CHARACTERISTIC STUDIES ON TYPES OF PAINT SPRAY FOR AUTOMOTIVE PARTS IN SMALL AND MEDIUM INDUSTRY

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Dedicated to my beloved wife, Shuhaida Masni Binti Che Abdullah,
my mother, Zurina Binti Yusof, my father, Jamaluddin Bin Ahmad,
my childrens, Luqman, and Aisyah
To my supervisor, Assoc.Prof. Dr. Norzelawati Asmuin, lecturers and friends for all of their help and friendship.

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ABSTRACT

This research studied on characteristics of the conventional paint spray compared to the High Volume Low Pressure (HVLP) type of paint spray used in the automotive painting industries in terms of cost and air quality in the spray booths. Characterization of conventional and HVLP of paint spray gathered through experimental methods. Results recorded from the experiments are air pressure, air volume, paint viscosity, transfer efficiency, and overspray. The analysed results are used as parameters in the Computer Fluid Dynamics (CFD) software ANSYS CFX V.15. The simulated paint spray patterns of the conventional paint spray compared to the High Volume Low Pressure (HVLP), concurred with the findings from the experiments. At the end of this research, it concluded that HVLP has a more stable flow rate compared to the conventional spray gun. HVLP produces smaller droplet size of paint thus reducing overspray impact on hygiene and surrounding environment. HVLP recorded 77.39% transfer efficiency which was 20% more than the conventional spray gun. The spray patternation of HVLP nozzle using ANSYS CFX Version 15 simulated a full cone and symmetry spray right after the paint discharge from the nozzle. In terms of practicality, the HVLP spray gun is more suitable for coating of a car's part in the SME compared to the conventional spray paint.

ABSTRAK

Penyelidikan ini adalah untuk mengkaji ciri-ciri semburan cat jenis konvensional berbanding dengan jenis *High Volume Low Pressure* (HVLP) yang digunakan dalam industri mengecat kenderaan dari segi kos dan kualiti udara di dalam tempat mengecat. Teknik yang digunakan untuk kedua-dua jenis alat penyembur akan dikaji menggunakan kaedah eksperimen. Keputusan yang akan direkodkan adalah tekanan udara, kuantiti udara, kelikatan cat, kadar pemindahan haba cat ke permukaan dan *overspray* serta kos *overspray.* Data yang diperolehi dari eksperimen akan digunakan sebagai parameter dalam CFD untuk simulasi. Kemudian perbezaan untuk simulasi dan eksperimen akan digunakan untuk membuktikan kepada industry kecil dan sederhana keberkesanan pengunaan jenis HVLP. Pada akhir eksperimen, dapat diputuskan bahawa alat penyembur cat jenis HVLP adalah lebih stabil berbanding jenis konvensional. Alat penyembur jenis HVLP menghasilkan titsan zarah cat yang lebih kecil dan mengurangkan masalah *overspray* yang memberi imak kepada masalah kesihatan dan persekitaran dalam tempat mengecat. Alat penyembur jenis HVLP mencatat kadar pemindahan yang lebih baik iaitu sebanyak 77.39% di mana melebihi 20% berbanding jenis konvensional. Simulasi menggunakan Ansys CFX Versi 15 menunjukkan alat penyembur jenis HVLP menghasilkan pattern penyemburan jenis kon penuh dan simetri selepas zarah cat meninggalkan muncung alat penyembur. Secara praktikalnya, alat penyembur jenis HVLP adalah lebih baik digunakan dalam industri kecil sederhana berbanding jenis alat penyembur konvensional.

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LIST OF SYMBOLS AND ABBREVIATIONS

HVLP	–	High Volume Low Pressure
CAD	–	Computer Aided Design
CFD	–	Computational Fluid Dynamics
VOC	–	Volatile Organic Compound
ERBS	–	Electrostatic Rotary Bell Sprayer
DMEA	–	dimethylethanol amine
AMP	–	2-amino-2-methyl-1-propanol
HMMM	–	Hexamethoxymethylmelamine
EPA	–	Environmental Protection Agency
TE	–	Transfer Efficiency
SCAQMD	–	South Coast Air Quality Management District
PIV	–	Particle Image Velocimetry
PDA	–	Phase Doppler Anemometry

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Automobile refers to a passenger vehicle designed to operate on the road and off-road, typically having four wheels and gasoline or diesel internal combustion engine. The automotive industry is the design, operation, manufacturing, or sale of automobiles. There are several processes in manufacturing a vehicle in the automotive industry such as stamping process, painting process, welding process, body assembly process, and inspection. Paint is a substance composed of colouring matter suspended in a liquid medium and applied as a protective or decorative coating to various surfaces, or to canvas or other materials in producing a work of art.

