Optimization in Vibration Cell

Grado en Ingeniería
en Tecnologías Industriales

Trabajo Fin de Grado

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Abstract

The aim of this project is to optimize the processes that take place in the Vibration Cell. By applying lean manufacturing techniques to produce lighting products with similar manufacturing processes, the factory expects to reduce rejection, cycle times and costs and improve quality and throughput. This project outlines a method for assessing, designing and implementing lean manufacturing techniques. The object of study and improvement is the Vibration Cell that produces automotive lighting systems for commercial customers in the Chakan plant of Rinder India Pvt. Ltd. All products that are produced in the cell have in common vibration welding and annealing, followed by assembly, testing and packaging processes.

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1. Introduction

1.1 Current Environment

The environment in which Rinder India Pvt. Ltd. operates today is very different from the one in which it had initially commenced. Current production systems are developed in a changing global environment, which, due to the emergence of new obstacles such as market saturation, increased competition or the changing needs and demands of customers, have forced the company to adapt to ensure survival.

India is an emerging economy in which the automotive industry is one of the most booming industries. Large population and rapid economic growth mean India will become the powerhouse of middle class consumerism over the next two decades. India registers a continuous growth in vehicle sales and that means that the automotive industry needs to be prepared to the new market demand.

Important improvements in technology, communications, and transportation are not sufficient to ensure adaptation to the environment. Companies must change their outdated methods with more efficient and appropriate organizational structures. The challenge for companies is to produce large quantities of good quality products at low cost. To achieve this goal it is important to accommodate the patterns of production to the burgeoning demand using competitive advantages such as low cost of manpower.

1.2 Necessity of implementation Lean Manufacturing techniques

The main objective of Lean Manufacturing is to remove and minimize non-value work activity from the manufacturing process. Since the introduction of continuous flow and the concept of assembly line processing by Henry Ford[1] with the production of the Ford Model T, the industrial world has experienced a huge number of changes and modifications due to the continuous and ever-increasing customer demands and expectations.

The manufacturing world has transformed the production and operational fields in recent times. The use of new fabrication and assembly methods based on technology has created the need to reorganize management and engineering policies in order to keep high quality standards and minimum possible cost. Lean Manufacturing definitely takes the lead for such changes in the industrial world.

Lean manufacturing has changed the way factories have operated in the past. Managers of different companies such as Toyota, IBM Credit, and Kodak among others have demonstrated with their own experiences that lean manufacturing is a tool that has helped them eliminate waste and achieve efficiency in production.

- Streamlines the company's processes: The implementation of Lean Manufacturing techniques allows a manufacturer to streamline their processes throughout the entire organization. Efficiencies are witnessed, processes are

[1] *Henry Ford:* American industrialist, the founder of the Ford Motor Company, and sponsor of the development of the assembly line technique of mass production.

optimized and the manufacturer is able to work at its full potential. This results in an important reduction of manufacturing cost and increased speed to market.

- Reduction of costs and removes waste: Lean addresses the following areas of waste: motion, inventory, waiting time, transportation, information, quality, overproduction, processing and creativity. If the company reaches the goal of eliminating unnecessary waste, it has the opportunity to abolish time spent on unnecessary tasks and save money.
- Quality and working conditions improvement: In order to improve the quality of processes and products without extra waste, Lean techniques allow the employee to carry out his tasks in the best possible way. In addition, Lean techniques build teamwork and cooperation.
- Continuous Improvement: The job is never done because there are continuous opportunities to improve the performance of the company.

1.3 Legislative requirements and regulations

During the execution of a project, legal requirements must be considered. Adhering to legislative requirements and regulations is essential for industrial activities, and if they are not considered the company can face serious penalties. A range of legal requirements to be considered are as follows:

1) BS OHSAS 18001:2007: Legal requirement that sets out the minimum requirements for occupational health and safety management best practice.
2) ISO 14001:2004(E): Standard that specifies requirements for an environmental management system to enable an organization to develop and implement a policy and objectives which take into account legal requirements and other requirements to which the organization subscribes, and information about significant environmental aspects.
3) ISO/TS 16949:2009: In conjunction with ISO 9001:2008, defines the quality management system requirements for the design and development, production and, when relevant, installation and service of automotive-related products.
4) CNCA-02C-065:2005: This regulation applies to various kinds of exterior lighting and light signaling devices (hereinafter called lights for short) used for motorcycles and mopeds, but does not apply to reflex reflectors.
5) Directive 2004/104/EC: This directive requires manufacturers to gain type approval for all vehicles, electronic sub-assemblies, components and separate technical units. Products that have direct control of the vehicles must not emit EMC[2] emissions above the limits and must be immune to interference levels stated in the directive. Products without direct control only have to meet the emission requirements.

[2] *EMC*: Electro Magnetic Compatibility

1.4 Phases

All the executed work is divided into 5 different phases.

1) Literature review where knowledge is acquired to understand the topics and be able to develop the work subsequently. First, the basic knowledge about the company have been acquired. Then the different lean manufacturing techniques have been identified. Also, the different processes and products are understood. Then information about components of automotive lighting systems is studied. Finally the overview is focused on the cellular manufacturing.
2) Analysis of vibration cell situation. All processes and products involved are analyzed. Cycle times have been measured, process flow was identified and all products were classified. Capacity of the cell are calculated and then the number of required assembly lines was obtained.
3) Optimization of the vibration cell. Design of lines are made according to the products requirements. Proposal of changes in lay-out, stages and processes are presented. Lean manufacturing techniques are used in the proposal of productivity improvement.
4) Implementation of changes. Accepted proposals are implemented. Then new performance of the cell is analyzed and problems observed in implementation are solved. Finally new capacity calculation with new cycle times is made.
5) Economic and production impact is analyzed. Conclusions and personal opinion about the project is discussed.

1.5 Planing

This project was carried out in parallel with an internship program. The guidelines given by the tutor of the company have been the guide to its realization. The optimization process of the cell was occurring within eighteen weeks, coinciding with the duration of the partnership held in the factory of Rinder in Chakan, India.

	February		March					April				May				June		
Tasks	16	23	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15
Knowledge acquisition																		
Literature overview																		
Study of the actual Vibration cell Processes																		
Required investments																		
Regulation and Legislation																		
Product																		
Analysis of produced products																		
Actual process flow																		
Technical aspects																		
Process optimization																		
Analysis of problems in processes																		
Design of assembly lines																		
Lay out																		
Tasks and production orders																		
RRHH																		
Throughput																		
Production impact																		
Economic impact																		
Process set up																		
Report writing																		

Figure 1: Gantt Diagram

2. General description of the company

2.1 History of Rinder Corporación

Rinder Industrial was founded in 1952 in Gernika (Bizkaia). From the beginning, its activity was the creation, design and development of lighting equipment and grew to become a world leader in designing and manufacturing lighting equipment for the automotive industry.

It started manufacturing bicycle dynamos (Figure 1). In 1963 the first lighthouse for an OEM[3] was made. In 1973 Rinder exported its products to all countries of the CEE[4]. Since then, the market has expanded to over sixty countries on five continents.

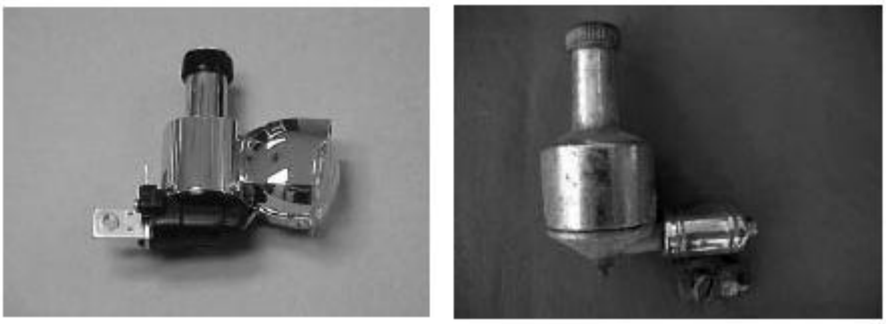


Figure 2: First product of Rinder Industrial

Rinder Industrial was, therefore, the origin of Rinder Group, which in September 2006 was configured as Rinder Corporation as a result of the business growth that the company had experienced. The plant in Gernika, and having grown since to five different factories (last in 2000), has always been dedicated mainly to the standard product market (mainly parts), producing a simpler product easy to sell, and delivered positive returns. However, over the years also has supplied to the principal manufacturers in the Spanish market (from the Gogomobil, made in Mungia, to SEAT or Pegasus, through the Spanish majors: Derbi, Sanglas, Motovespa, Barreiros, etc.). For those manufacturers, so few in those years, they produced lights, indicator lamps ... and that was the beginning of working as a Tier-1 supplier, to which, later, it also started exporting.

