Development of Automated Spray-Painting System for Anti-Static Coating Process

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Abstract. This paper is presented to document a development process of automated system for the spray-painting process and for the purpose of advantage of implementation of automation to the production line instead of manual spray process and know-how of thickness control when applying three spray guns compared to single gun as normally implemented in automated spraying system. Three spraying could reduce the process time to spray the workpieces, in this case, is airplane wing’s parts built from composite material. But these three guns automation system comes with challenging tasks in order to find an even thickness of overlapping spray pattern coming from these three separated guns. Ultimately, various studies on atomization parameters and other factors resulted in successful mass production.

1. Introduction

Spray painting process has been widely used in painting and coating applications, where the paint or coating liquid is atomized and flown to deposit on the target surface (workpiece). In this study, the workpiece is a composite part uses in making airplane wings. From manual spraying process, the gantry type automation system is developed to counter inconsistency in painting thickness, to increase productivity and for the environmental and health issue of manual painting to the painters. This Automation Spray Painting System or in-short, ASPS is consists of three spray guns located on three-axis gantry type carrier and moved in X, Y and Z-axis powered by three electrical motor. Spray gun is type HVMP (High Volume Medium Pressure) by De VILBISS. Mixture solution supplies to the spray gun are transferred by a pressurized tank to ensure a constant supply. A separate pressurized tank is used to fill with thinner for flushing out balance paint solution from transfer tube.

This ASPS system is designed for a company X located in northern region of Peninsular Malaysia. The development of ASPS was started in December 2017 and successfully installed and tested at Paint Booth No.1 in August 2018. This paper is organized as follow subsequent: Section II encompasses literature review of the related researches of the manual and automated spray painting. Section III presents the structure of the system and main parts and components use in the developed system. Section IV describes the detail about Spray Gun position and setting parameters. Section V expresses the conclusion over the developed system.
2. Literature Review
The spray thickness and the evenness of coating layer are the major issues in the painting process. A lot of studies are undertaken in the analyses of spraying path, spray overlap, spray gun orientations and spray flow rate as reported by Wang et.al [1], From et.al. [2] and Kout et.al. [3]. Controlling spraying path is an important parameter in achieve uniformity or evenness of coating layer thickness [5]. Real time simulation and CAD-guided tool planning also contributed much to the uniformity of spray pattern distribution and thickness deposition [4,6]. Radfar et al. utilized ANFIS to predict paint thickness of the automobile paint process using a robot [7].

Company X is facing quality problems concerning paint thickness and color unevenness with existing manual painting line. Manual painting is carried out using a single gravity feed spray gun as in Figure 1, held by the painter based on the individual experience and expertise to spray the workpiece. The company plans to upgrade existing manual systems to automatic paint systems, control thickness, maintain quality, and improve productivity and efficiency. Currently the manual spray is painting based on the spraying parameter stated in Table 1.

![Manual Gravity Feed Spray Gun](image)

Figure 1. Manual Gravity Feed Spray Gun

| Control Items              | Specification                                      |
|---------------------------|---------------------------------------------------|
| Manual spray gun type     | DeVilbiss GTIPRO                                  |
| Paint Thickness           | 0.4-0.8 mils (10μ~20 μm)                          |
| Resistivity (Anti-Static) | < 300kOhm                                         |
| Distance nozzle to Panel  | 8-10 inch                                         |
| Overlap between paint     | 4 inch (X-direction) and 50% (Y-direction)         |
| Flash-Off time*           | > 15 minutes                                      |

Flash-off time is the necessary waiting time taken to warm room for heating process once a coat is applied on a material. If the flash-off time is short, irregularities such as uneven thickness in the paint job can be expected. With the implementation of automated system ASPS, productivity and effectiveness are expected to be improved as stated in Table 2.
Table 2. Comparison Cycle Time

|                | Cycle Time [minutes] |
|----------------|----------------------|
| Manual         | 35                   |
| ASPS (estimated)| 25 (29% shorter time)|