Car painting is a complex combination of different layers of primer coat, base coat or colour and protective finishing coat or clear coat. The setup for the painting process requires the optimal and best parameters such as humidity, booth temperature and the consistence of the lacquer itself. Painting process for automotive industries is very important to give a more attractive appearance to the vehicles and to provide a layer of protection for the body against corrosion and weathering. It is one of the major costs in car manufacturing, it may cost more expensive than the body itself. Maybe the high costs are in terms of the processes that occur in painting process and not the price of the machines that are used in the paint shop. So, many companies try to reduce the cost of the painting process, so the quality of the painting may not be durable for a long time. It will benefit a medium-size or aftermarket paint shop to gain profit.

Medium-size or aftermarket paint shops use a manual paint spraying method in the spray booth. There are two common type of manual sprayer use in the market, which are commercial sprayer and a High Volume Low Pressure (HVLP) sprayer. Thus, this project will be focus on the study of how paint spray is applied on car's part and characteristic studies on the flow of paint spray visualization using digital still camera.

1.2 Problem Statement

It is impossible to achieve perfect work in the whole painting processes. There are some problems arising from men, machines, methods and materials. So, to improve the process is by reducing the problems as low as possible. The studies are about the method that use in the process and propose a new method that can overcome those problems. An experimental of automotive paint sprays will be conducted with some parameter focused on the flow visualization using experimental method. An experiment also will be conducted to study the system of paint spray applied for car's part using two types of automotive paint spray guns as well as to understand more about its system and technology.

1.3 The Project Aim and Objectives

The aim of this project is to reduce the problems that occur at the automotive painting industries in term of cost and air quality in the spray booths. So, the following objectives need to be done:

I) Determine the system of paint spray either conventional or High Volume Low Pressure (HVLP) type of paint spray suitable to apply on car's part for small medium painting industries to reduce cost and improve the air quality in the spray booths.

II) Study on flow visualization using experimental and Computer Fluid Dynamic (CFD) simulation methods.

1.4 Scopes of the Study

The scopes of the study are as follows:

I) Types of the paint spray guns are conventional paint spray gun and high volume low pressure (HVLP) paint spray gun.

II) Type of automotive paints is using base coating CPP 34N Phantom Purple.

III) The spray angle of paint spray gun is at 60°- 90°.

IV) Calculate the flow rate of paint spray for the best performance using both type of paint spray.

V) The booth area with size (12’9” W x 8’4” H x 20’1” L). The temperature of the booth is about 65-70°C with humidity is 50% relative humidity.

VI) CFD 3D modelling of selected paint spray.

VII) CFX-15 ANSYS software will be used in analysis.

VIII) Simulation on steady state condition.

1.5 SIGNIGICANT STUDIES

The researches of this project are improving the system that used in paint spray applied on automotive car body. Two experiments to be conducted and the best paint spray will be simulated using Ansys CFX-15 software to continue the experimental results. The expected results from the experiments are parameters recorded which are air pressure, air volume, paint viscosity, transfer efficiency, and overspray. With these values, the last objective of this research can be obtained. All those parameters will be compared as well as their advantages and disadvantages.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Automotive painting was started with the process of coating metal, wood and stone surfaces long time ago. It was applied to a carryover from the horse and buggy. In 1900, the coating process was applied to the true vehicle roughly 6 years after Henry Ford founded Ford Motor Company. Much like old wood coatings, they were brushed on the surface and allowed to dry. The coating was then sanded smooth and refinished in the same manner. When a desired thickness was achieved the surface was polished. The process of painting a car to be completed may take 40 days. But these products were not colourful. Henry Ford set that a car can be any colour you like as long as it is "black.' This system was used until the mid 1920's.

