Product development of a nickel-plated fire fighting helmet

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ABSTRACT

This thesis describes the development of a fire fighting helmet for the French market for manufacture by Pacific Helmets (NZ) Ltd, including the major technical development of a process for electroplating unsaturated polyester resin (UP resin).

The need for this study arose from an opportunity identified by PHNZ to enter into the French fire fighting market. The major technical problem was that the helmet shell must be manufactured from nickel-plated UP resin. However, no current technology existed for plating UP resin with a suitably high quality or durability that would withstand the user conditions of a fire fighting helmet.

Literature from existing technologies for plating of similar materials, and attempts at plating UP resin for decorative purposes were reviewed, along with advice from Industry experts in order to understand plastics plating technology and to develop potential methods for plating UP resin for this application.

An iterative hypothesis generation and trial process was used to test potential plating methods in a laboratory on samples of UP resin. A successful methodology was identified. Following this an electroplating pilot plant was constructed and the successful plating methods were used to plate full UP resin helmet shells. Works-like prototypes were constructed using helmet shells that had been successfully applied with a quality and durable electroplated coating suitable for fire fighting helmets. The prototypes were successfully tested against the required product safety standards.

The project concluded with the successful development of a works-like prototype of a Nickel-plated fire-fighting helmet for the French market that met all consumer and technical requirements identified.

Going forward, Pacific Helmets (NZ) Ltd plan to showcase the product at the next annual International Fire-fighting trade show. Plans are currently underway to expand the production facility in Wanganui in order to accommodate the additional helmet production.

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1 INTRODUCTION

This section introduces the study topic, need for research, and the aims, objectives and approach of the study.

1.1 PRODUCT DEVELOPMENT

"The economic success of manufacturing firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low cost."(Eppinger and Ulrich 2000) A product development process is a set of activities used to achieve this goal by taking a market opportunity and developing it through to production, sale and delivery of the product.

Product Development is an interdisciplinary activity requiring contributions from nearly all functions of a firm; however, three functions are almost always central to a product development project: marketing, design and manufacturing. The marketing function mediates the interactions between the firm and its customers. The design function plays the lead role in defining the physical form of the product to best meet customer's needs; and the manufacturing function is primarily responsible for designing and operating the production system in order to produce the product.

The generic Product Development process includes six phases; planning, concept development, system-level design, detail design, testing and refinement and product ramp up. The process is adapted dependant on the unique context of any one product. Common variants of the product development process include; market pull, technology push, platform products, process intensive and customised product development. A market pull process arises when the firm begins with a market opportunity, then finds appropriate technologies to meet customer needs. A technology push situation is when the firm begins with a new technology, and then finds an appropriate market. A platform product is one in which the firm assumes that the new product will be built around an established technological sub-system. A process intensive product development is when characteristics of the product are highly constrained by the production process. A customised product is developed when new products are slight variations of existing configurations.

This study is an interdisciplinary product development process with emphasis on the manufacturing function. The product development opportunity was initialised when the company, Pacific Helmets NZ Ltd (PHNZ) identified an opportunity, a market pull in the French and greater European fire fighting helmet market. The marketing team identified

that the customers were unsatisfied with the existing products on the market and were interested in using PHNZ's helmets as an alternative. In order to meet customer needs it was necessary to customise; develop a product that was a variant of an existing helmet configuration. The company identified one major problem in meeting the needs of the French market; the helmet shells were required to be nickel-plated. At this point the product development project changed from what PHNZ initially thought to be a common customisation of an existing product into a complex process-intensive project with emphasis on the technical development of the process. The development of a process to nickel-plate the helmet material (unsaturated polyester resin) was therefore central to the development of the Nickel-plated F7A fire-fighting helmet.

1.2 THE OPPORTUNITY

Over the past three years, correspondence with PHNZ's existing European distributors identified an opportunity to enter the French fire fighting helmet market. A substantial number of fire brigade members were unsatisfied with the existing product commonly in use, the F1 helmet produced by MSA Gallet (France). Users complained that the design of the Gallet helmet created potential, yet unnecessary risk of injury and fatality through lack of impact and heat resistance. In addition, due to MSA Gallet's monopoly over the market, prices were not competitive and customer service disappointing.

In light of this market opportunity PHNZ conducted initial research on product requirements for the primary market. A comparison of the French product requirements and the specifications of helmets in PHNZ's existing portfolio identified that the PHNZ F7A helmet was consistent with the requirements of the French, bar one characteristic. The N.I.T.No.311 technical information sheet, rules for personal equipment for fire service and rescue personnel in France stated in the general description that the required helmet *"shall be "nickel" in colour, to enhance the thermal reflection properties"*. Further investigation into the needs of the customers identified that the helmet shells must not only be nickel in colour, but nickel-plated in order to compete with the existing product. This alteration to the product formed the major problem-solving challenge of this project.

