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**DESIGN AND DEVELOPMENT OF A  
COMPETITIVE WIRE SPLICING  
SYSTEM FOR THE AUTOMOTIVE  
WIRE  
HARNES INDUSTRY**

**A thesis presented in partial fulfilment of the requirements for the  
award of**

**M.Tech**

**In Manufacturing And Industrial Technology**

**Department of Production Technology, Massey  
University, Palmerston North, New Zealand**

***Venkata Subbarao Potharaju, 1997***

## ABSTRACT

The work presented in this thesis is aimed at developing a very comprehensive system of manufacturing wire splices for automobile wire harnesses. Ultrasonic welding is increasingly being used in various industrial applications. Lack of a scientific data-base of its properties when applied to wire splicing is a major reason for lack of proper usage by the wiring harness industry and its subsequent acceptance by the end user. This thesis presents various experiments conducted to develop tensile strengths and electrical resistances of various types of ultrasonically welded wire splices. Crimping technology was evaluated for its mechanical strengths and electrical properties by conducting various experiments to make it possible for the industry to compare it with other alternative splicing technologies. The results are then compared with ultrasonic welding.

The next stage of this thesis discusses the economic feasibility of ultrasonic wire splicing. In order to find the number of ultrasonic welding machines required to meet a particular level of demand, which is a prerequisite for establishing the economic feasibility, a virtual model of the process and the manufacturing cell has been prepared and this model was used to study the dynamics of demand and the number of required machines. Simulation in manufacturing-problem-solving is being used very widely by researchers. Proper understanding and visualisation of the future of the factory and understanding and answering various questions related to the adoption of new technology, is another major reason why companies shy away from adopting ultrasonic welding systems. An advanced simulation tool namely QUEST was used to model the wire splice manufacturing cell of Alcatel and simulation studies were conducted to foresee how the production dynamics would be if ultrasonic welding machines were incorporated in place of crimping machines and various what if scenarios were developed and some vital production related questions were answered.

Material handling is a major bottleneck in any wiring harness manufacturing environment. Some conceptual designs are presented on automating the task of feeding wires to ultrasonic welding machines and transferring the wire assemblies from welding stations to different work stations, currently being done manually. A wire palletising system was designed to improve the productivity.

This thesis concludes that ultrasonic welding could be very effectively used for wire splicing and could be safely used in the manufacture of wiring harnesses for the automobile industry.

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*I dedicate this thesis to my wife Madhavi*

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# *Chapter-1*

# 1. INTRODUCTION TO THE THESIS AND OBJECTIVES OF THE RESEARCH PROJECT

## Introduction

This chapter gives an overview of the current state of affairs of the wiring harness industry. After having established the back-ground of this research, an introduction is given to the current methods of manufacturing wiring harnesses. This research was carried out for Alcatel New Zealand Limited, the industrial collaborator for this activity.

### 1.1 Introduction to the wiring harness industry

Electrical wiring harness can be visualised as a kind of nervous system of many electrical systems in which it finds its place, with the mantle of reliably and efficiently transmitting the power falling on it. There are over 160 manufacturers of wire harnesses and fabricated lead wires for passenger auto, truck and other commercial and industrial vehicle applications in the world today [1]. There are many other major industries including white goods, brown goods, office/electronic data processing, control and industrial electronics, aerospace and others accounting for a multi billion dollar market world wide.

With today's advanced automotive control systems, manufacturers of electrical harnesses for vehicle use are faced with even more stringent requirements for reliable connections in their automotive harnesses, with the other industries the case being no different and far more demanding in some industries like aerospace. Increasing demands for on-board sensors and microprocessor controls create a need to achieve flawless wire terminations capable of reliably transmitting low-voltage signals. Even the slightest variation in resistance across a circuit will create havoc. In addition to the quality control by the various industries, there is an increasing emphasis on overall weight reduction of vehicles. A typical wiring harness assembly amounting to about 100 lbs, is a major area for considering weight reductions [1].

Furthermore, the manufacturing of cable harnesses and networks has, using traditional methods, been an extremely costly, labour intensive and monotonous process. Methods used to construct cable harnesses have necessitated long lead times, large series and a substantial amount of tied up capital. The cost of producing and installing cable harness represents a large proportion of the total manufacturing cost of any electrical system. For example, the cost associated with cables in a modern car represent the second largest item, after the engine but before the bodywork [2].

