UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE DESIGN AND DEVELOPMENT OF PORTABLE ELECTROLESS NICKEL PLATING APPARATUS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Design of Manufacturing) with honors.

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment to the requirements for the degree of Bachelor of Manufacturing Engineering (Design of Manufacturing) with Honors. The member of the supervisory is as follow:

……..

(Dr. Muhammad Zaimi Bin Zainal Abidin)

ABSTRAK

Kajian ini memberi tumpuan kepada reka bentuk dan pembangunan alat mudah alih untuk tanpa elektrik peralatan nikel saduran untuk memberikan fleksibiliti kepada plat jenis logam atau plastik dengan mudah dalam industri. Apabila bahagian-bahagian kecil logam yang perlu bersalut untuk mengelakkan hakisan dan mengekalkan rintangan haus, ini alat tanpa elektrik plating mudah alih memberikan kelebihan dan darjah kebebasan untuk plat cekap tanpa apa-apa masalah atau kecacatan. Untuk menguji peralatan yang cukup serasi, ia perlu dilakukan dengan ujian produk eksperimen dengan reka bentuk prototaip tanpa elektrik mudah alih alat penyaduran menggunakan set asas peralatan yang telah sedia ada di dalam makmal seperti bikar, termometer, hos, plat pemanasan , beg vakum, dan meter kadar aliran. Analisis hartanah salutan akan dilakukan untuk menganalisis morfologi permukaan lapisan nikel dengan menggunakan Carl Zeiss mikroskop optik digunakan untuk mengkaji pemerhatian visual pada logam sampel. Analisis ini adalah untuk membuktikan bahawa tanpa elektrik alat penyaduran mudah alih akan dapat memberikan jumlah yang sama komposisi salutan peralatan saduran yang sedia ada bukan mudah alih tanpa elektrik. Analisis struktur reka bentuk baru akan dilakukan dengan cara Analisis Unsur Terhingga (FEA) dalam perisian SolidWorks untuk mengkaji kesan permukaan selepas menggunakan kuasa yang di atasnya. Analisis ini akan merangkumi tekanan, anjakan dan faktor keselamatan reka bentuk baru sebelum memulakan proses fabrikasi itu. Pemerhatian visual komposisi nikel ke sampel menunjukkan terdapat lapisan nipis lapisan di atasnya. Tambahan pula, analisis permukaan pada beg vakum yang merupakan sebahagian yang penting dilakukan dengan menggunakan FEA menunjukkan faktor keselamatan lebih daripada 1 selepas daya 100 N dikenakan ke atas permukaan dalaman beg vakum mana bahan adalah nilon. Oleh itu, proses pembangunan adalah selamat untuk dibina tanpa sebarang kebimbangan kerosakan kepada mana-mana alat atau bahagian produk.

ABSTRACT

This study is focusing more on design and development of a portable apparatus for electroless nickel plating equipment to provide flexibility to plate any type of metal or plastic with ease in the industry. When small parts of metal that need to be plated to avoid corrosion and to maintain wear resistance, these portable electroless plating apparatus gives an edge and degree of freedom to plate efficiently without any problem or defect. To test the apparatus is compatible enough, it need to be done by an experimental product test by design a prototype of portable electroless plating apparatus using a basic set of apparatus that is already available in the laboratory such as beaker, thermometer, hose, heating plate, vacuum bag, and flow rate meter. Analysis of coating properties will be done to analyze the surface morphology of the nickel coating by means of Carl Zeiss optical microscope are used to study the visual observation on the sample metal. This analysis is to prove that a portable electroless plating apparatus will be able to give the same amount of coating composition as the existing non-portable electroless plating equipment. Structure analysis of the new design will be done by means of Finite Element Analysis (FEA) in the SOLIDWORKS software to study on surface effect after exerting a force on it. The analysis will include the stress, displacement and factor of safety of the new design before beginning the fabricating process. The visual observation of nickel composition onto the sample shows there are thin layers of coating on it. Furthermore, the surface analysis on the vacuum bag which is the critical part done by using FEA shows a factor of safety more than 1 after a 100 N force exerted on the inner surface of the vacuum bag which the material are nylon. Thus, the development process is safe to be built without any concern of damage to any tools or part of the product.

DEDICATION

To everyone that contributes to this research and my friend that has been helping me all along

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First of all I would like to express my gratitude to Allah S.W.T. for blessing on me throughout this while in completing this final year report. Therefore, I would like to take this opportunity to express our gratitude to all those who helped me either directly or indirectly in carrying out this research.