A critical juncture in the evolution of Rinder occurred during the economic crisis of the Spanish and European economies in 1992, when they began to assess a number of major changes in the organization and strategy of the company. The shareholders took the decision to bring a person of the "outside" to management, rather than choosing it among the shareholders as they used to do. In 1993, Fernando Echevarría, managing director of Corporación Rinder, reached Rinder Industrial Management from its previous management experience in the machine tool industry.

The market, coming out of the crisis, had new needs and there was only one Spanish lighting manufacturer, which was devoted exclusively to original equipment. The

[3] OEM: *Original Equipment Manufacturer.* The OEM is the original producer of a vehicle's components (Toyota, General Motors, Volkswagen, Honda,Yamaha etc.).

[4] *CEE: European Economic Community.*

standard product Rinder Industrial was a business that was doing well in its natural setting, which was the Spanish domestic market. The future of business standard product would be a matter of price, and that, sooner or later, would be a serious problem.

This new strategy was that Rinder Industrial would bank on its position as a Tier-1 supplier, because there was not much competition in the sector at that time. The idea was to invest in the ramping up as an OEM supplier with all money gained through its spare parts products. This vision of two distinct and complementary businesses began to mark two different strategic lines also with regard to the geographical markets, which would be key in the internationalization of Rinder. On one side was the standard replacement product, which had been exporting for some time to a few countries (UK, Sweden, France, Morocco, Norway, Israel, Chile and Mexico, amongst others), usually through agents and in other cases, wholesalers (exclusive or not). Then there was the first computer market in which there were significant changes and the environment offered more opportunities.

This firm commitment as an OEM supplier was established with the idea of having as Rinder´s clients the world's leading motorcycle manufacturers, but the gateway to those companies were subsidiaries of these organizations in Spain. Facing this situation, in late 1995 Rinder started to think of establishing itself abroad. The possibility of working with Japanese multinationals in its original market (Asia) did not seem too far-fetched if they were already worked with them in the European market.

The result of this multi-nationalization, developed by the team led by Fernando Echevarría, was the implementation of Rinder in India in a sequential manner, with the establishment of four production plants abroad under two separate companies: Rinder India Pvt Ltd. with three plants, and Rinder Tools India Pvt Ltd. with one. The chronological sequence is as follows:

• Rinder India Pvt. Ltd. (Pimpri) in 2000[5], located in Pimpri, Pune, India.
• Rinder India Pvt. Ltd. (Chakan) in 2002, located in Chakan, Pune, India.
• Rinder Tools India Pvt. Ltd. in 2006, located initially in Pimpri, Pune, India, and later moved to Chakan.
• Rinder India Pvt. Ltd. (Delhi) in 2008, located in Delhi, Bahadurgarh Haryana, India.

Similarly, in Spain, this new corporate strategy produced the creation of new plants which were added to Rinder Industrial, SA, from the plant of Gernika (Bizkaia). The new locations were:

• Light & Systems Technical Center, SL in 2006, located in Zamudio, Bizkaia.
• Global, SL Electrical Systems in 2006, located in Parets del Valles, Barcelona.
• Lampsys Light Systems, SL in 2008, located in Gasteiz, Araba.

Rinder continues its internationalization policy, is why Rinder has recently installed a new plant in Colombia:

• Rinder Riduco in 2013, located in Colombia.

[5] Since 1997 in collaboration with a partner Hindu.

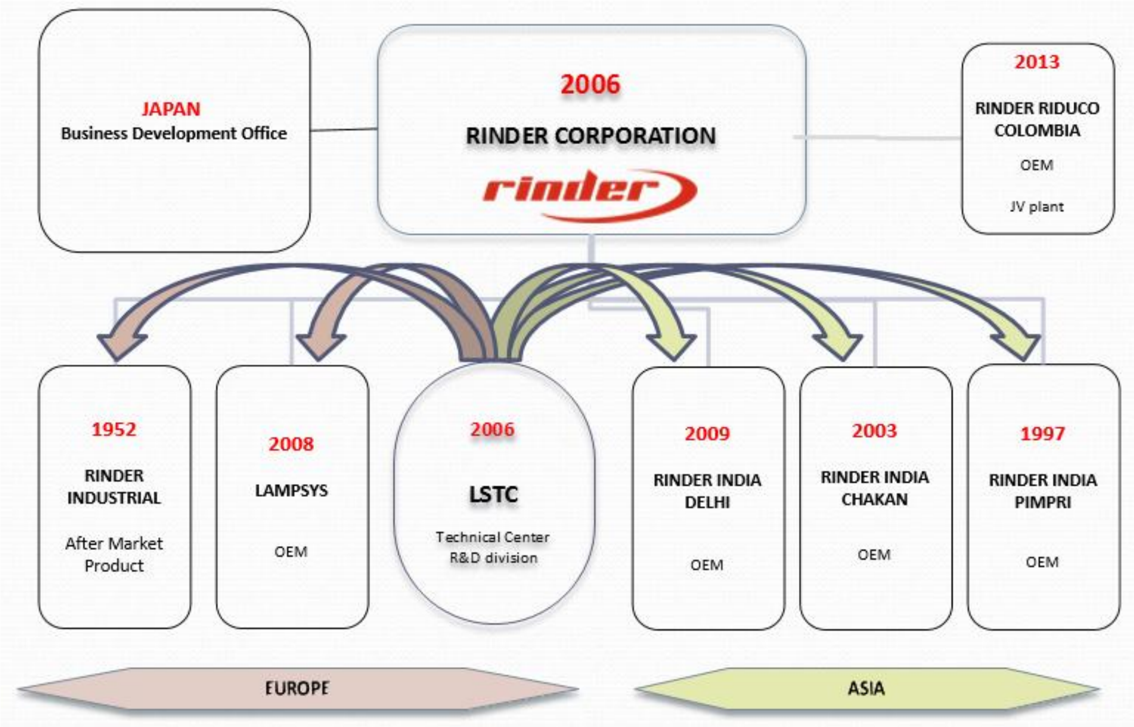


Figure 3: Rinder Corporation structure

2.2 Rinder India Pvt. Ltd.

The creation of Rinder India Pvt Ltd arose from the need to convert Rinder Industrial into an international and competitive company in the field of first automotive lighting equipment. It was in late 1995 when the approach of entering a new country began to take shape.

JK Jain, an Indian manufacturer, had contacted Rinder offering a cooperation agreement. Rinder evaluated the risks and decided to enter India through a technical assistance agreement[6]. The agreement was that Rinder designed and made molds of the products, so with the charging of the molds it recovered expenses and also obtained a royalty per piece.

In 1997 Rinder had a very large portfolio of projects and that boosted the interest in collaborating with the Indian partner. After arduous research and hiring an Indian consultant, who was the owner of Derbi, it was decided to sign a joint-venture with JK Jain in 1998.

With the signing of the joint-venture Rinder bought an Indian plant. This was rudimentary, but that allowed Rinder to begin to have contact with customers and have a factory in operation. Rinder invested half a million euros in exchange for half the shares of a new company named Fien Rinder Pvt. Ltd. With this agreement it became the co-owner of a plant located in Pimpri. Among the advantages of locating this plant

6 *Technical assistance agreement:* is essentially an agreed to "rule book" that governs how and what technical information will be discussed, presented, and/or conveyed by any means to a foreign national.

was one of the projects underway at a major company located nearby, TATA[7]. The plant was working on producing their product, but the benefits were very low.

The first problems began to emerge when the company decided to rebuild the factory. Cultural differences and the requirements of the partner made Rinder spend too much money on proposals related to Indian culture. Pimpri plant had to be constructed in two phases and according to Vastu Shastra philosophy[8].

The projects took time (about five or six months), but were ending and the factory started to have little to no capacity to produce. There were only available three very old injection machines. A metallic machine was bought, nonexistent up to this point in the plant, with cash made by Rinder, but when the funds depleted, there was no more capital. The partner refused to provide more investment capital and Rinder decided to block the company until the situation was untenable.

In 2000 Rinder was made with 100% of the shares of the company and the previous partnership was dissolved leading to another with the name of Rinder India Pvt. Ltd. The purchase of the property resulted in the loss of the largest customer (TVS Suzuki[9]) but kept the other (Bajaj[10]). Bajaj was successful in the market and this relationship led to Rinder starting to work with Kawasaki. Kawasaki took the decision that Rinder be their sole supplier and everything produced in India for Kawasaki was exported to Indonesia, Malaysia, Thailand, the United States and Japan.

Figure 4: Rinder India locations

[7] *Tata Motors Limited:* The largest manufacturer in Indian automotive industry. It is the leader in commercial vehicles, and among the top in passenger vehicles.

[8] *Vastu Shastra philosophy:* ancient building science which covers the philosophy and theory of Architectural works to construct any building and as well as living style of people.