During the early 30's the auto industry "stoving enamels" based on alkyd resins had been introduced. Initially the product was applied much like the "varnish" used earlier based on Croll, S. 2009. These enamels were originally selected because of a higher gloss yield than varnish. They were also thicker and applied a little faster. Then, spray gun had been introduced by a dentist to replace the brush method somewhere between 1930 and 1940. Using spray gun, the work can be done faster than the method using brush. It can minimized sanding between coatings and applied the product evenly. Now, the works that have to take over a month could be done in a third of the time. This product and process was the system of choice for most vehicle manufacturers until the 1950's.

According to Croll S. 2009 General Motors (GM) started to work with a new raw material supplier in 1955 by choosing a different kind of enamel paint product.

Here instead of the early alkyd resins they chose to start using new acrylics. This product was used in a process that GM called "reflow acrylics." By using spray gun the coating was applied to the vehicle surface but at that point of the product, it still wet, contained a large amount of solvents. So, they decided to place the vehicle in a large oven caused the solvents to evaporate and the product to flow to a uniform smooth finish. There was some gloss, but not quite up to the level of stoving enamels. Nevertheless, it was quick and efficient. Saving time was a way to save money and build a product faster. So "reflow acrylics" became the popular system until 1960.

In 1960 the Ford Motor Company went back to the stoving methods after realizing that consumers made a vehicle purchase using their eyes and not their heads. They also decided that they liked many of the properties that the early acrylic resins provided. They went to work with yet another new group of suppliers to create "acrylic stoving enamels." At this point Ford had the best method to offer the consumer and it wasn't long before the competition kept pace. This product was also applied with a spray gun to get very high gloss, durable and also was oven cured to produce a hard and colourful surface. This process was popular throughout the industry into the early 70's.

Japanese cars began to become popular in the 1970's and so its painting industries. Japanese and the Europeans had begun application of two-coat acrylic painting systems too numerous to list here. Metallic or metal flake paints introduced by them to consumer. American loved with this unique and colourful surface. Later in the decade manufacturers were looking for harder paints. They wanted more resilient elements that could dry faster. The answers were found in products that reacted with each other to enhance drying rather than wait for total solvent evaporation. A "cross-linking" free radical additive is included in the formula. At the time of use, a catalyst is added to the paint. The product is sprayed on and the process of curing begins. This process became more popular for larger vehicles like airplanes and fire engines. It is still in use today in both Acrylic Enamels and newer Polyurethane products. However, based on Craig Kelly et al. 2009, it is cost prohibitive for automotive applications [9].

In the mid 70's the number of raw material suppliers to the paint industry had grown such as names like BASF, Du Pont™, Ditzsler, PPG and hundreds more. This enabled the manufacturer to pick the best process and product for the job. Today's

Base Coat/Clear Coat and Basecoat/Tint Coat painting processes were experimental at the time. Improve gloss and depth of colour is the main purpose by all company in paint industries. The process was perfected in the late 70's. However durability of the Clear Coat was poor. Not until the 80's would manufacturers have confidence in these paint systems. The carmakers needed Clear Coats to last 5 years. This was a magic number because that's how long consumers usually kept new cars.

The late 1980's saw major changes for makers of painting systems. All were hoping to capture market share with the big three automakers. Two and three stage "clear coat" and "tint coat" systems were popular on cars. However, for their rugged durability, the old standby acrylic enamels and polyurethanes were still in wide use on trucks and SUV's.

The late 80's and early 90's brought about rapid changes in the paint industry. New laws were enacted that governed the content and application of paints. Auto manufacturers were scrutinized due to the large volume of product they used. With the assistance of suppliers, the painting processes were changed. The amounts of "volatile organic compounds" (VOC) were lowered once again by government mandate. "Urethane" and "polyurethane" blends, along with custom hybrids were the order of the day. All of this presented a unique set of challenges for the manufacturers, car owners, wax companies, body shops and detailers. Initially, these new paint systems began flaking away and were being damaged by ordinary waxes and polishes. This created huge repair or replacement bills and much controversy. According to Croll, S. 2009, The paint industry worked furiously and was able to solve most of the problems early in the decade.