This need to achieve improvements in wiring harnesses has led to research in many institutions world wide, in the design, manufacturing and assembly of wiring

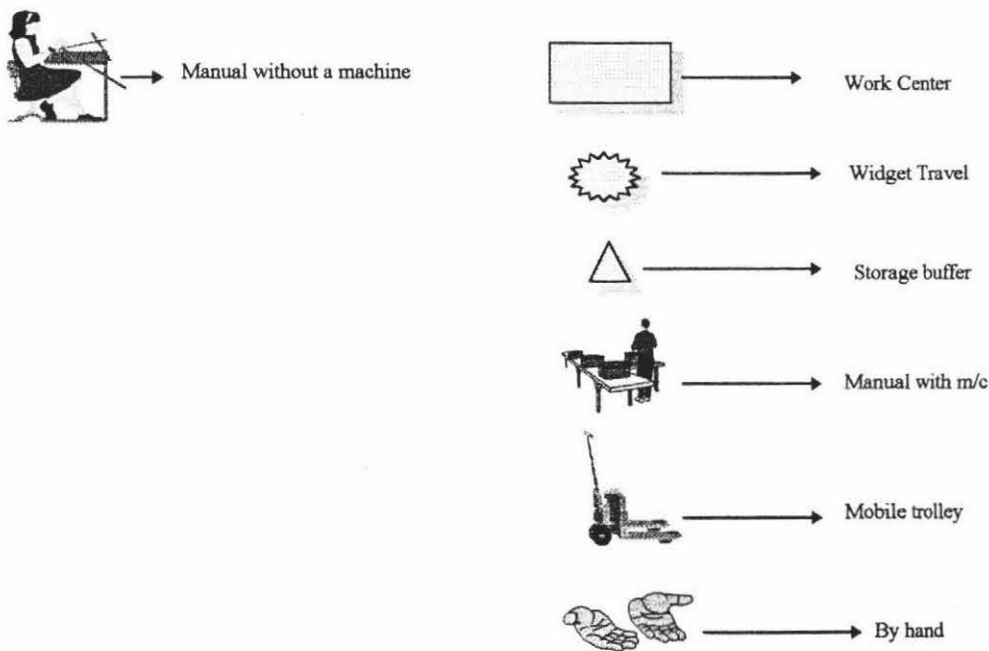
harnesses.

It is high time for the New Zealand wiring harness industry to look at not only improving productivity but to drastically reduce the cost of manufacturing to compete in new markets. Besides the cost, a better quality and appearance to the product is a major thrust for the industry's success in the future.

### 1.1.1 The wiring harness manufacturing process

The most common method of manufacture, being adopted currently by the majority of the industry, is presented below.

The different operations involved in the manufacture of the wiring harness could be easily understood by looking at typical operations identified as following:



**Figure 1-1, Legend to the system description**

The system flow chart described below, uses the legend of various operations in the above Figure.

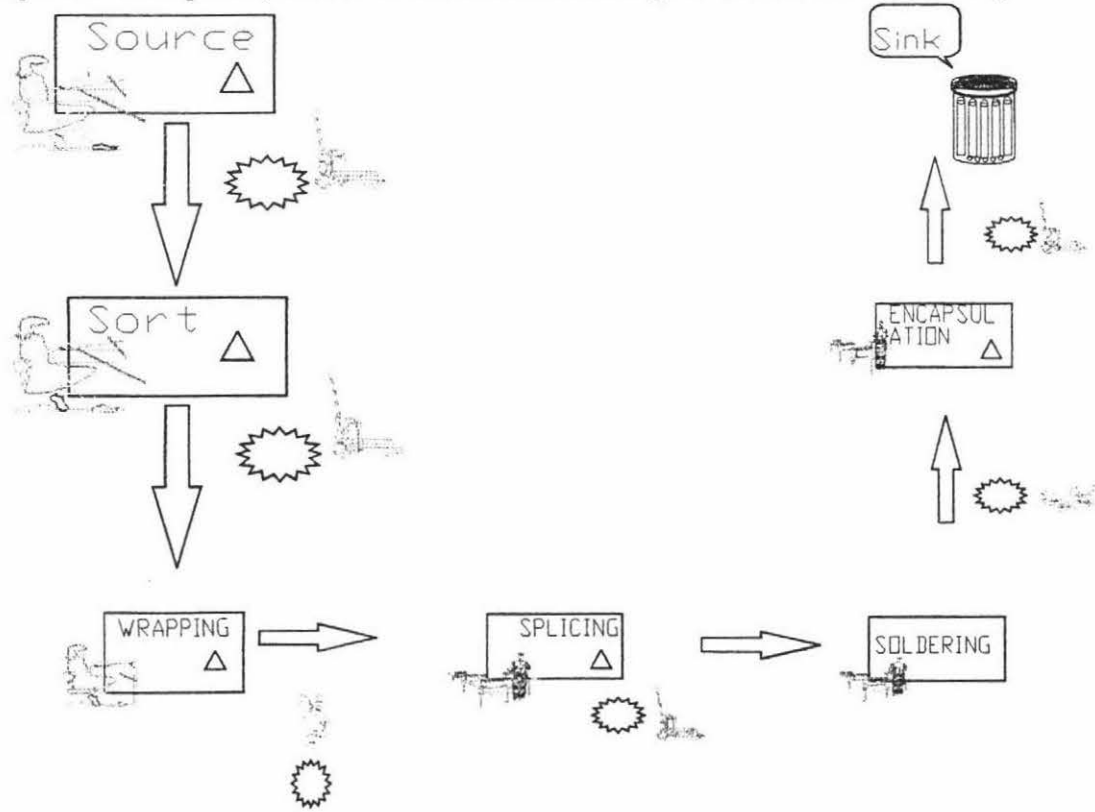
- Source, is the station where all the wires are cut and stripped-off the insulation at the ends, come and wait before going in for the next operation.

