ISSUES IN IMPLEMENTING SYSTEMS FOR QUALITY IMPROVEMENT IN A JOB SHOP

M. Bhasi

The Quality Management revolution is on; all firms are focusing on quality. Job shops do not want to be left behind in their efforts to implement programs for quality improvement. Quality management systems are very advanced in continuous and batch manufacturing plants. Statistical quality and process control techniques, inspection and measurement used in these industries are highly standardized. They have also successfully implemented programs for ISO 9000, TPM and six-sigma.

However, job shops are very different from the two types of manufacturing set-ups mentioned above because of the nature and variety of the jobs they do, the general facilities they have, and the way they are run. Implementing the quality improvement plans mentioned earlier present a different set of problems in the Job shop. In this paper I have dealt with some of the quality system implementation problems in a Powder Coating Job shop.

1.0 Introduction

Quality improvement provides organizations with significant opportunities to reduce costs, increase sales, provide on-time deliveries and foster better customer relationships. In manufacturing setups for mass production such as continuous and batch manufacturing environment, advanced techniques for improvement of quality are in use. However a significant amount of manufacturing and service still gets done in a Job shop environment. The large variety of jobs that come in and the small batch size, if in batches, make quality improvement in Job shops a challenge of a different kind. Efforts for quality improvement in products are focused either on design improvement or manufacturing improvement. The approaches for design improvement of products in Job shop production should focus more on simplification and standardization. Except for the focus, the tools and processes used for design improvement are more or less the same in the Job shop environment.

2.0 Quality improvement in Job shops

In the continuous and batch manufacturing environment, quality approaches have long since changed from product inspection to process control. This change has led to a great increase in quality and a reduction in defects. Implementing such a program in the Job shop environment presents a different and more complicated challenge because of the large variety of jobs handled and their low numbers in each lot. The machines, tools, jigs, fixtures and processes in use in Job shops are general or multipurpose and flexible. Making these do tight tolerance jobs is a challenge. Problems arise due to the following reasons:

- The effect of frequent changes in set up and the time needed to run in and become steady
- The effect of the previous job and its residue in the system
- The effect of very small batches, or even single item jobs where there is almost no scope to do a defective job.
- The lack of past data on which to base decisions on set-up and processing for determination of product related machine settings

The quality systems that are easier to implement in this environment are those related to standardization, execution and monitoring of the workflow and quality checks in Job shop

Dr. M. Bhasi is a Professor in School of Management Studies, Cochin University of Science and Technology, Kochi

systems. These systems help in improving the flow of work in the Job shop and assign responsibility of flow control and actions during manufacturing and delivery. These systems lead to productivity improvements and reduction of instances of complaints due to loss of flow and control. The level of preparedness in the organization for all possible outcomes is also better. This certainly improves quality indirectly.

The points discussed above are further elaborated and discussed using the case of a Job shop doing powder coating work.

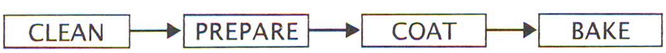
3.0 A Powder coating Job Shop

Powder coating is by far the youngest of the surface finishing techniques in common use today. Powder coating is the technique of applying dry paint to a part. The final cured coating is the same as a 2-pack wet paint. In normal wet painting such as house paints, the solids are in suspension in a liquid carrier, which must evaporate before the solid paint coating is produced. In powder coating, the powdered paint may be applied by either of the techniques described below

- The item is lowered into a fluidized bed of the powder, which may or may not be electro-statically charged
- The powdered paint is electro-statically charged and sprayed onto the part.

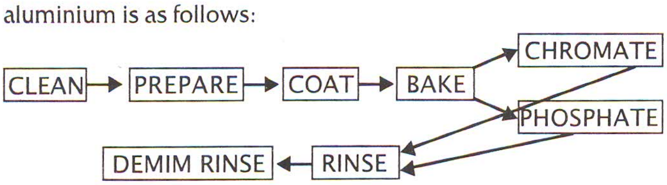
The part is then placed in an oven and the powder particles melt and coalesce to form a continuous film. There are two main types of powder available to the surface finisher:

- Thermoplastic powders that will re-melt when heated
- Thermosetting powders that will not re-melt upon reheating. During the curing process (in the oven) a chemical cross-linking reaction is triggered at the curing temperature, and it is this chemical reaction which gives the powder coating many of its desirable properties. The process is shown below.