In automotive industry, the colour of the car becomes a part of aesthetic value for the buyer. The first automobiles were made in the late 18's, there have been many changes in paint technologies to protect and attract these manmade transportation devices. Car paint could be from natural products to high tech polymers. Many improvements have been made by the car paint industries since 18's. It was implemented from small to automatic. Variety of equipment and facilities have utilize as car body paints method such as commercial spray guns, airless spray gun, High Volume Low Pressure (HPLV) spray and Rotary Bell Spray. Most of automotive body paint industries used manual process. They preferable used spray guns to develop the coats of paint onto the car body and parts compared to Electrostatic Rotary Bell Sprayer (ERBS) based on B. Anderson, et al. 2013

The process of automotive paint spray can be summarized into several steps which started with prime the surface with a corrosion resistant, self-etching primer for removing all paint down to bare metal. Prime any surface covered by body filler or removed rust from, feathering these areas to a smooth transition and applying enough paint to fill scratches or pits left in the preparation process. Speed up drying of the coating by heated to cure in special infrared ovens or heated spray paint booths. Then, the surface is sanded to remove any irregularities and improve the adhesion of the next coat using certain grade of sandpapers until final sanding. After that, a sealer is applied and allowed to dry followed by the final topcoat. Lastly when lacquer is used, the finished surface is usually polished after the final coat has dried where enamel will gives out a high gloss appearance. Refer to Pfanstiehl, J. 1998, worker activities at automobile refinishing shops include wet sanding, car washing, stripping (paint removal), machine sanding, blowing, buffing, polishing, paint spraying, paint and primer mixing, and inspection.

2.2 System of Paint Sprayer

2.2.1 Types of Paint Nozzle

2.2.1.1 Single Phase of Paint Nozzle

For the single phase of paint that comes in a sealed pressurized container and released in a fine spray mist when depressing a valve button called aerosol paint. It can produce a smooth and coated surface, unlike many rolled or brushed paints. These types of paint nozzle are portable, cheap and easy to store. The history of this type on paint nozzle by Edward Seymour in 1949 was designed to demonstrate aluminium paint.

The uses of this type paint sprayer from small to medium-sized repairs to automobile bodywork can be completed, but it would be difficult and expensive if use this way to paint the entire vehicle. The main disadvantages, compared to professional spray guns, are the limited quality offered by the built-in nozzle and the lack of infra-red baking after applying the paint, which means the paint can take several months to achieve its final hardness. Figure 2.1 illustrate aerosol paint can. Propellant in the top of the can pressures down on the paint propellant mixture in the

bottom. The paint mixture is pushed up through the dip tube when the valve is opened.

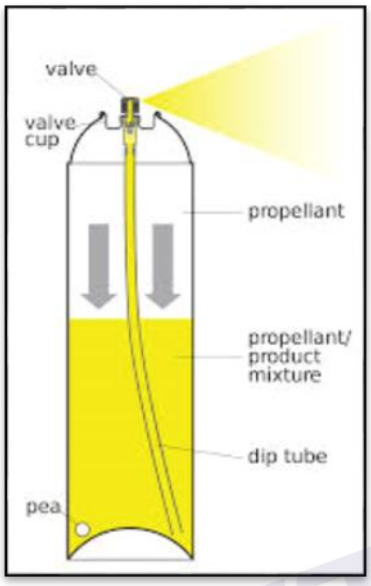

Figure 2.1: Aerosol paint can

2.2.1.2 Two Phase of Paint Nozzle

There are several types of two phase of paint nozzle in this industry. There are combinations of air and paints, also airless and paint. The stated sprayers are cup sprayer, air sprayer, and airless sprayer. Each type of sprayer is designed for different painting tasks that allow an efficient work to produce amazing arts. The study of paint spray for automotive car body is important to make beautiful appearance on cars. This is why choosing the right paint spray and its system are important in spray painting works. It can be determined by the surfaces of the body where it will be painted, what types of paint or stain that needs to apply as well as the coverage whether it will be large or small. Gravity feed spray guns for spraying paints are the most commonly used guns in these industries.