[9] *TVS Suzuki*: manufacturer of motorcycles, scooters, mopeds and auto rickshaws in India.

[10] *Bajaj:* Manufacturer of motorcycles and Vespa-style scooters in India.

During the first decade of this century, Rinder continued their journey through India as a Tier-1 supplier to the automotive industry with technology and design that came from the Basque Country. Rinder India Pvt. Ltd. was established as a wholly-owned subsidiary of Rinder Corporation, and thus began their new ventures in India: in 2003 at Chakan, Pune; in 2006 in Pimpri, Pune; and in 2008 in Delhi, Bahadurgarh Haryana.

Currently Rinder India Pvt. Ltd. continues to grow and now has over 20 customers and a high demand for new projects. Given the good experience with its implementation in India, Rinder continues its internationalization strategy, which is being considered for its implementation in other developing countries.

2.3 Rinder India Pvt. Ltd. Chakan

The plant of Rinder in Chakan is the biggest of the corporation in India. It started activities in 2003 and now has 25.200 m^2 of manufacturing facilities. Its production capacity is over 4.000.000 headlamps and has 650 employees. The products that are manufactured in the plant are headlamps, tail lights and exterior lighting for motorcycles, scooter, commercial and industrial vehicles.

Figure 5: Factory of Rinder India Pvt. Ltd. in Chakan

2.4 Customers

Rinder India has expanded its coverage to almost every part of Asia and has established a good customer base in the ASEAN[11] countries as well. The Rinder Chakan plant produces lighting systems for domestic and foreign customers. While Rinder business is based solidly in two wheelers, and it also has a small base in four wheelers sector. The experience of Rinder Group in manufacturing lighting equipment and its capability to offer its customers global solutions with the same quality standards no matter where they are located are important strengths to continued growth. The support of the design center of the group, their molds-developing center and the capacity to

[11] *ASEAN:* Association of South East Asian Nations.

offer a global vision of sector trends are a very high added-value component that benefit its customers to the extent of being considered a Leading Company in technology and services in his field.

Customer	Type of product	Market
BAJAJ	Two Wheelers	Domestic
TVS	Two Wheelers	Domestic
FIAT	Four Wheelers	Domestic
TATA	Four Wheelers	Domestic
ROYAL ENFIELD	Two Wheelers	Domestic
MARUTI SUZUKI	Four Wheelers	Domestic
HERO	Two Wheelers	Domestic
MAZDA	Four Wheelers	Domestic
ASHOK LEYLAND	Four Wheelers	Domestic
NISSAN	Four Wheelers	Domestic
SUZUKI	Two Wheelers	Domestic
TELCON	Four Wheelers	Domestic
JCB	Four Wheelers	Domestic
MAHINDRA	Four Wheelers	Domestic
DAIMLER	Four Wheelers	Domestic
TRIUMPH	Two Wheelers	Domestic
V.S.T.	Four Wheelers	Domestic
HONDA	Two Wheelers	Domestic
KAWASAKI	Two Wheelers	Exports
PEUGEOT	Two Wheelers	Exports
KTM	Two Wheelers	Exports
YAMAHA	Two Wheelers	Exports
PIAGGIO	Two Wheelers	Exports

Table 1: Customers of Rinder India Pvt. Ltd.

Rinder India has achieved a phenomenal growth since its inception a decade ago. Today, Rinder India enjoys a market share of nearly 17 percent in the two-wheelers lighting solutions business. The company hopes to continue to grow between 15 to 20 percent year-on-year. In the two-wheeler business, Rinder counts Bajaj Auto (its largest client), TVS Motor and Hero as key clients. This sector remains the core business area.

Customer	Sales (INR)	Sales (€)
BAJAJ	741727954	10596113,63
TVS	481388827	6876983,24
Hero	260321662	3718880,89
KAWASAKI	211444740	3020639,14
ROYAL ENFIELD	90881325	1298304,64
AL-NISSAN	47919868	684569,54
SMR	20451586	292165,51

Suzuki	7821350	111733,57
PIAGGIO	6829964	97570,91
TATA	6608910	94413,00

Table 2: Sales by customer in 2014

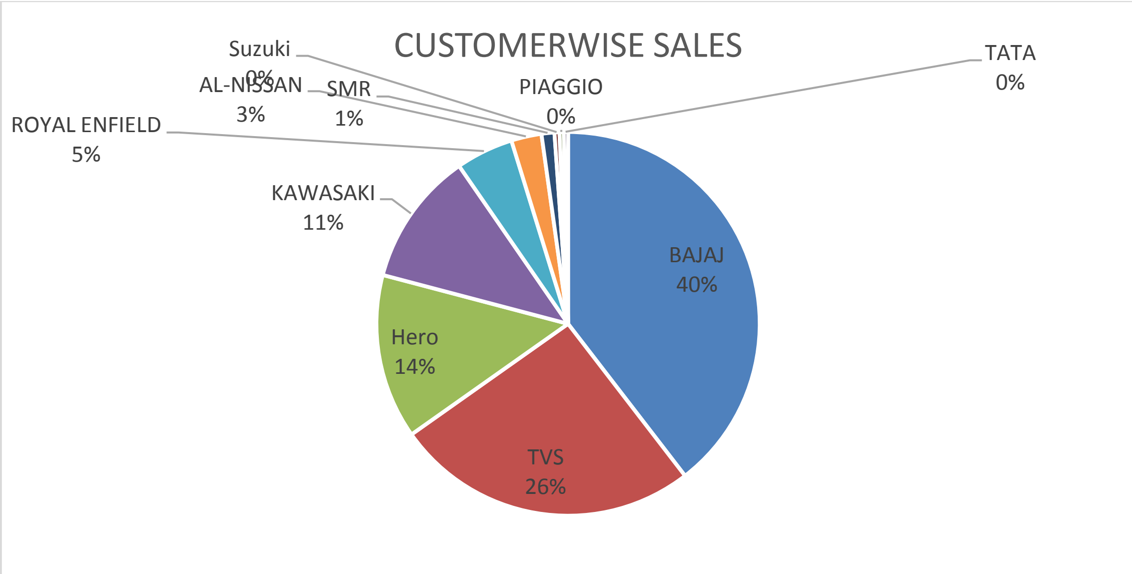


Figure 6: Comparative chart of sales by customer in 2014

2.5 Products

The products that Rinder produces are head lamps, work lamps, front lamps, rear lamps, position lamps, side marker lamps, side indicators, brake lights, number plate lights, reversing lights, fog lamps interior lights and reflectors.

The main production is focused on two wheelers products like head lamps, tail lamps, blinkers and license plate lamps. Rinder is a company with great experience in two wheelers products, but the increasing market sales of four wheelers forces the company to develop its technology to produce products for the four wheelers market to then becoming more competitive. The market of the four wheelers is much more demanding than that of the two wheelers sector, but this is due to quality and safety requirements. Below is a table with the volume of sales by type of light.

TYPE OF LIGHT	**SALES (INR)**	**SALES (€)**
HEADLAMP	1282832473	18326178,19
TAILLAMP	420928107	6013258,67
BLINKER	168723560	2410336,57
LICENSE PLATE LAMP	2912045	41600,64

Table 3: Sales by type of light in 2014

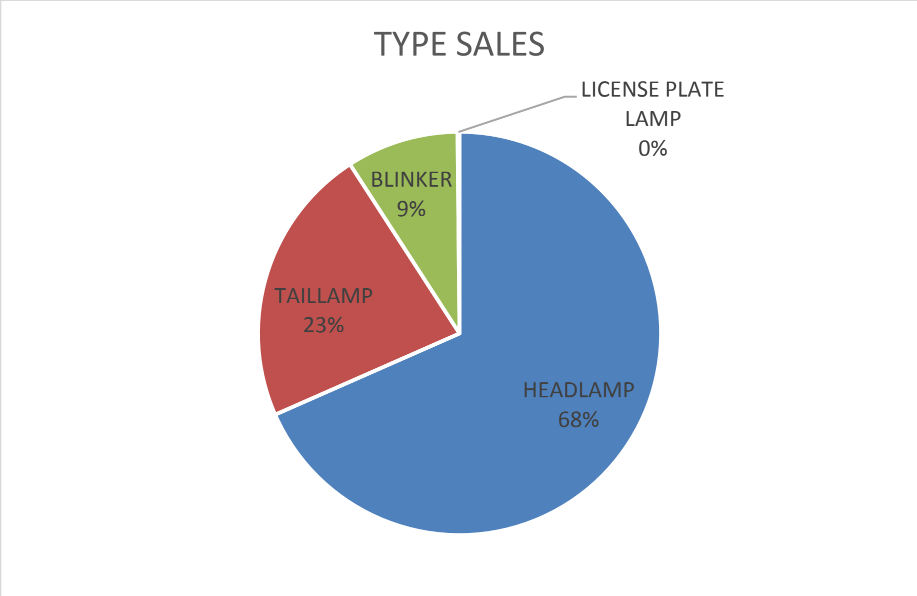


Figure 7: Comparative chart of sales by type of light in 2014

2.5.1 Headlamp

A headlamp is a lamp attached to the front of a vehicle to light the road ahead. While it is common for the term headlight to be used interchangeably in informal discussion, headlamp is the term for the device itself, while headlight properly refers to the beam of light produced and distributed by the device. The following lighting functions can be combined in the headlamp:

- Low beam: This beam provides short-range illumination. The low-beam functions are subject to legal regulations designed to protect oncoming traffic from being dazzled.
- High beam: This beam provides long-range illumination of a road, chiefly for use in nonurban areas.
- Front fog light: Powerful light for use in foggy conditions.
- Position light: This light provides nighttime standing-vehicle conspicuity.
- Daytime running light: Light that increase the conspicuity of the vehicle during daylight conditions.
- Direction indicator and side marker light: Light to advertise intent to turn or change lanes.