- Sorting is where, the wires are grouped on the information available from their route cards and sorting decides where the wires would go next.
- Wrapping is where the wires are individually wrapped to conform to the drawing of a specific joint that the wires are supposed to form.
- The next operation is where the wires are spliced before they go for joint encapsulation, where the joints are wrapped with insulation.

Wires coming from the storage facilities are cut to the desired lengths and stripped, i.e., the insulation sheath at the wire ends are removed. This is made on one machine i.e., the cutting and stripping is done in single stroke on one machine. The insulation at the wire ends is removed to facilitate the placement of other electrical terminals. This piece, known as “lead” goes further in the series of operations to get joined with other leads, then called J-lead, or may as a single lead go downstream.

In the next step of operations the electrical terminals are attached to the leads or J-leads by crimping machines . The other possible operations on these leads could be of sleeving or connector assembly.

Some cables need to be joined or spliced together to form a joint, known in the industry jargon as “internal join”. This could be a down stream operation after the termination, sleeving or it could be a direct downstream from the cut and strip. These spliced wire splices, with terminals attached then go to the on board assembly.



**Figure 1-2, A flow diagram of a typical wiring harness manufacturing process**

## 1.2 Wire splicing

Wiring harnesses typically contain several splice junctions of multiple wires. The number of splice junctions (in other terms called wire splices) coming in a wiring harness vary typically with the size and design of the harness. Nevertheless, irrespective of the number of wire splices, they are like nodal points prone to mechanical, electrical and chemical failures [6]. The overall reliability of the wiring harness, undoubtedly, depends on the reliability of the wire splices.

There are three major methods [3] of making the splices; the crimp method, resistance welding and ultrasonic welding, explained in section 2.1.

## 1.3 Objectives of the project

The objectives set out for this project, which was sponsored by The Foundation For Research, Science and Technology (FRST), Government of New Zealand, under the Graduate Research in Industry Fellowship (GRIF) [45], were:

- Evaluate the crimping technology, currently being used by many wiring harness manufacturers, to manufacture the wire splices. This was to be done by quantifying the electrical and mechanical properties.
- Study other alternative techniques of producing the wire splices and identify the one which is technically and otherwise superior among all the alternative techniques.
- Evaluate the identified alternative technique for its electrical and mechanical strengths, when used for wire splicing.
- Compare the crimping technique with the alternative technique on electrical and mechanical strengths and weaknesses.
- Help the industry in adopting the technology in the right technical form and help them in implementing the technology, to make it successful. Implementation of the technology is again divided into two sections:
  1. Study the effect of the new technology on the production dynamics of the industry. Specifically on the factors like how the new technology would cope with the fluctuations in demand and other important production related factors. This was envisaged to be made by developing simulation models of the future plant, with machines using the new manufacturing technique and give feedback to the

industry.

2. Study the manufacturing aspects of the technology and come up with some solutions to some of the material handling problems. This was to be made by identifying the problems currently being faced and then come up with some conceptual solutions in terms of automatic part presentation systems and part transfer systems and produce a conceptual design.

#### **1.4 Industrial collaboration**

This project is made in industrial collaboration with Alcatel New Zealand Limited, a leading automotive wiring harness manufacturer in New Zealand.

Alcatel is one of the world's largest manufacturer and supplier of telecommunications equipment. Alcatel New Zealand is a major supplier to Telecom, providing locally designed and manufactured telephones and other sophisticated hardware and software products. Submarine optical fibre cable systems, printed circuit boards and wiring harnesses for the automobile industry are among the other products manufactured at the Alcatel's manufacturing plants in Masterton and Upperhutt [4].

This project was based at the Masterton plant which is concerned solely with the processing of electric cables into wiring harnesses for the automobile industry. The majority of these harnesses are manufactured for domestically assembled cars and commercial vehicles.

#### **1.5 Preview of the thesis**

In this section a brief overview of what is being presented in various chapters is discussed.

Chapter-2, presents the fundamental introductory discussion of different types of wire splicing techniques and a relative comparison is made between the three known types, viz., crimping, resistance welding and ultrasonic welding.

In Chapter-3 an attempt is made to bench mark the crimping technology, which is by far most widely used for making crimped wire connections. Experiments, which have been carried-out to quantify the mechanical and electrical strengths, are discussed and the results are presented.

Chapter-4, discusses the technique of making wire connections with ultrasonic welding. Quantification of the electrical and mechanical strengths have been made in this chapter.

In Chapter-5 a comparison is made between the crimped connections and

ultrasonically welded connections. Electrical and mechanical properties are compared, besides a comparison of other factors such as the splice volume, appearance, modes of failure etc., is also made.

Economic feasibility of ultrasonic welding is discussed in chapter-6. A virtual model has been presented as a tool to study the dynamics of production and an attempt is made to use this to establish of economic feasibility.

How ultrasonic wire splicing could be implemented in an industrial environment, where crimping is the current method of splicing, is discussed in chapter-7.

Finally, the thesis is drawn to a conclusion after chapter-7.