3.1 Preparation

The basis of any good coating is preparation. The vast majority of powder coating failures can be traced to careless preparation. The preparation treatment is different for different materials. In general, for all applications the preparation treatment for aluminium is as follows:



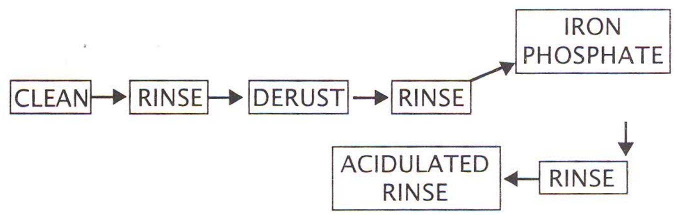
Oils and greases are removed in weak alkali or neutral detergent solutions and the surface is etched to remove heavy oxides. After rinsing, the aluminum is dipped into a chromate or phosphate solution to form a conversion coating on the aluminum. This film is chemically attached to the aluminum. After rinsing, the aluminum is finally rinsed in dematerialized water. Some non-chrome, dried-in-place pretreatment is available in the market; however these are not recommended for exterior applications.

The conversion coating has two functions:

- It presents a surface to the powder which favors adhesion more than the oxides that form very readily on aluminum surfaces.
- It reduces the incidence of under film corrosion, which may occur at holidays in the coating.

The use of dematerialized water reduces the presence of chemical salts on the aluminum surface. These salts have been found to cause filiform corrosion in humid conditions.

For steel, the preparation for interior applications may be:



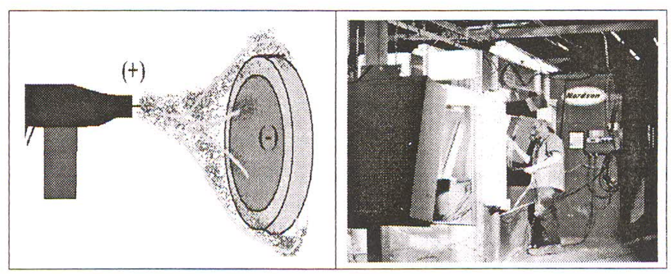


Figure 1 Schematic Diagram of electrostatic spray gun and a spray booth picture

The powder is applied with an electrostatic spray gun to a part that is at earth (or ground) potential. Before the powder is sent to the gun it is fluidized for the following reasons:

- to separate the individual grains of powder and so improve the electrostatic charge that can be applied to the powder
- to allow the powder to flow more easily to the gun.

Because the powder particles are electrostatically charged, the powder adheres to the back of the part as it passes by towards the air offtake system. By collecting the powder which passes by, and filtering it, the efficiency of the process can be increased to 95% material usage. The powder will remain attached to the part as long as some of the electrostatic charge remains on the powder. To obtain the final tough, abrasion resistant coating, the powder coated items are placed in an oven and heated to temperatures that range from 160 to 210 degrees C (depending on the powder). Under the influence of heat, a thermosetting powder goes through 4 stages to full cure.

MELT → FLOW → GEL → CURE

The final coating is continuous and will vary from high gloss to flat matt depending on the variety of powder supplied.

3.2 Powder coating guns

There are at least three types of electrostatic guns in use:

- Corona charging guns where electric power is used to generate the electrostatic charge. Corona guns are either internal or external charging.
- Tribo charging guns where the electrostatic charge is generated by friction between the powder and the gun barrel.
- "Bell" charging guns where the powder is charged by being "flung" from the perimeter of the "bell"

Not all powder is applied using guns. There are systems that make use of electrostatic tunnels.

3.3 How is colour introduced?

Colour is added to powder coatings during the manufacturing process, ie before the powder reaches the powder coater. There is little that can be done to change the colour consistently, once the powder leaves the manufacturing plant.