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Last but not least, thanks also to all the parties involved in providing encouragement to me while completing this research, including both my parents and all staffs of FKP for giving me guidance to accomplish my research. Not forgotten, I would like to thank to all my friends that have helped me a lot by giving some ideas and suggestions to accomplish this research.

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LIST OF ABBREVIATION, SYMBOL AND NOMENCLATURE

Au	-	Aurum (Gold)
B	-	Boron
Co	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
CPVC	-	Chlorinated polyvinyl chloride
Cr	-	Chromium
Cu	-	Copper -
EN	-	Electroless Nickel
H_2S	-	Hydrogen Sulphide
K	-	Kelvin
Kg/m^3	-	Density
N	-	Newton
$Na_3C_6H_5O_7 . H_2O$	-	Trisodium Citrate Dihydrate
$NAH_2PO_2.H_2O$	-	Sodium Hypophosphite Monohydrate
$NaWO_4 . 2H_2O$	-	Sodium Tungstate Dihydrate
$(NH_4)_2SO_4$	-	Ammonium Sulphate
Ni	-	Nickel
Ni-P	-	Nickel – Phosphorus
$NiSO_4 . 6H_2O$	-	Nickel Sulphate Hexahydrate
P	-	Phosphorus
Pa	-	Pascal
PEEK	-	Polyetheretherketone
PET	-	Polyethylene terephthalate

Pd	-	Palladium
SS	-	Stainless Steel
VLD	-	Flexible Polymer Foam

CHAPTER 1
INTRODUCTION

This chapter describes in basic information about the research on fabricating the portable electroless nickel plating apparatus. Additionally, the problem statement, objective of the research and scope of the research are also highlighted in this section.

1.1 Background of a study

Electroless Nickel-Phosphorus (Ni-P) coating has gained a lot of interest in various industries due to outstanding characteristics such as uniform coating and be able to be deposited on any shape and substrate. Furthermore, electroless Ni-P coatings have superior corrosion and wear resistance. For that reason, the electroless Ni-P coating has many potential advantages such as selective autocatalytic metal deposition, good solder wettability and in application as solder diffusion barrier. It has high potential for lower cost under bump metallurgy and flip chip bump them for flip chip packaging. Electroless nickel plating is also frequently applied on aluminum to provide a solderable surface.

Electroless nickel plating is used to deposits nickel without the use of an electric current. Since the first discovery in 1944, electroless nickel-phosphorus (Ni-P) deposits have been widely used in various industries. Typical electroless nickel baths use hypophosphite reducing agents and deposits phosphorus along with the nickel. Mid-phosphorus (5-8%P) deposits are bright, hard, and magnetic as deposited. High phosphorus (9-15%P) deposits are non magnetic as deposited, semi-bright, and slightly softer than mid-phosphorus. High-phosphorus nickel has greater corrosion resistance

than lower phosphorus deposits. The basic electroless plating tank construction are commonly made from polypropylene that is natural; stress-relieved polypropylene is well regarded for tank constructions, as it is inert to plating solutions. It easily fabricated for industrial uses and when using proper nitrogen welding techniques, are fairly reliable. Polypropylene-lined electroless nickel tanks have been fabricated in sizes up to 20 feet long and 10 feet wide. However, the life of the welds and of the polypropylene itself are directly related to the strength of nitric acid used in cleaning and stripping the tank, as polypropylene is oxidized by nitric acid, thereby accelerating deterioration. Moreover, the components from industrial factories such as piping, need to be removed before undergoing plating process. Some cases may require stopping the production for simple maintenance.

Currently, the portable version of electroplating has already been developed. Nevertheless, it requires the surface to be electrically connected to the apparatus and the surface need to be conductive. On the other hand, electroless deposition does not use external current for deposition, but still, the portable version of electroless deposition apparatus is not yet designed.

In this study, a portable version of electroless plating bath apparatus is designed base on both industrial scale and laboratory scale plating bath design. Concept of portable electroless plating of Ni-P alloy is done using laboratory apparatus. The producibility of the Ni-P is needed to be confirmed using optical microscope Carl Zeiss. The surface analysis are done by using Finite Element Analysis (FEA) in Solidworks. Detailed design will be done by using several tools such as Solidworks and Materials Selection CES Edupack.

In the present investigation, electroless Ni-P coatings were prepared at various conditions including the type of bath, heat treatment temperature, and plating solutions composition.