A financial analysis of the project was made on the assumption that a conservative 25% of the 220,000 fire fighters market share would be gained within 5 years of product launch. The Nickel F7A sale price was estimated at NZ$330. The total cost of production was estimated at NZ$230 - NZ$258, which would result in a total profit of between $4.0 and $5.5 million over 5 years, after which PHNZ aim to continue to increase its market share. See Section 2.13 for further detail.

In addition, there is potential for profits from applications of the process to alternative industries and the intellectual property royalties that may arise from the technology development. Therefore, this project is not only financially viable, but had the potential to be highly profitable for the company.

At this stage a decision was made to progress in the development of a customized Nickel-plated F7A helmet for the French market.

1.3 THE PROBLEM

Gallet's F1 helmet is manufactured from an injection-moulded thermoplastic; acrylonitrile-butadiene-styrene (ABS), which can be electroplated readily due to the chemical make-up of the material. PHNZ helmets are manufactured from resin-transfer-moulded (RTM) unsaturated polyester (UP) resin, which is known to be very difficult, even thought to be impossible, to electroplate. The costs of PHNZ changing from UP resin to a thermoset material such as ABS are considered too high as they outweigh the increased profit that would result from the project. UP resin also offers advantageous mechanical properties over thermoset materials. Thermoset materials have lower melting points than thermoplastic materials. Given that the helmets are required to withstand extremely high temperatures for use in bush fires, the advantage of using UP resin will be central to PHNZ's 'increased safety' marketing strategy. Therefore the project's technical problem lies in developing a method to produce a quality nickel-plated coating on UP resin.

In addition, a constraint in the development of this process is the cost involved. The conservative (exaggerated) additional cost of plating the helmet shells was initially estimated at a maximum of $50NZD is based on existing electroplating costs for similar plastics. If this estimation is accurate, the Nickel-plated F7A will be competitive with Gallet's helmet price.

1.4 PLATING POLYESTER RESIN

"Electroplating is the coating of an object with a thin layer of metal by use of electricity. The industry was developed to plate metals such as copper, zinc, or silver on other less expensive metals, and more recently, plastics." (Hill 1992)

The plating of plastics with metal is an established technology most commonly used for applications in the printed circuit boards, automobile accessory and decorative industries. The process is of particular importance due to its ability to improve the mechanical and aesthetic properties of plastic.

The ability to plate on plastics has been dramatically improved with the development of the electroless plating process, discovered in 1946 by Brenner and Riddel. The reaction/action is purely chemical and runs by itself once started. Plastics most commonly plated in this way are thermoset materials such as ABS, polycarbonate-ABS blends and polycarbonate blends. ABS is the preferred plastic for plating because it has many butadiene rubber particles (seeding points) uniformly distributed throughout the plastic, that can be chemically etched from the surface to produce chemically active, minute holes in the plastic that provide sites for absorption of a catalyst for the chemical plating process (A.E.S.F. 2004).

Among methods of electroplating non-conductive plastics a widely employed method comprises, in succession; degreasing, etching, optionally neutralising and pre-dipping, then applying a catalyst for electroless plating using a colloidal solution containing a tin compound and a palladium compound, and optionally activating (accelerator treatment), followed by electroless plating and electroplating.

Despite advances in the plating of plastics such as ABS, a process achieving a quality surface plating of nickel on UP resin is yet to be found. It is possible to apply a coating of nickel on UP resin. However the low-quality coating is not durable enough for applications to products such as the helmet shells. This is because UP resin cannot be chemically etched to produce chemically active minute holes as readily as ABS.

Recent studies aimed at achieving a quality plated finish on UP resin include techniques of pre-treatment or conditioning of polyesters by exposing them to a solution to provide them with a hydrophilic surface. This permits electroless and electroplating to provide metal surfaces, which possess superior adhesive properties, as opposed to metal surfaces plated onto untreated surfaces (Sopchak and Skovrinski, 1989). However, to date there is no known method of plating UP resin with a nickel coating of high enough quality required for the application to the fire fighting helmets.

Therefore the development of the 'nickel-plating of UP resin' process is not only central to the development of the Nickel-plated F7A fire fighting helmet, but is the technical constraint and technical focus of this study.

1.5 AIM AND OBJECTIVES

The overall aim of this project is to develop a fire-fighting helmet to meet the requirements of the French fire fighting markets. A central focus of this research will be to develop a process to produce a quality nickel-plating finish on UP resin.

The specific objectives of the research were to:

- Identify initial product specifications.
- Develop a process for Nickel-plating UP resin for application to the F7A fire fighting helmet shell.
- Construct a pilot plant in order to produce sample plated helmet shells.
- Produce sample helmets for testing and validation purposes.
- Test the product to ensure all specifications are met.
- Plan production and commercialisation of the product.
- Evaluate the financial and technical feasibility of the project.

1.6 DELIVERABLES

- Process for quality nickel-plated UP resin.
- Nickel-plated F7A fire fighting helmet prototype.
- Recommendations for production plan.