Figure 8: Headlamp of Kawasaki Ninja ZX6R

2.5.2 Tail lamp

A tail light or a tail lamp is the part of the lighting system of a vehicle which is attached at the rear part of the vehicle. They can be one or can come in pairs (left and right). It has different types for different functions:

- Signal lights: This lights indicate whether the vehicle is going to turn right or left. They are also used during times of emergency.
- Reverse lights: The reverse lights indicate if the vehicle is backing up and are automatically turn on when the driver puts the vehicle in reverse shift.
- Park light: This light signals the drivers behind that there is a presence of another vehicle whenever it is dark, foggy or rainy weather. It is also used as a brake light. The park light usually has the highest part in the assembly which turns on as the driver steps on the brakes.
- Position light: This light provides nighttime standing-vehicle conspicuity.

Figure 9: Tail lamp of Ashok Leyland truck

2.5.3 Blinker

A blinker is a type of automotive lighting, known also as directional indicator. It is an indicator that gives out an intermittent light. The blinker is activated by the driver to advertise intent to turn or change lanes.

Figure 10: Standard Rinder Blinker for motorbikes

2.5.4 Reflector

A reflector is a side-facing device that makes the vehicle's presence, position and direction of travel clearly visible from oblique angles. It uses the principle of retro-reflection to alert another road user of the vehicle presence on the road. The light striking the rear, inside surface of the prisms, does so at an angle greater than the critical angle thus it undergoes total internal reflection. Due to the orientation of the other inside surfaces, any light internally reflecting is directed back out the front of the reflector in the direction it came from. This alerts the person close to the light source to the presence of the vehicle.

Figure 11: Rear reflector of Volkswagen Polo

2.5.5 Mirror Indicator

Mirror indicators are blinking lamps mounted in the mirrors of a vehicle, activated by the driver on one side of the vehicle at a time to advertise intent to turn or change lanes toward that side.

Figure 12: Mirror Indicator of Mahindra XUV 500

2.5.6 License plate light

A license plate light illuminates the vehicle license plate so they can be seen at night or in difficult driving conditions.

Figure 13: License Plate light of TVS Scooty Pep

2.6 Parts of automotive lighting products

2.6.1 Housing

The housing is manufactured in the form of a moulded tile of opaque plastic. It usually is the part of the lamp that is attached to the vehicle. The general requirements are mechanical and thermic resistance. It usually holds the other parts of the lamp like the lens, light guide, PCB and reflector. The most common materials used for the manufacture are thermoplastics such as ABS.

Figure 14: Housing of Bajaj DT Tail lamp

2.6.2 Lens

The lens is a transmissive optical device which affects the focusing of a light beam through refraction. The general requirements are mechanical, thermic and radiation resistance. It is usually made from a transparent material because the light needs to pass through the lens. The most common materials used for the manufacture are thermoplastics as PMMA, and glass for lamps that need a high impact resistance.

Figure 15: Lens of Garnish lamp of Mitsubishi Fuso Canter

2.6.3 Reflector

The reflector is the part of the lamp that has the function of reflect the artificial light of the led or bulb. Reflectors are fixed to an artificial light source to direct and shape the otherwise scattered light, reflecting it off their concave inner surfaces and directing it towards the road. Although there are a large number of variants, the most common types are:

- Spherical, short-sided, giving a relatively broad spread of light.
- Parabolic, providing a tighter, parallel beam of light.

Modern reflectors for automotive lighting systems are commonly made of compression-moulded or injection-moulded thermoplastic. The reflective surface is vapor-deposited aluminum with a clear overcoating to prevent the extremely thin aluminum from oxidizing. Extremely tight tolerances must be maintained in the design and production of complex reflector headlamps.

Figure 16: Reflector of Kawasaki 8943 Tail lamp

2.6.4 Bulb

Light bulb is a glass bulb containing a gas, such as argon or nitrogen, at low pressure and enclosing a thin metal filament, usually made of tungsten[12], which emits light when an electric current is passed through it. Light bulbs for automobiles are made in several standardized series. There is a huge range of bulbs for vehicles in the market. According to the requirements bulbs can have one filament[13] (only one type of light) or two filaments (two types of lights). Furthermore the colour of the bulb can be clear, amber or red depending in the function of the lamp.

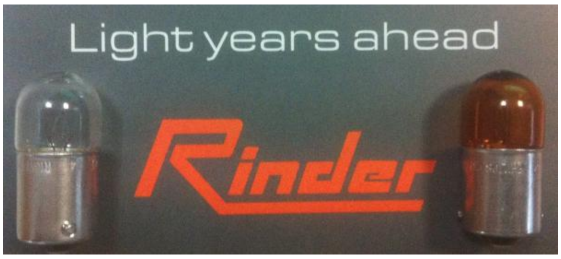


Figure 17: Clear and amber bulbs used in Rinder products

[12] *Tungsten:* Rare metal used in filaments due to an efficient electrical conduction.
[13] *Filament:* A fine wire that is heated electrically to produce light in an incandescent lamp.

2.6.5 Printed circuit board

Printed circuit board (PCB) provides both the physical structure for mounting and holding electronic components as well as the electrical interconnection between components. The essential components of a printed circuit board are:

- The base, which is a thin board of isolating material, rigid or flexible, which supports all conductors and components. It provides mechanical support to all copper areas and all components attached to the copper.
- The conductors, normally of high purity copper in the form of thin strips of appropriate shapes firmly attached to the base material. They provide not only the electrical connections but also solderable attachment points for the same.

Figure 18: Electronic equipment of Kawasaki 8943 Tail lamp

2.6.6 LED

Light emitting diode based (LED) lighting products have emerged as a credible, energy-efficient, and long-lasting alternative for some real world commercial and industrial applications. In LEDs the production of light takes place in a semiconductor crystal which is electrically excited to illuminate, this process is known as electroluminescence. The colour of LED depends on the type and composition of the semiconductor crystal. There are generally two main types LED used for lighting system:

Material	Colour
Aluminum gallium indium phosphide (AlGaInP)	Red, orange and yellow
Indium gallium nitride (InGaN)	Green, blue and White

Table 4: LED specifications

LED used for indication purpose requires low voltage (2 to 4 V) of direct current (1 to 50 mA). On the other hand for illumination purposes High Power LED requires the same voltage, but operating currents are much higher, typically in the range of 350mA to1000mA.

Figure 19: Light device based in LED source

2.6.7 Ligth guide

A light guide is used for transporting or distributing the light of LEDs for the purpose of illumination. The light tube is molded from a single piece of plastic, permitting easy device assembly. It allows the illumination along the lamp and the common material used in this part are thermoplastics as PMMA.

Figure 20: Light guides of TVS Wego Tail lamp

2.6.8 Wire-to-wire connector

An automotive connector is used to connect the cabling of the lighting system. The material used in the connector must have an excellent resistance against stress whitening and a high melt flow. During assembly, when the cables are inserted in their connectors, incorrect connections should be corrected directly, with the connector remaining intact mechanically and electrically. This requires the connector to be very robust mechanically speaking.

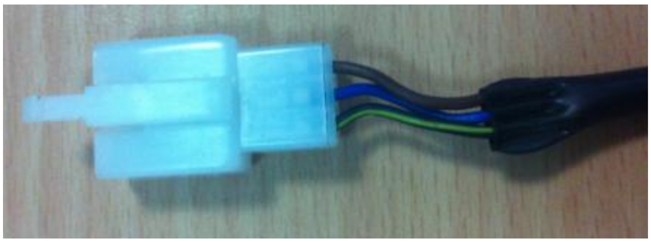


Figure 21: Wire-to-wire connector of Bajaj JG Tail lamp

2.6.9 Wire harness

Wire harness in automobiles are assembled largely off-line and incorporate a multitude of differently coloured or coded wires. The purpose of these colours and codes is to facilitate identification during inspection or in the event of possible repairs.