3.4 Why powder coat?

Powder coating produces a high specification coating, which is relatively hard, abrasion resistant (depending on the specification) and tough. Thin powder coatings can be bent but this is not recommended for exterior applications. The choice of colours and finishes is almost limitless, if you have the time and money to spend on a made-to-order powder.

Powder coatings can be applied over a wide range of thicknesses. A coating of a minimum thickness of 25 micron is necessary for mild interior applications and a thickness of up to 60 micron minimum is recommended for exterior applications. Care must be exercised when quoting minimum thickness because some powders will not give "coverage" below 60 or even 80 micron. "Coverage" is the ability to cover the colour of the metal with the powder. Some of the white colours require about 75 micron to give full "coverage". One of the orange colours must be applied at 80 micron. Colour matching is quite acceptable batch to batch. The important reasons for choosing powder coating are given below.

1. Powder coatings emit zero or near zero volatile organic compounds (VOC).
2. Powder coatings can produce much thicker coatings when compared to conventional liquid coatings, without running or sagging.
3. Powder coating overspray can be recycled and thus it is possible to achieve nearly 100% use of the coating.
4. Powder coating production lines produce less hazardous waste than conventional liquid coatings.
5. Capital equipment and operating costs for a powder line are generally less than for conventional liquid lines.
6. Powder coated items generally have fewer appearance differences between horizontally coated surfaces and vertically coated surfaces than liquid coated items.
7. A wide range of specialty effects is easily accomplished, that would otherwise be impossible to achieve with other coating processes.

3.5 Installations and maintenance

During installations, the powder coating should be protected from damage due to abrasion and materials of construction such as mortar and brick cleaning chemicals.

Once installed, maintaining the initial appearance of a powder coating is a simple matter. The soot and grime, which builds up on surfaces from time to time, contains moisture and salts which will adversely affect the powder coating and must be removed. Powder coatings should be washed down regularly (at least once every 6 months in less severe applications, and more often in marine and industrial environments). The coating should be washed down with soapy water — use a neutral detergent — and rinsed off with clean water.

When powder coated items are installed without damage to the powder coating and they are maintained regularly, they should be relatively permanent. The correctly applied coating, although not metallurgically bonded to the metal will not crack, chip or peel as with conventional paint films.

4.0 Quality Improvement in Powder coating Job Shop

In today's metal finishing industry, quality and efficiency are of equal value to the customer. Quality is important for obvious reasons; efficiency is desired because it keeps prices down and results in short lead-times for customers. The finishing process typically is the final operation before shipment, so the process must be flexible and reactive. Orders often must be coated and shipped the same day, so scheduling, efficiency, and quality are critical. Reworking is not an option, and time is of the essence.

Best Coaters Ltd—a powder coating job shop—has organized its powder coating operations into control points to help regulate quality and efficiency as parts move through this finishing process. It also uses test strips, which are processed along with the jobs and subjected to more detailed destructive tests to control the process.

4.1 Pretreatment

The first control point is pretreatment during the cleaning process, which involves a six-stage parts washer. The washer must be controlled within the parameters specified by the chemical supplier to ensure adhesion of powder to metal, so the machine is monitored every two to three hours. Four of the six stages incorporate V-jet nozzles to help maximize the directional pressure of the spray patterns. The third stage, phosphatizing, contains hollow cone nozzles for a flooding action that promotes high-phosphate coating weights. Phosphate acts like a primer—it adheres powder to metal. The sixth stage incorporates misting nozzles for the light rinsing.

De-ionized water mist is used for a final rinse in the sixth stage. By removing the particulates of hard water, this rinse reduces the dissolved solids remaining on the parts before they are dried. A dissolved-solids meter helps keep solids levels at less than 10 parts per million. The drain water is relatively pure and is recycled back to stage two: another rinse stage.

4.2 Paint Booth

A second control point in the powder coating process is the paint booth itself, where painters apply the powder manually. Control at this stage is difficult because of the possibility of human error. Theories abound for controlling quality in a manual paint booth, but painter training seems to be the key. Application equipment continues to advance, and operators must be familiar with the principles of electrostatic attraction. When changing colors, they must know what is needed to eliminate even the slightest potential for contamination.