2.2.1.2.1 Cup Sprayer

Cup sprayers are operating at a basic with high pressure that is best for solo paintings or hobby activities. They connect to an air compressor and the finish is blasted onto the project using this high pressure. It is also suitable for small jobs, touch-up work

or when using multiple colours. They are low in price in terms of models, parts and do not require more advanced models for large-scale work. So, a person can do a painting work very quickly with it with unnecessary expenditure. The sample of cup sprayer is show in Figure 2.2.

Figure 2.2: Cup Sprayer

These sprayers draw paint to the gun nozzle where the spray pattern is formed and propelled forward onto the surface. The ink cartridge is a cup which can be simply use by filling the cup with paint and plug it into an outlet or its extension cord. Then, the sprayer is ready for use. The paint may need to be thinned to avoid blockage in the spray cord.

2.2.1.2.2 Air Sprayer

The air gun has a nozzle, paint basin and air compressor. Due to wide range of nozzle shapes and sizes, the consistency of the paint can be varied. The shape of the project, the paints and pattern are important factors in choosing a nozzle. The three common nozzles are the full cone, hollow cone, and flat stream. These conventional air sprayers are usually used for automotive works that gives high quality finishes for both interiors and exteriors surface of a project. An air sprayer is made of compressed air system that creates a smooth spray pattern and projects paints that covers a large surface. A stream of paint meets air will form the paint droplets and then are exerted out by a pressure which will flow them out through the spray nozzle.

An extensive masking is required when handling this sprayer for safety. Besides that, a spraying distance of at least 15 cm to 30 cm is suggested to prevent user from inhaling the paint droplets. This sprayer can use a lot of paint types and may be adjusted for paint thickness by diluting with liquid to suit it with its uses.

2.2.1.2.3 Airless Sprayers

Airless sprays guns are widely used in heavy industries mainly focussing on corrosion protection, such as metal construction work, bridges or ships. Usually it produce thick films due to high impact momentum of droplets, the coating material is penetrating into pits. Its working principle is the paint was pressured to go out through small nozzle to the surface. Its applications are for spraying large interior and exterior projects. But this type of spray gun have to maintain its nozzle because of the dirt come from paint always block the nozzle hole. However, most of the sprayers' fabricator companies come out with reversible spray tips that include in the pamphlet or catalogue of their products to overcome that problem according to Qiaoyan ye, et al: 2013.

This type of spray considered the fastest spray gun and also minimizes overspray as shown in Figure 2.3. This spray was characterized by relatively large droplets and a high axial momentum according to Qiaoyan ye, et al: 2013.

Figure 2.3: Airless Sprayer

2.2.1.3 Multiphase of Paint Nozzle

The multiphase of paint nozzle is an outlet for combination three types of substances which are paint, air and activator. Usually, the paints already mixed with the activator. The most common activator is hardener. The common type of multiphase of paint nozzle is High Volume Low Pressure (HVLP) spray guns which can give a better result than the conventional spray gun because of less air entrapment. Based on Craig Kelly 2009 it also saves material.

2.2.1.3.1 HVLP Sprayers

The meaning of HVLP is high volume low pressure refers to conventional spray gun using a compressor to supply the air, but the spray gun requires a lower pressure (LP). A higher volume (HV) is used to aerosolise and propel the paint at lower air pressure. Higher proportion of paint reaching the surface with reducing overspray and air pollution can be achieved with HVLP sprayer. Thus, it's suitable for small project to heavy projects according to William C. Smith, 1996.

For small industries, automotive painters can use HVLP sprayer with portable air compressor but a regulator is required to lower the pressure. Some masking may be required for this type of sprayer depending on the time use and proficiency of the user. 15cm to 20cm is the best spraying distance for this type of sprayer. HVLP sprayers are not good with thick paint such as latex, but works great with thinner substances. Additional to that, this sprayer provide the highest level of transfer efficiency. Thus, more paint reaches the spraying surface resulting less masking and drop cloth usage. HVLP sprayers become popular because it can provide a high quality finish with good transfer efficiency. Figure 2.4 illustrate a simple type of HVLP sprayer.

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