Increased and consistent product quality is the most widely regarded advantages gained by automation system of all types. For painting or coating, film thickness tolerance and appearance (visual) are the most important point to tackle. An industry standard assumption is that a paint savings of 15% to 30% are achieved when manual painters are replaced by automation (reduce overspray). Flexible to change, expand and adapt to a different kind of workpiece size and paint thickness. Savings achieved through film thickness tolerance control and trigger accuracy will be related directly to many other savings:

Reduces stack VOC (volatile organic compounds) at Exhaust system, Reduce rework jobs thus increase customer’s satisfactory, Reduce overspray thus reduce filter/chemical usage. Other automation advantages would be less reliable on expert painters thus reduce Human Resources cost for hiring & training, and a safer and more effective workplace and the work process are ergonomically optimized.

3. Development of ASPS

Technically, the system consists of gantry spray gun (see Figure 2) with movement by an explosion-proof type servo motor, automatically adjust spraying distance by height sensor. Controlled by PLC, this automation spray painting system provides all necessary data for managing the process optimally, including the selection of workpiece type, pressure control, paint volume, XYZ spray direction & positioning, alarm buzzer etc.

![Gantry Spray Gun](image)

With the implementation of this automation process, painter (who did manual painting) is not necessary to be inside painting booth and this is good for the safety and health of the worker. Furthermore, space for painter inside the booth for manual spraying process becomes unnecessary thus new cart can be designed to increase the number of the workpiece (panel to be painted) that can be allocated on the cart. Figure 3 shows the painted workpieces on the new designed cart. This new cart design could increase the number of the panel based on the increasing painting area, up to 70%.
The overall proposed system is consists of the following items.

- Main structure with nozzle bar and height sensor
- Automated Spray Gun (Nozzle) c/w pressure tank, flow counter, tubing etc
- Explosion-proof motor for XY control c/w cable
- Main Control Panel c/w Push button and Tower light

![Figure 3. Painted workpieces on the new cart](image)

**A. Spraying Paint Booth**

Dimension of the paint booth is 7000mm x 5500mm with entering door in front of the booth, blower on the top roof and vacuum mechanism on the floor. There is an exit door to warm room on the rear site of the booth. Painted workpieces have to be transferred to warm room for 45 minutes after 15 minutes flashing time inside the paint booth. Flashing process is a partial evaporation process or settle down process when a liquid changes its phase and becomes partly vapour and partly liquid.

**B. Automated Gantry System**

To fit with the booth dimension, the gantry system (Figure 4) is designed at L6950mm x W4800mm and Height 2380mm built from mild steel 3” x 2” square pipe. The guns can be moved freely in X and Y-axis supported by cable chain covered by flexible bellow and powered by a set of AC servomotors. For gun height adjustment, the gun also can be moved up and down and controlled by another servomotor. All servomotor movement is controlled by PLC equipped with Touch screen panel for automation mode and Teach pendant for manual control mode.

**C. Spray Gun**

LVMP gun with high transfer efficiency that provides superior cost performance DA-300 type is a product of De VILBISS. It is used in this development for the reasons of the compact and high performance general-purpose automatic spray gun with superior fine atomization and transfer efficiency.
There are four main characteristics highlighted by the manufacture as follow [8].

- **Compact size and High Performance**
  Featuring superior atomization, the gun is designed to be suitable for spraying metallic and pearl type paints.

- **Air cap**
  Superior atomization is made possible by using the DeVilbiss air cap which is already highly regarded in the market.

- **LVMP**
  Compared to conventional guns and HVLP guns, the LVMP gun achieves finer atomization and higher transfer efficiency with much less air consumption.

- **Waterborne**
  Has stainless steel passage for waterborne paint.

Table 3. LVMP Gun Specification

| Specifications                         | Details                        |
|----------------------------------------|-------------------------------|
| Atomization Air Pressure (Gun Inlet)   | 0.25 MPa                      |
| Fluid Pressure (Max.)                  | 0.7 MPa                       |
| Working Pressure (CYL)                 | 0.35 ~ 0.5 MPa                |
| Weight                                 | 507 g                         |
| Fluid Inlet                           | G 1/4                         |
| Cylinder Air Inlet (CYL)               | G 1/4                         |
| Atomization Air Inlet                  | G 1/4                         |
| Measurement                           | L150 × W38 × H76 mm           |

Table 3 shows the specification of the spray gun sets by DeVILBISS.