3. Lean Manufacturing. Applicable techniques.

3.1 Goals of the chapter

Lean Manufacturing is the base of this project. For that reason it is necessary to define it and to make an exhaustive analysis of its principles. The goal of this method will be defined throughout this chapter.

After the basic concept is defined, the techniques of Lean Manufacturing will be explained in a proper way. Maybe some techniques of the Lean method will not be applied, but we have to be conscious that Lean Manufacturing is a compounding of different actions and that it is a continuous method. Once the actions that will be proposed by the project are implemented, the improvement process must continue.

3.2 Lean Manufacturing. Definition

Lean Manufacturing is a comprehensive set of techniques that, when combined and matured, will allow you to reduce and then eliminate the Seven Wastes. This system not only will make the company Leaner, but subsequently more flexible and more responsive by reducing waste. This method is called Lean because, in the end, the process can run using less material, requiring less investment, using less inventory, consuming less space and using less people.

To further explore the depth of what a Lean Manufacturing system really is, we will look at the Toyota Production System. This is the best-documented system and it has proven itself over a very long time. Taiichi Ohno, the Chief Engineer of Toyota, is the accepted architect of the TPS[14], others contributed greatly to develop the method, but Ohno wrote the most about it.

TPS is characterized by the cost reduction through the waste elimination. This waste elimination system is built on two pillars:

- Just In Time: technique of supplying exactly the right quantity, at exactly the right time, and exactly the correct location.
- Jidoka: This pillar can be defined as "automation with a human touch." It is the concept that no bad parts are allowed to progress down the production line.

Ohno states in his book “The TPS, with its two pillars, advocating the absolute elimination of waste, was born in Japan out of necessity.” Before eliminate all wastes, we have to identify them. Ohno categorized wastes into seven principle types:

- Transportation: Activities of transport never add value. The waste of moving the parts happens between processing steps and that affects to the delivery commitments. The solution to this problem is to reduce the number of displacements and optimize the means of transport.
- Delays: Mismatches between production rates and movement of materials in different parts of the processes generate queues and waiting. Unbalanced chains,

[14] *TPS:* Toyota Production System.

stock outs or machinery failure generate wastes and be prepare for any unexpected problem solves that.

- Inventory: This is a common waste. All inventories are waste unless the inventory translates directly into sales. It makes no difference whether the inventory is raw materials, WIP[15], or finished goods. It is waste if it does not directly protect sales.
- Over-processing: This is the waste of processing a product beyond what the customer wants. Engineers who make specifications that are beyond the needs of the customer often create this waste due to an inefficient design stage. Sometimes all processes that are involved in the manufacture of one product are not necessaries.
- Defective parts: the presence of defects leads to losses of material, increased risk of accidents, equipment breakdowns and if the product reaches the customer, significant losses on guarantees and image.
- Movement: This is the unnecessary movement of people, such as operators walking around, looking for tools or materials. Too common in current industries, this is frequently overlooked as a waste.
- Overproduction: produces accumulation products and this problem increases the written wastes.

The Lean method distinguishes three different types of causes that are considered as the origin of all waste:

1) Muda: means totally useless or waste.
2) Mura: means waste referring to uneven resources utilization or loading varies from time to time or from resources to resources.
3) Muri: means waste due to the reduced output because of overloading and overburdening, but sometime it can also cause by some abnormality, hence creating congestions or bottlenecks.

3.3 Value Stream Mapping

A “value stream” is the set of activities, both value-adding and non-value adding that occurs in taking a product from concept to launch, from order to delivery, from raw material to finished product. Value is what the customer is willing to pay for.

Value stream mapping (of the production value stream) develops a kind of graphical diagram, showing each activity that occurs in the flow of material from the supplier to the customer as well as the information flow from the customer back to the production floor and the supplier and a lead time diagram contrasting value-adding time to elapsed time.

[15] *WIP:* Work in progress. Partially finished goods waiting for completion.

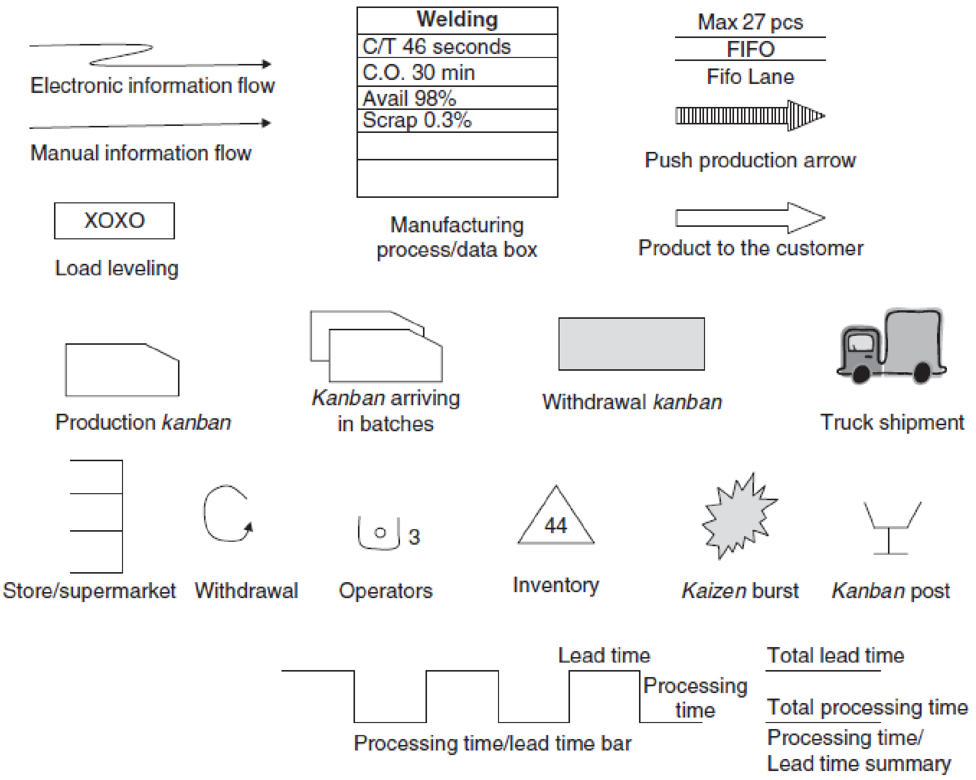


Figure 22: Typical value stream mapping icons

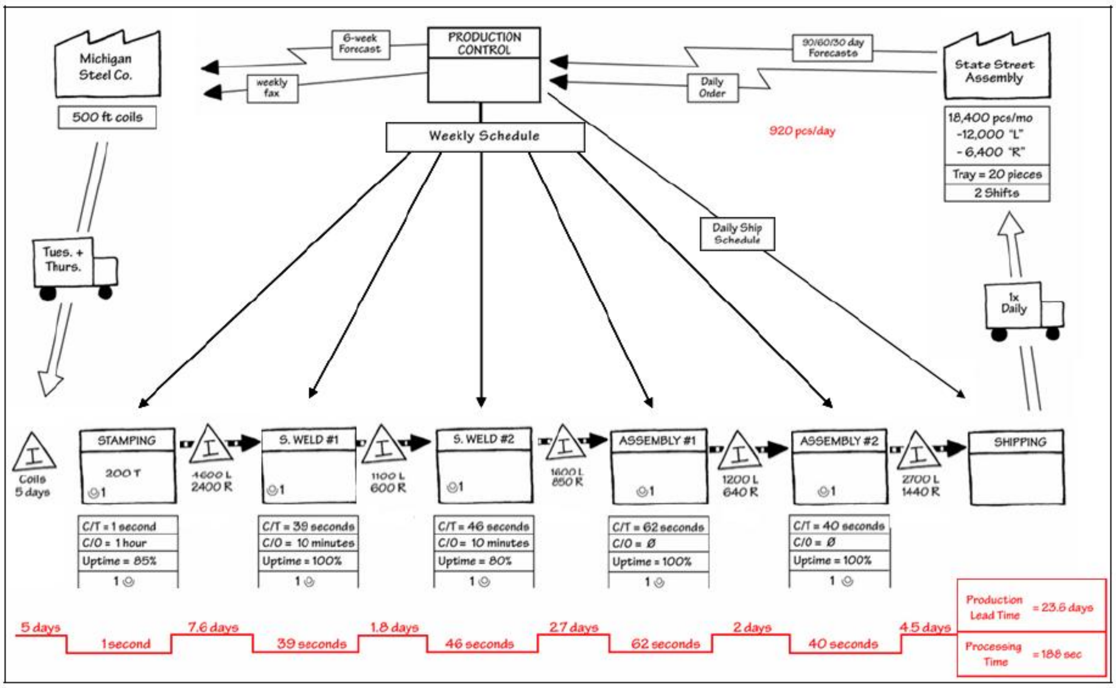


Figure 23: Value Stream Mappping example

3.4 5S's Theory

Five S (5S) an improvement process, originally summarized by five Japanese words beginning with S, to create a workplace that will meet the criteria of visual control and lean production.

