveyor, and that each fixture will hold one part.

Once the part family and conveyance type is established, the next finishing cell system design consideration is what demand rate is needed

Figure 2: COE lean powder cell with four parts per fixture on 12-in. centers.

to finish parts within the family. This demand rate is also known as the "takt time" and is derived by dividing the work time available by the number of units required. This takt time is often referred to as the heartbeat of the system. Continuing our example, let's assume Company XYZ needs to finish 2,100 parts per shift within our example product family (nine-in. wide x nine-in. deep x two-ft. high product, up to 10 pounds). This manufacturer plans to have an uptime of seven hours per shift. The takt time is shown in Figure 3.

$$\text{Takt time} = \frac{(7\text{ hr./shift}) * (60\text{ min./hr.}) * (60\text{ sec./min.})}{2{,}100\text{ parts/shift}}$$

$$\text{Takt time} = 12\text{ sec./part}$$

Figure 3

The combination of the part-to-part fixture centers, the parts per fixture density, and the takt time enables us to determine the line speed of the chain-on-edge (COE) conveyor in Figure 4.

$$\text{COE line speed} = \frac{(\text{fixture/1 part}) * (12\text{ in./fixture}) * (\text{ft./12 in.})}{(12\text{ sec./part}) * (1\text{ min./60 sec.})}$$

$$\text{COE line speed} = \frac{(1\text{ ft./part})}{(1\text{ min./5 parts})} = 5\text{ ft. per min.}$$

Figure 4

The next consideration is what coating or series of coatings needs to be applied to the parts. Most metal parts will be finished with a single application of either a liquid coating or a powder coating, but there are several products that require multiple coating applications in differing combinations of liquid and/or powder coatings. Examples include liquid primers with liquid topcoats, liquid primers with nylon or Teflon powder topcoats, and powder primers with powder topcoats. As an example, a green stripe is being applied to red painted machined parts in Figure 5.

The spray application booths are designed to permit through passage of the continuous conveyor type. Liquid booths and powder booths will differ in their filtration media

Figure 5: Some products require multiple coating applications in differing combinations.

and exhaust discharge points so they cannot be co-mingled. Frequently it will make economic sense to reclaim overspray coatings.

The coatings might be manually applied in the booths, or the booths might be automated and contain automatic guns, automatic gun movers, and other automated features. Figure 6 shows an overhead enclosed-track lean powder cell with a gun mover and an automatic powder gun.

Continuing with our example, Company XYZ wishes to automatically apply and reclaim a black TGIC powder at two to three mils thickness. Photo-eye sensors outside of the spray booth detect the presence and height of parts on fixtures. As the parts progress into the cartridge-style powder booth, a variable speed rotator will engage the fixture base to spin the parts. The powder guns, as needed, will automatically trigger as the parts are presented. Overspray powder will be captured and

Figure 6: Lean powder cell with automatic gun and gun mover.

reclaimed via the powder booth's fluidized hopper base (see Figure 7).

The next lean finishing cell design consideration is what type of oven is most appropriate to cure the liquid or powder coating onto the parts. In selecting the oven, the objectives are to apply the right oven technology that achieves a consistent and repeatable cure while minimizing the cure time. For example, a convection oven might require 30 minutes residence time to cure the powder on Company XYZ's parts. It would have to be sized to enclose 150 feet of chain-on-edge conveyor (30 minutes

Figure 7: COE lean cell powder booth with automatic guns and powder reclaim.

at five foot per minute line speed). An infrared oven (IR) might cure the powder on Company XYZ's parts in four minutes (see Figure 8). It would only need to be 20 feet long (four minutes at five-foot-per-minute line speed). The lean finishing cell with the smaller oven will cost less, use less energy, have a smaller footprint, and have a shorter cycle time.

There are no limits to the types of oven technologies that can be incorporated into a lean finishing cell. In addition to convection and IR ovens, combination ovens [convection (Figure 9) and IR] and UV-cure ovens are utilized as appropriate.

Figure 8: A 100-pound powder coated part curing in a lean cell IR oven.

Figure 9: COE liquid cell with convection oven for heat-sensitive substrate.

Care needs to be taken to safely cool the parts exiting the oven prior to unloading "finished" products from the lean cell. As a rule of thumb, parts need to be at a temperature below 120°F to safely unload them without personal protective equipment. Company XYZ's powder coated parts will exit the IR oven at approximately 400°F. Cured parts may be quickly cooled by using high-volume fans to move ambient plant air over the hot parts. Figure 10 shows a lean cell with integral cooling fans.

Figure 10: COE lean powder cell cooling section.

LEAN FINISHING CELL BENEFITS

Lean finishing cells exhibit extreme functionality in a compact footprint. They have the flexibility to finish a wide variety of parts within a product family and can efficiently finish either high or low volumes of parts. Right-sized lean finishing cells occupy a small floor space, and their acquisition and operating costs are a fraction of traditional batch or in-line finishing systems.

Let's examine a completed lean finishing cell (Figures 11 and 12) for powder coating Company XYZ's

Figure 11: Deimco Lean Powder COE Finishing Cell at run-off.

parts. An operator will load parts up to nine in. wide x nine-in. deep x two-ft. high onto a fixture on the variable speed chain-on-edge conveyor. As the products enter the powder booth, the parts are automatically powder

Figure 12: Lean cell with manual spray powder booth.

coated and the overspray recaptured. After coating, parts will exit the powder booth and enter an IR curing oven. Four minutes residence time is provided at the design line speed of five foot per minute. Upon exiting the IR oven, the parts will be cooled to room temperature before returning to the load/unload station. (Table I demonstrates the features and benefits of Deimco's lean manufacturing cell for Company XYZ.)

Finishing cells incorporating overhead enclosed track conveyors exhibit many similar features and benefits.

How do the lean finishing cells minimize and reduce the seven types of waste?

1. Overproduction—lean finishing cells efficiently produce to demand whether a single piece or high volume is needed;
2. waiting—the line is only staffed when operating, there are no idle WIP buffers;
3. transportation—parts travel less than 100 ft. on most cells;
4. non-value-added processing—all finishing processes are linked;
5. excess inventory—is eliminated as the cells can quickly finish what is needed;
6. defects—quality feedback is immediate, cells exhibit high process capabilities; and
7. excess motion—one operator is used to run the line and to load/unload parts.

The pressures of quick service and cost competitiveness are real in the finishing departments of most manufacturing firms. Lean finishing cells eliminate and reduce the seven types of waste, which lead to reduced costs, shorter lead times, improved customer service, and greater production capacity.

For more information, contact the author at (phone) 6410484-8806 or (fax) 641-484-8807.

Table I: Company XYZ Lean Powder Cell Features and Benefits

Characteristics	Cell Result
Part travel distance	< 75 feet
Takt time	12 seconds/part
Total cycle time	< 15 minutes
Total footprint	~ 150 square feet
Equipment acquisition cost	~ $100,000
Labor cost	1 operator
Utility cost	Low