**D. Pressure Tank**

There are two pressure tank provided in this system development. To reduce flushing time or cleaning time, separate pressure tank is used. One pressure tank is use to fill mixture solution paint and another one is use for solvent or thinner for flushing or cleaning purpose. After finished spraying process, pressure tank with the solvent will connect to the hose (tube) for flushing process. With this versatile PT-10M pressure tank (Figure 5), almost professional painting result can be easily carried out. Special materials such as enamel paint, chemical liquid, solvent-based coating, can be transported as smoothly as required [9].
There are three AC servomotors (Figure 6) are used in this development – HG-SR52, HG-SR102 and HG-KR23B, all are from Mitsubishi Electric Co. Each of the servomotors is installed for controlling the spray gun mechanism in X-axis, Y-axis and Z-axis, respectively.

The selection of the servomotor can be decided by using Motor sizing software provided by the manufacturer. It can be downloaded online and the servomotor selection can be done by setting all necessary parameters such as load, gear type etc based on actual application.

E. AC Servomotor

F. New Cart

New spray cart in Figure 4 is designed with new dimension L2370mm x W820mm and H920mm to maximize the number of cart that can be enter to the paint booth and more workpieces can be put on the cart for spraying process.
4. Spray Gun

A. Paint Material and Mixing liquid
There are two paint materials used in this spray painting process named as Liquid A and Liquid B where both of them have to mix in a ratio of 1:1. With the spray gun flow-rate of 200cc/min, mixture paint of 1 can 3.79L (1 gallon) of Liquid A and 1 can 3.79L of Liquid B theoretically can be used for 37.9 minutes of painting based on consumed solution volume as calculated in (1).

\[
painting \ time, t \ [\text{min}] = \frac{solution \ vol \ [\text{cc}]}{flow \ rate \ [\text{cc/\text{min}}]} \quad (1)
\]

One complete cycle of painting takes 2.4 minutes painting time, make 1 mixture liquid can be use for 15 to 16 lots of painting products.

B. Spray Gun Position
In this development, 3 spray guns are used and they are positioned 100mm each other and one in the middle is shifted 100mm as can be seen from the bottom as shown in Figure 5. The guns are positioned exactly right angle to the workpiece as seen from the side view in Figure 6.

![Figure 8. Gun Position (bottom view)](image)

![Figure 9. Gun angle to the Workpiece](image)

The guns are designed in such position so that when the paint is sprayed out from the designated height with the correct opening valve (gun knob setting), the desired spray pattern of each gun is not overlapped each other as shown in Figure 7.
C. **Fluid pressure and Gun (air-cap) pressure setting**

Fluid pressure is needed to move-out spray paint from the tank and transfers it through-out long tube to the spray gun. While air-cap pressure is the pressure needed to atomization the paint liquid during the spraying process.

On the design stage, fluid pressure and air-cap pressure were under-went several testing and the optimum condition was as shown in Table 4.

| Parameter range   | Optimum |
|-------------------|---------|
| Fluid Pressure    | 0 ~ 1.0 bar | 0.8 bar |
| Air-cap Pressure  | 0 ~ 25 bar  | 2.5 bar  |

**D. Nozzle distance and Paint volume setting**

Nozzle to work-piece (as shown in Figure 8) is tested for range of 8 to 10 inches while for the Gun knob valve opening (as shown in Figure 9) is tested for 0.5 turn to 2.5 turns. The turn is measured based on the fully close as 0 turn and complete 1 turn as 1.0 turn. In the other word, the turn also can be translate in degree unit as 0 turn as 0°, 1 complete turn as 360°, 1.5 turns as 440° and so on.
5. Conclusion
This report stated the overall process of development of Automated Spray Painting Process (ASPS) and some of the important parameters setting in achieving best spray pattern with an optimum overlapped area between the three guns in to achieve target thickness. This film thickness is controlled at 0.4 to 0.8mils.

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