- Seiri (sort) means to separate needed tools, parts, and instructions from the unneeded and to remove the latter.
- Seiton (set in order) means to neatly arrange and identify parts and tools for ease of use.
- Seiso (shine) means to clean and inspect.
- Seiketsu (standardize) means to require as the norm that everyone sort, set in order, and shine at frequent (daily) intervals to keep the workplace in perfect condition, and also to make use of visual control systems.
- Shitsuke (sustain) means to maintain the five S gains by training and encouraging workers to form the habit of always following the first four Ss.

3.5 SMED/OTS

SMED stands for Single Minute Exchange of Dies and OTS stands for One Touch Setups. SMED technology is a science developed by Shigeo Shingo and is designed to reduce changeover times. The problem is simple. Any machine that has long changeover times must have an excess capacity to account for the downtime of the changeover. Furthermore, to supply the rest of the downstream process during the changeover, a large batch must be stored up. Any effort to reduce the changeover times also reduces these two forms of waste: excess capitalization and overproduction. ("Single minute" means a single digit number of minutes that is less than 10.) In actuality, the objective is to reduce the changeover time as much as possible.

Changeover time is not only the time for change and physical adjustments of the machinery. It is define as the time from the manufacture of the last valid piece of a series until getting the first good piece of the next set.

In some refined cases, the changeover is handled by having multiple fixtures on the same basic machine, and by simply throwing a switch the changeover is made. This is called One Touch Setups (OTS), or sometimes One Touch Exchange of Dies (OTED). In his writing, Ohno refers to three basic elements of JIT[16]. They are pull systems, operating at takt time with continuous flow. Those may be the big three but JIT is seldom practical without some application of SMED technology. It is a major batch destruction technique. The basic procedure of SMED is simple, it is a three-stage process:

1. Separate internal from external setup

2. Convert internal setup to external setup

[16] *JIT:* Just in time. Production strategy that strives to improve a business' return on investment by reducing in-process inventory and associated carrying costs.

3. Streamline all aspects of the setup operation

3.6 Kanban

Kanban means sign board. A Kanban can be a variety of things, most commonly it is a card, but sometimes it is a cart, while other times it is just a marked space. In all cases, its purpose is to facilitate flow, bring about pull, and limit inventory. It is one of the key tools in the battle to reduce overproduction. Kanban provides two major services to the Lean facility:

• It serves as the communication system.

• It is a continuous improvement tool.

Kanban provides two types of communication. In both cases, it gives the source, destination, part number, and quantity needed.

• Parts movement information, the transportation Kanban—this is like a shopping list.

• Production ordering information, the production Kanban—among other things, this is primarily a production work order.

Rule No.	Rule	Function
1	Later process goes to earlier process and picks up the number of items indicated by the *kanban*	Creates pull, provides pick up or transportation information. The replenishment concept is formed here
2	Earlier processes produces items in a quantity and sequence indicated by the *kanban*	Provides production information and prevents overproduction
3	No items are made or transported without a *kanban*	Prevents overproduction and excessive transportation
4	Always attach a *kanban* to the goods	Serves as a work order
5	Defective products are not sent to the subsequent process	Prevents defective parts from advancing; identifies defective process
6	Reducing the number of *kanban* increases their sensitivity	Inventory reduction reduces waste and makes the system more sensitive

Table 5: The six rules of Kanban

Let's analyze a production Kanban system. Recall that the Kanban represents the entire inventory in the system. To assure delivery to the customer we will use a management policy with our finished goods inventory. It will involve the use of three types of finished goods inventory. To assure we have stock on hand for the normal pick-ups by the customer we will carry cycle stock. In addition, in order to provide supply to the customer we will carry stocks to handle external demand variations and the internal supply variations of the finished goods. Hence we need a buffer and a safety stock volume, respectively. So our inventory management philosophy will include carrying three types of finished goods inventories and each one will be statistically calculated to minimize the total volume yet maintain a high level of customer service (in this case the level of customer service will be 99% on time delivery). Hence, the total number of finished goods kanban is the sum of these three stock volumes, divided by the container size.

No. of Kanban = (CS + SS + BS) / Container size

Kanban cards set inventory ongoing processes needed to connect without interruptions in material flow system.

No of Kanban cards = (ADD * LT * (1 + SS))/n° of parts in an standard container

CS: Cycle stock. Portion of inventory available for the normal demand during a given period.
BS: Buffer stock. A supply of inputs held as a reserve to safeguard against unforeseen shortages or demands.
ADD: Average daily demand.
LT: Lead time. Time between the initiation and completion of a production process.
SS: Safety stock. Extra stock that is maintained to mitigate risk of stockouts.

Figure 24: Standard Rinder Kanban card

3.7 Cellular Manufacturing

Cellular Manufacturing offers an opportunity to combine the efficiency of product flow layouts with the flexibility of functional layouts. In cellular manufacturing, products with similar process requirements are placed into families and manufactured in a cell consisting of functionally dissimilar machines dedicated to the production of one or more part families. By grouping similar products into families, the volume increases justifying the dedication of equipment. But since this volume is justified by process and product similarity, cellular manufacturing warrants much more flexibility than a pure product-flow layout. In terms of the Product-Process matrix, cellular manufacturing allows movement down the vertical axis, i.e. it allows increasing the continuity of the manufacturing process flow without demanding that the products be made in large volumes.

The benefits of cellular manufacturing include faster throughput times, improved product quality, lower work-in-process (WIP) levels and reduced set-up times. These gains are achieved because the batch sizes can be significantly reduced. As set-up times decrease through the use common tools or the collaboration of cell workers during set-up times, batch size can be reduced. The shorter the set-up time the smaller the batch size, and as a goal a batch size of one is feasible when set-up time is zero. Within a cell, small batch sizes do not travel very far as machines are collocated, resulting in less work-in-progress, shorter lead times and much less complexity in production scheduling and shop floor control.

Unfortunately, in a cellular layout as in the product-flow layout, a machine break down may still cause a work stoppage in the cell. Another limitation of this approach is that to ensure cell profitability and low unit costs, a large enough volume of products must be processed within the cell so that capital expense of buying the dedicated equipment to each product is low. Managers who disregard this fact when pursuing the improvements that cellular manufacturing promises, may end up with less benefits than expected.

3.8 Continuous improvement (Kaizen)

Kaizen is the concept of improving a process by a series of small continuous steps. Often times these improvements are small and hard to measure, however the accumulated effect is significant. Over the years, Kaizen has evolved to mean improvement.

Improvement begins with the admission that every organization has problems, which provide opportunities for change. It evolves around continuous improvement involving everyone in the organization and largely depends on cross-functional teams that can be empowered to challenge the status quo[17]. The essence of Kaizen is that the people that perform a certain task are the most knowledgeable about that task, consequently, by involving them and showing confidence in their capabilities, ownership of the process is raised to its highest level. In addition, the team effort encourages innovation and change and, by involving all layers of employees, the imaginary organizational walls disappear to make room for productive improvements.

3.9 Standardization

Standardization is a critical ingredient for Jidoka and Just in Time. Consistency in methods is critical to limiting variation in the process and achieving efficient production in a timely manner. Many documents exist to guide operators, define processes, document standard methods, and train team members. Two common documents posted in the production area are the Standardized Work Chart and Quality Check Sheets.

[17] *Status quo:* existing state of affairs.

The Standardized Work Chart is a document, centered around repetitive human movement, that combines the elements of a job into an effective work sequence, without waste. The Standardized Work Chart also serves as a visual control tool for leaders and managers to easily determine if there is a problem in the work area. This document is also used as a tool for continuous improvement and serves as an operator instruction for repetitive work.

Quality check sheets define the quality checks that must be performed by team members in the work area. It provides instruction on which characteristics are to be checked, the required specifications to be met, what inspection method is used, where data is recorded, the frequency of the quality check, and what the inspector must do if there is a problem.

In addition, there are other procedures and documents that provide instruction on how to perform other production activities, such as final audits, first article inspection, etc. These procedures, as well as team member training, 5S for work areas, and work standards defining production processes, are tools that help support the pillar of Jidoka. The procedures, tools, and documents not only help to minimize variation in manufacturing processes, but also aid in problem identification and resolution.