Methods for eliminating contamination include cleaning all gun parts with compressed air, vacuuming all powder from the walls and floor, and keeping the outside area of the booth clean at all times. A lead painter, one who has been coating parts for at least one year, trains new painters to clean with utmost quality and efficiency.

In addition, the company rotates painters every two weeks to keep people fresh in the booth. The painters are held accountable for their work; as a result, they check their work frequently by stopping the line and ensuring there is full, consistent coverage on each part. Occasionally, the supervisor will spot-check parts while the line is running. An extra set of eyes is key to controlling quality of parts exiting the booth.

4.3 Baking Oven

When a thermosetting powder is exposed to elevated temperature, it begins to melt, flows out, and then chemically reacts to form a higher molecular weight polymer in a network-like structure. This cure process, called crosslinking, requires a certain degree of temperature for a certain length of time in order to reach full cure and establish the full film properties for which the material was designed. Normally the powders cure at 200□ C (390□ F) in 15 minutes. The curing schedule could vary according to the manufacturer's specifications.

The oven cycle time comprises of the bring-up time plus the dwell time for a proper powder cure. The bring-up time is the time required to attain the desired substrate cure temperature of the part. The dwell time is the time required to hold the substrate at cure temperature. These times and temperatures are available from the cure schedule for the powder coating. In some applications, shorter oven cycle times are possible by rapidly heating the substrate to a higher cure temperature for a shorter dwell time. The main controls have to be applied here to check whether the required temperature is maintained in all parts of the oven and secondly if the material remains in the furnace for the specified time.

4.4 Final Inspection

The final control point is inspection. A designated inspector is responsible for completing a visual and physical check of the parts for each job that is coated. An inspection report containing information such as paint thickness, adhesion test results, and cure test results is included with every job. A thickness gauge with portable probe is used to check paint thickness.

In addition, a six-point cross-hatch blade is used to scribe an X to create small squares in the paint. After scribing, the operator applies a piece of Permacel® tape over the squares and lifts it quickly to determine if adhesion passes or fails. Proper curing of paint to substrate occurs when parts are heated to a specified temperature—usually 375 to 400 degrees F—and held at that temperature for 15 to 20 minutes. Methyl ethyl ketone (MEK) is used to check curing of the powder to substrate. A swab is dipped in MEK and rubbed on the paint 30 to 40 times in a rapid back-and-forth motion.

If the swab is generally free of paint (or contains very little), the paint is cured and passes the test. If the swab softens the paint and rubs to bare metal, the paint is not cured. A gloss meter also is used to measure gloss levels at 20- or 60-degree angles.

4.5 Conclusion and Tips for Efficiency

From an efficiency standpoint, line density is critical. The company manufactured racking for the finishing operation. This allows high-quantity runs to be hung densely on the line to help increase throughput. For this company's operations, the racking design was the most efficient way to hang parts with the least amount of effort.

The company's customer product line is diverse, and so are the colors applied during powder coating. As a result, color change time affects both quality and efficiency. Not only must a color change be thorough enough to prevent contamination, but it must also be completed on time.

To assist in color change, the company uses a pneumatic vacuum designed for dust collection. The high level of suction allows painters to clean spray-to-waste material quickly to prepare for the next color. A mild color change (gray to white) takes about 15 minutes. A major change (blue to white) takes about 20 to 25 minutes.

In addition, parts hangers leave a slight gap in the line to accommodate the color change. This gap acts as a timer for the painters to accomplish the color change.

Finishing plays a vital role in many fabricating and stamping operations. Finding methods to improve efficiency and quality can only add to customer satisfaction. From the paper it can be seen that the focus on quality improvement is directed towards the process in general and the specifications mentioned by suppliers of the coating powder are adhered to. Since it is very difficult to make product shape and size-wise process settings, this is rarely attempted.