1.7 CONCLUSION

In conclusion, the following thesis documents the development of the Nickel-plated F7A fire-fighting helmet for the French fire fighting markets. The product development began with the identification of an opportunity and was executed through to small-scale production and prototyping. The major technical challenge within the product development project was to develop a process for electroplating UP resin suitable for fire fighting helmets.

1.8 ORGANISATION OF THESES

The project can be divided into three major phases:

A) Product development of the Nickel-plated F7A fire fighting helmet targeted at the French market.
B) Technical development of a process for producing a quality nickel-plated coating on the surface of UP resin for application to the helmet shells.
C) Process development in which the technical process development (B) is scaled-up to accommodate the production of the product.

Figure 1.8-1 illustrates the organisation of the research in which the completion of the product development process (A) is dependant upon the success of the technical development (B) and the process development (C) phases. The relevant chapters to each phase of the process are also indicated.

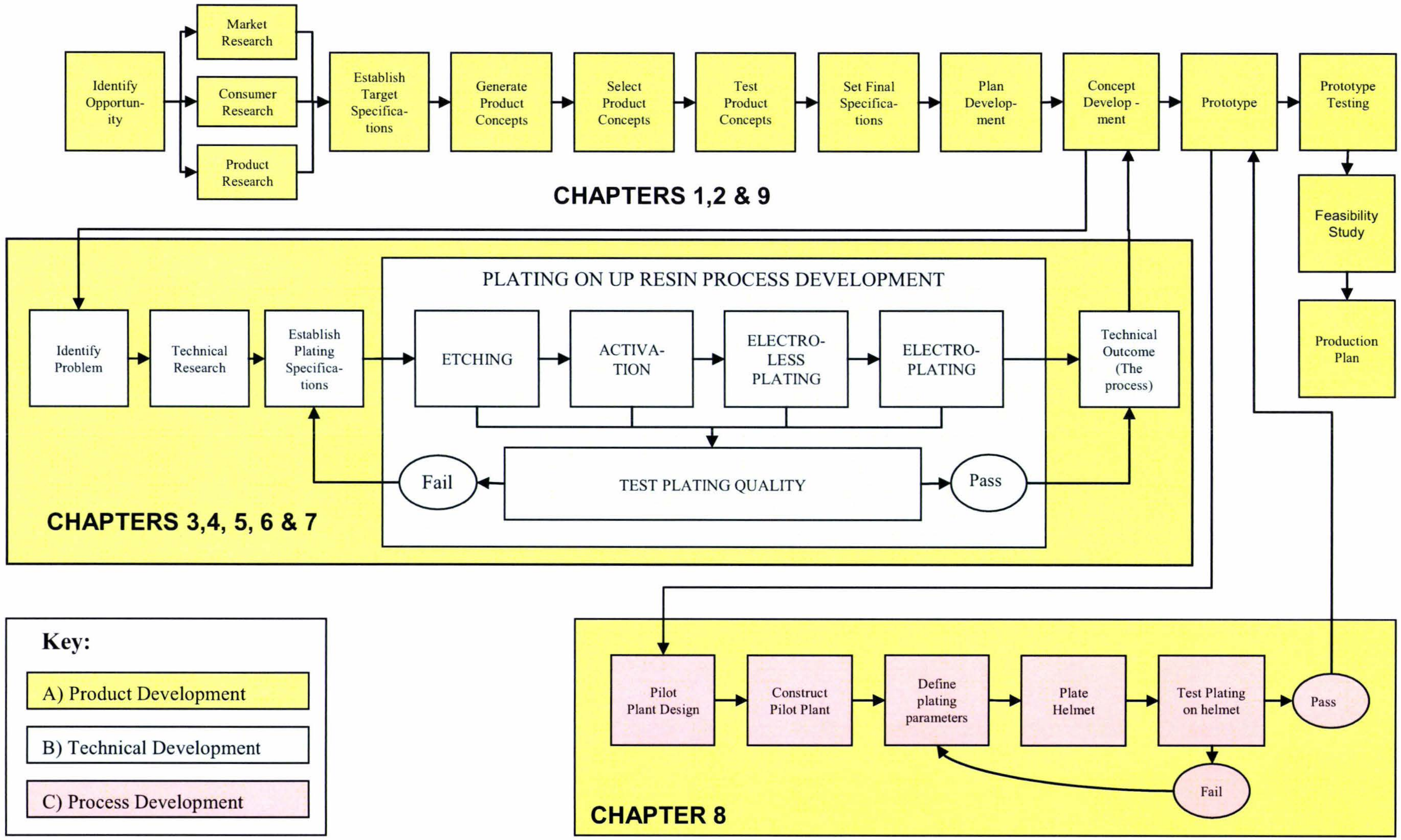

Figure 1-1: Flowchart illustrating the organisation of the research