3.10 Level production

Leveled production is the averaging of model mix and volume of production, over a given time. The final process assembly line must produce all the different models in a continuous sequence and limit the fluctuations in scheduled production requirements. By leveling the volume and mix at the final process, we also level the output requirements of any upstream processes. The ability to take advantage of the smaller incremental production requirements results in more frequent changeovers, smaller batches and smaller WIP (work-in-process) inventories.

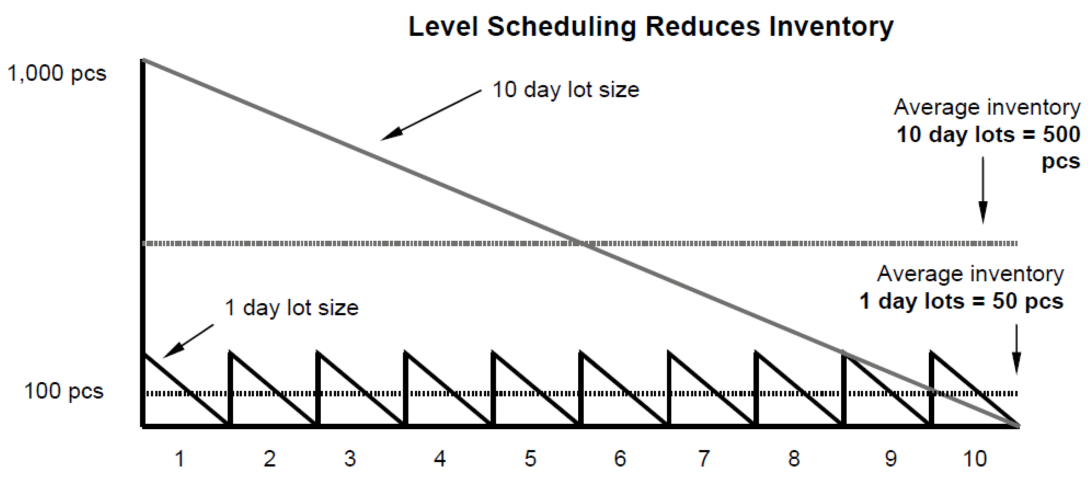


Figure 25: Example of inventory evolution by leveling the production

3.10.1 Takt time

The leveling of the production quantity means that one product should be manufactured in a given number of minutes and seconds. This time is called the "takt time." This is based on the average quantity required by the customer.

Takt time is calculated using the following information:

• Time available for manufacturing for the same period of time.

• Customer requirements for a period of time.

Takt time = Time available/Customer Requirements

3.11 Quality

Producing high-quality products is paramount for any manufacturing industry and, therefore, must be given priority. Customers will never continue purchasing a product if its quality is poor. In the case of automobile parts manufacturing, safety is considered especially important. Taking shortcuts, doing shoddy work, or in the extreme case, putting a faulty product on a vehicle in the market amounts to an antisocial act, and can have devastating consequences for the company. The mission is to supply customers (internal and external) with trouble-free products. To do this, products must be produced conforming the design quality specifications. Defect-free parts eliminate the wastes of rework and scrap, which in turn reduce costs. Reducing costs allows the company to remain competitive in an aggressive global market, and increase the market share.

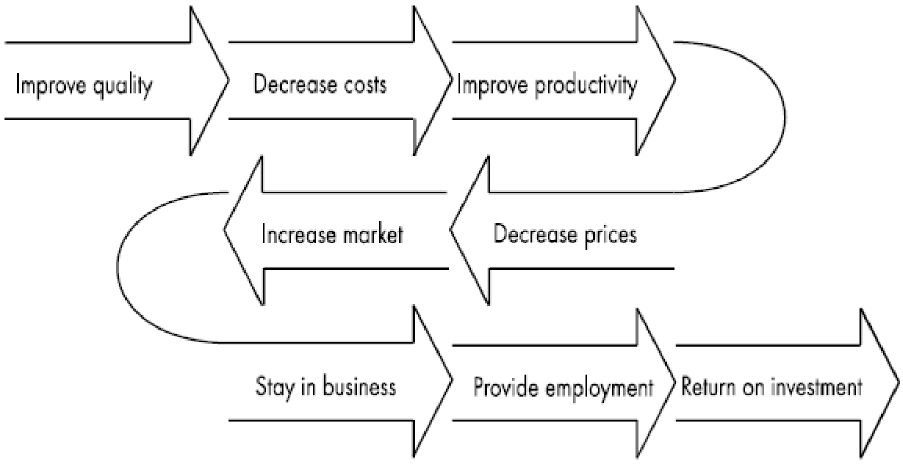


Figura 26: Quality improvements chain

3.11.1 Poka-Yoke (Mistake proofing)

Poka-yoke is a japanese term used by Shigeo Shingo to mean "innocent mistake-proofing," it is an improvement technology that uses a device or procedure to prevent defects or equipment malfunction during order-taking or manufacture. Mistake proofing devices are important to the production line in several ways: They enforce correct operations by eliminating choices that lead to incorrect actions, signal or stop a process if an error is made or a defect created, and prevent machine and product damage.

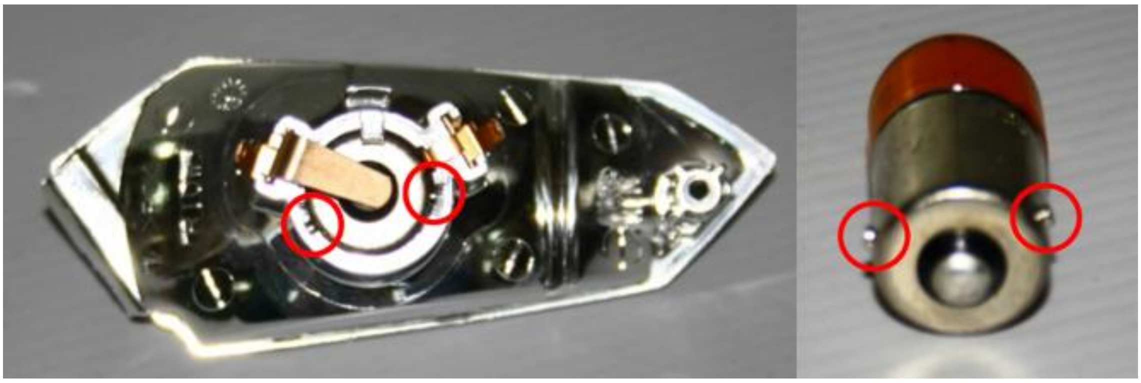


Figure 27: Bulb fitment Poka-Yoke

3.12 Total Productive Maintenance (TPM)

TPM are the initials for Total Productive (not preventive) Maintenance. It is a revolutionary approach to the management of machinery. It consists of activities that are designed to prevent breakdowns, minimize equipment adjustments which cause lost production, and make the machinery safer, more easily operated, and run in a cost-effective manner. In most plants, wishing to implement a Lean Initiative, we find that equipment availability is a large source of the process losses. Frequently, the largest of the three losses in the OEE metric. TPM is therefore a powerful tool to improve overall performance of the plant. It is generally defined as having five pillars, which are:

- Improvement activities, designed to reduce the six equipment-related losses of:
    - Breakdown losses
    - Setup and adjustment losses
    - Minor stoppage losses
    - Speed losses
    - Quality defects and rework
    - Startup yield losses
- Autonomous maintenance, which is an effort to have many routine activities performed by the operator rather than the maintenance department.
- A planned maintenance system, which is based on failure history. This is not timed maintenance. Instead, it is based on historical evidence.
- Training of operators and maintenance personnel to improve operations and maintenance skills.

A system for early equipment maintenance to avoid the loss that occurs upon new equipment startup.

4. Description of the Vibration Cell

4.1 Goals of the chapter

It is necessary, as preliminary to the proposal for a new design study, to describe the products and processes involved as well the layout and the capacity calculation, in order to know how it is organized the production before making any changes in the cell.

4.2 Processes involved in vibration cell

4.2.1 Injection molding

4.2.1.1 Introduction

Injection molding is a process that consists in producing parts of a product by injecting material into a mold. The theory of injection molding can be reduced to four simple individual steps: Plasticizing, Injection, Chilling, and Ejection. Each of those steps is distinct from the others and correct control of each is essential to the success of the total process.

- Plasticizing: describes the conversion of the polymer material from its normal hard granular form at room temperatures, to the liquid consistency necessary for injection at its correct melt temperature.
- Injection: is the stage during which this melt is introduced into a mold to completely fill a cavity or cavities.
- Chilling: is the action of removing heat from the melt to convert it from a liquid consistency back to its original rigid state. As the material cools, it also shrinks.
- Ejection: is the removal of the cooled, molded part from the mold cavity and from any cores or inserts.