1.2 Problem Statement

Some surface maintenance of factories components require the removable of the components before coating, thus may reduce the production. It is easier to be able to do the maintenance directly without stopping the production. Currently, the portable version of electroplating has already been developed. Nevertheless, it requires the surface to be electrically connected to the apparatus and the surface need to be conductive. On the other hand, electroless deposition does not use external current for deposition, but still, the portable version of electroless deposition apparatus is still not yet designed and tested.

1.3 Objectives

This research was aimed to design a prototype of portable electroless nickel plating using a basic set of experimental apparatus. This research is carried out under certain objectives as follows: -

i. To fabricate portable plating apparatus based on the existing electroless nickel plating tank.
ii. To evaluate the functionality of the fabricated portable electroless nickel plating apparatus.

1.4 Scope of study

The focus of the research is on the creating a portable electroless nickel plating apparatus. This research will be carried out by design an idea of portable electroless nickel plating apparatus and then fabricate it into model item by making use of

fundamental set of experimental apparatus such as electrode, beaker, vacuum case, and PVC hose. The surface properties and the composition of the Ni-P coating are studied using optical microscope. The final design will be analyze using FEA and constructed using SOLIDWORKS software, and the analysis of the component design will be done by CES Edupack.

CHAPTER 2
LITERATURE REVIEW

This chapter is about the review study from the previous research. The objective of this chapter is to develop knowledge on electroless nickel plating, its applications on various fields, the design of mobile plating tank, reaction mechanism, quality of coating, and analysis.

2.1 Electroless Deposition of Nickel

2.1.1 Introduction

Electroless plating happens in the existence of a chemical reducing agent in solution to reduce metallic ions to the steel state. The title electroless is often deceivable. Nevertheless, there are no outside electrodes current, but there's electric present or charge transfer included. As an alternative of an anode, the steel is provided by the steel sodium; replenishment is accomplished by incorporating either sodium or an outside cycle with an anode of the matching steel that features greater effectiveness than the cathode. There's, therefore, as an alternative of a cathode to reduce the steel a substrate serving as a cathode, although the electrons are supplied by a reducing representative. The procedure takes location just on catalytic areas instead than throughout the solution. The observation on the additive of NAH_2PO_2 causes the obvious cathode efficiencies of

more than 100% in a nickel electroplating bath based on the accidental innovation of electroless Ni plating in 1946 by Riddell and Brenner. (Mordechay Schlesinger and Milan Paunovic, 2010)

Electroless plating is outlined as the deposition of a metallic layer by a managed chemical reduction that's catalyzed by the steel or alloy being deposited. Such plating features been utilized to produce buildup of Ni, Co, Pd, Cu, Au, and Ag as well as some alloys containing these metals plus P or B. Electroless Cr deposition features additionally been advertised. Chemical reducing representatives have included NAH_2PO_2 (sodium hypophosphite), formaldehyde, borohydrides, hydrazine, amine boranes, and a number of their derivatives. (Mordechay Schlesinger and Milan Paunovic, 2010)

A number of the outstanding characteristics of electroless deposition coatings are superior wear and corrosion opposition, excellent uniformity, broad range of depth as well as physical and mechanical properties, great solderability, and area lubricity (Baudrand, 1978). They're commonly utilized either as decorative or protective coatings in numerous sectors, including optics, aerospace, chemical, mining, plastic, printing, petroleum, automotive, nuclear, electronics, paper, textile, computer, and meals (Parker, 1972). In addition, compared to traditional electroplating methods, electroless nickel coatings can be used on various substrates (conductive and nonconductive) since no outside up-to-date is used to the component (Khoperia et al., 1997;Gemmler et al. 1990; and Ma and Gawne, 1987).

Electroless plating includes couple of characteristics maybe not discussed by other methods and that reports for its ever growing appeal (Mordechay Schlesinger and Milan Paunovic, 2010).

2.1.2 Engineering Applications

Engineering applications towards electroless nickel is generally revealed in practically just about every industry. Various significant attributes regarding electroless nickel coatings, particularly hardness, apply coating, resistance uniformity, as well as corrosion prevention, and the potential to plate non-conductive areas make this method a coating of selection for countless engineering applications. Below are the types of engineering application in electroless nickel plating.