References:

1. Adam, E., 1994. Alternative quality improvement practices and organisation performance. *Journal of Operations Management 12, 27–44.*
2. Adam, E., Corbett, L., Flores, B., Harrison, N., Lee, T., Rho, B., Ribera, J., Samson, D., Westbrook, R., 1997. An international study of quality improvement approach and firm performance. *International Journal of Operations and Production Management 9 (17), 842–873.*
3. Ahire, S., Landeros, R., Golhar, D., 1995. Total quality management: a literature review and an agenda for future research. *Production and Operations Management, 277–307.*
4. Anderson, J., Rungtusanatham, M., Schroeder, R., 1994. A theory of quality management underlying the Deming management method. *Academy of Management Review 19 (3), 472–509.*
5. Barclay, C., 1993. Quality strategy and TQM policies: empirical evidence. *Management International Review, (1), 87–98.*
6. Choi, T., Eboch, K., 1998. The TQM paradox: relations among TQM practices, plant performance, and customer satisfaction. *Journal of Operations Management 17, 59–75.*
7. Davis, T., 1997. Breakdowns in total quality management: an analysis with recommendations. *International Journal of Management 14 (1), 13–22.*
8. Dawson, P., 1995. Implementing quality management: some general lessons on managing change. *Asia Pacific Journal of Quality Management 4 (1), 35–46.*
9. Dow, D., Samson, D., Ford, S., 1999. Exploding the myth: do all quality management practices contribute to superior quality performance? *Production and Operations Management 8 (1), 1–27.*
10. Garvin, D., 1984. What does product quality really mean? *Sloan Management Review, 25–43.*
11. Garvin, D., 1987. Competing on the eight dimensions of quality. *Harvard Business Review 65, 202–209.*
12. Hackman, J., Wageman, R., 1995. Total quality management: empirical, conceptual, and practical issues. *Administrative Science Quarterly 40, 309–342.*
13. Instone, F., Dale, B., 1989. A case study of the typical issues involved in quality improvement. *International Journal of Operations and Production Management 9 (1), 15–26.*
14. Juran, J., 1988. *Quality Control Handbook. McGraw-Hill, New York.*
15. Karmarkar, U., Pitbladdo, R., 1997. Quality, class, and competition. *Management Science 43 (1), 27–39.*
16. Kekre, S., Murthi B., Srinivasan, 1995. Operating decisions, supplier availability and quality: an empirical study. *Journal of Operations Management 12, 387–396.*
17. Kolesar, P., 1995. Partial quality management: an essay. *Production and Operations Management 4 (3), 195–200.*
18. Maani, K., 1989. Productivity and profitability through quality—myth and reality. *International Journal of Quality and Reliability/Management 6 (3), 11–23.*
19. Maani, K., Putterill, M., Sluti, D., 1994. Empirical analysis of quality improvement in manufacturing. *International Journal of Quality and Reliability Management 11 (7), 19–37.*
20. Oakland, J., Sohal, A., 1987. Production management techniques in UK manufacturing industry: usage and barriers to

acceptance. *International Journal of Operations and Production Management 7 (1), 8–37.*

21. Reger, R., Gustafson, L., Demarie, S., Mullane, J., 1994. Reframing the organisation: why implementing total quality is easier said than done. *Academy of Management Review 19 (3), 565–584.*

22. Samson, D., Terziovski, M., 1999. The relationship between total quality management practices and operational performance. *Journal of Operations Management 17 (4), 393–409.*

23. Sluti, D., Maani, K., Putterill, M., 1995. Empirical analysisof quality improvement in manufacturing: survey instrumentdevelopment and preliminary results. *Asia Pacific Journal of Quality Management 4 (1), 47–72.*

24. Spencer, B., 1994. Models of organisation and total qualitymanagement: a comparison and critical evaluation. *AcademyofManagement Review 19 (3), 446–471.*

25. White, G., 1996. A meta-analysis model of manufacturing capabilities. *Journal of Operations Management 14, 315–331.*

26. Yusof, S., Aspinwall, E., 2000. TQM implementation issues: review and case study. *International Journal of Operations and Production Management 20 (6), 634–655.*

Websites:

1. http://en.wikipedia.org/wiki/Powder_coating
2. http://www.powdercoating.org/industry/faq.htm