Electroless nickel qualities tend to be applied extensively throughout years within the aerospace industry. All of the characteristics regarding electroless nickel tend to be useful to feature within industry. In aircraft machines, turbine or compressor rotor blades tend to be plated with electroless nickel as protection up against the corrosive environment they are in contact with. The layer depth in this application is 1 to 3 mils of high-P electroless nickel. Once the rotor blades are plated with electroless nickel, there is about 25 % less losing weakness power compared to whenever plated with tough chrome (Tramontana and Colaruotolo, 1990).

Additionally towards engine-associated programs, electroless nickel discovers several other applications within the aerospace industry. The modestly low coefficient of friction to electroless nickel, mixed along with its corrosion opposition, tends to make it effective in plating servo valves. Landing gear components tend to be plated with 1 to 2 mils of electroless nickel to develop mismatched areas, as well as to provide corrosion opposition (Tramontana and Colaruotolo, 1990).

Gas and oil manufacturing is a crucial market for electroless nickel coatings. Typical environments experienced by equipment and tools utilized in gas and oil manufacturing includes CO_2 and H_2S at conditions of up to 350 to 400º F. Sand and other grit can additionally be experienced, compounding the serious corrosion issues that can develop. Figure 2.6 is a schematic diagram of a typical oil fine, showing the different major elements topic to wear and corrosion (Tramontana and Colaruotolo, 1990).

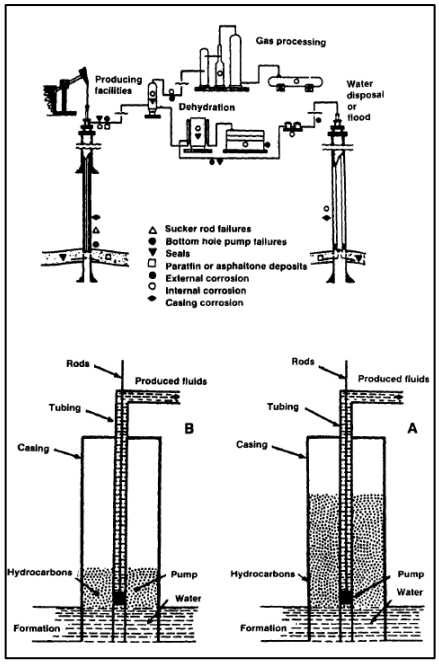

Figure 2.1: Schematic diagram of a typical oil well, showing common corrosion sites (Mallory and Hadju, 1990).

Electroless nickel is commonly utilized for protecting the different pumping elements. Pump housings, impellers, and pump release barrels are plated with 1 to 3 mils of electroless nickel, based on the corrosion environment experienced. Figure 2.6.1 shows another pumping system utilized for low amount creating wells. The sucker pole joint shown in the figure is a perfect electroless nickel application. The uniformity of the layer and the accuracy with which it can be used will keep the integrity of the threads. Tubing packers are utilized in the tubing sequence to seal down the room between the tubing and casing. The packers additionally assist help the fat of the tubing sequence, and anchor it to avoid moving. To avoid corrosion of packers, 1 to 2 mils of electroless nickel is used (Tramontana and Colaruotolo, 1990).

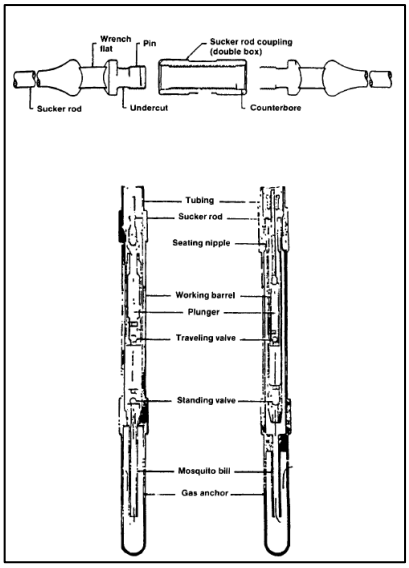

Figure 2.2: Schematic diagram of pumping system for low-pressure wells. The sucker rod (inset) is plated with electroless nickel for corrosion protection (Mallory and Hadju, 1990).

2.2 Comparison between Electroplating and Electroless Plating

Table 2.2 : Comparison between electroplating and electroless plating

Electroplating	Electroless plating
• Uses electricity in its process • Require electrodes of positive and negative • Electroplating deposits are not uniform and plate heavily on the outside edge that are high current areas • Involves more time to construct and skilled craftsmanship	• Does not use power source of electricity • Plating solution begins to plate the mold immediately upon contact and plates uniformly, even in high point areas. • Cost less • More economical