Repetition of these basic steps in sequence is the process of injection molding.

4.2.1.2 Injection molding process in plastic optics

The injection molding processes can be classified into two types: conventional injection molding and injection-compression molding. Injection-compression molding is preferred for molding parts with micro structures, e. g. lenses with diffractive structures.

Common to both processes is the injection of a “hot” polymer melt into a (compared to the melt temperature) cold mold cavity. This will introduce additional internal stress during the cool down and may spoil lenses for applications in polarized light. To overcome this potential show stopper one may temper lenses, which is practically not feasible because they will lose their shape, or to use compression-injection molding processes which have some big advantages here. Molding processes are very complex with a lot of different parameters and influence factors.

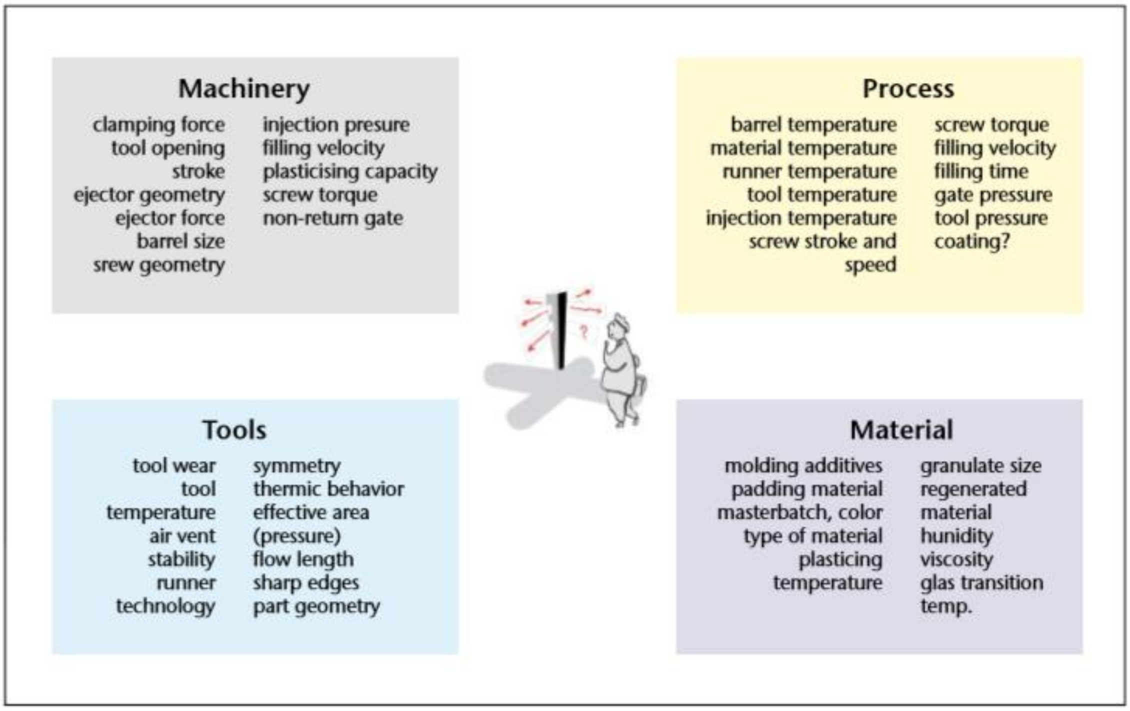


Figure 28: Parameters for Injection molding

Summarizing injection molding process parameter ranges, some important are:

- Mold temperature: 90 °C up to 170 °C
- Compound temperature: 180 °C up to 330 °C
- Cycle time: 30 sec to several minutes
- Packing pressure: part/material specific (up to >1000 bar)
- Injection velocity: mold/part/material specific

The mold process in the injection molding process is a part-specific process and has to be developed for each part separately. Process developments are based on the experience of the process engineers, on smart process evaluation strategies and statistic process evaluation methods. Some important parameters, such as shrinkage, are not only material specific but process and part specific too.

4.2.1.3 Injection molding machinery

The injection molding machine is of course another important element of the process chain. Within the machine the polymer is melted and reproducibly injected into the mold. This requires a precise control of all process temperatures, the displacement volume, the injection speed, the cavity-pressure. The injection molding machines have three different parts:

1) Injection and plasticizing unit. This unit injected and plasticized the polymer.
2) The clamping unit. Holds the mold, opens and closes the system and contains the ejector system.

3) Control unit. It is where you establish, monitor and control all process parameters (time, temperature, pressure and speed). In some machines may be obtained statistics molding parameters.

Mainly all injection machines are composed of the same elements. The differences between one machine and another lies in its size, the clamping unit design and plasticizing unit. Lesser extent, also differ in design variants of its assembly elements and drive systems.

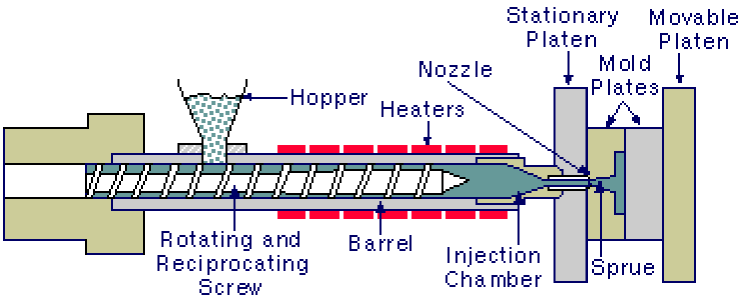


Figure 29: Parts of injection molding machine

- Parts of an injector unit:

  - Feed hopper:

    The solid particles of the resin in pellet form, are deposited in the hopper of the machine, this hopper is normally connected to a peripheral or auxiliary equipment that provides the conditions specified by the manufacturer of the resin to obtain optimal results processing. Depending on the material to be injected, it is necessary to dry before filling injection the barrel through a special hopper dryer. We also found that some manufacturers use continuous feed systems of resin centrally for all the factory or particular for each machine.

    As we mentioned, plastic pellets are poured into the hopper and this in turn feeds the barrel. Although the granules may be introduced directly to the screw, usually the material is gravity fed into the feed zone of the barrel. These hoppers are actually truncated cone shaped containers, although this depends on the geometry of the machine. There are classified into short and long hoppers.

Short hoppers are typically used when the resin is separately dried outside the injection molding machine. This process is necessary when we do not want accumulation of material that can absorb moisture from the atmosphere.

Figure 30: Short Hopper

Long hoppers usually require some reinforcement in the duct junction to mount directly into the duct of the machine. This type of hopper is also widely used, but present difficulties when you need to move it for doing an input material inspection.

Figure 31: Long Hopper

- Plasticizing unit:

The injection unit performs the functions of charging and plasticizing the solid material by rotation of the screw, moves the screw axially to inject the plasticized material into the mold cavities and keeps it under pressure until it is ejected. Moreover, the screw moves axially to act as a piston during the injection process.

The injection unit includes a barrel of steel capable of withstanding high pressures, the barrel is covered by band heaters to heat and help to melt the material as it moves along the screw. It also comprises a hydraulic unit that transmits linear movement to the screw in the injection process. Some machines have 2 hydraulic units, one for injection and one for closing.

Figure 32: Plasticizing unit

- The reciprocating screw:

The reciprocating screw is used to compress, melt, and convey the material. The reciprocating screw consists of three zones:

1. Feeding zone
2. Compressing zone
3. Metering zone

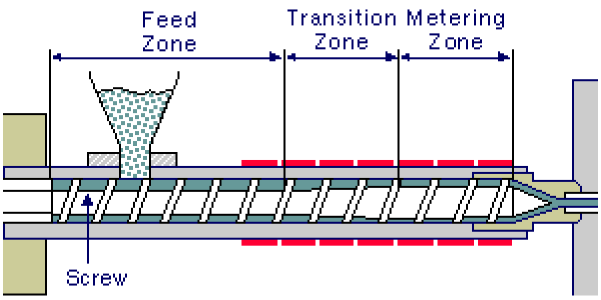


Figure 33: Zones of the reciprocating screw

While the outside diameter of the screw remains constant, the depth of the flights on the reciprocating screw decreases from the feed zone to the beginning of the metering zone. These flights compress the material against the inside diameter of the barrel, which creates viscous (shear) heat. This shear heat is mainly responsible for melting the material. The heater bands outside the barrel help maintain the material in the molten state. Typically, a molding machine can have three or more heater bands or zones with different temperature settings.

➢ Clamping unit:

The clamping unit main function is to open and close the mold along with ejecting the parts. The two most common types of mold clamps are the direct hydraulic and the toggle clamps. Toggle clamps are actuated by hydraulic cylinders. These clamps utilize mechanical linkages to generate higher forces than a direct connection from a hydraulic cylinder of the same size.

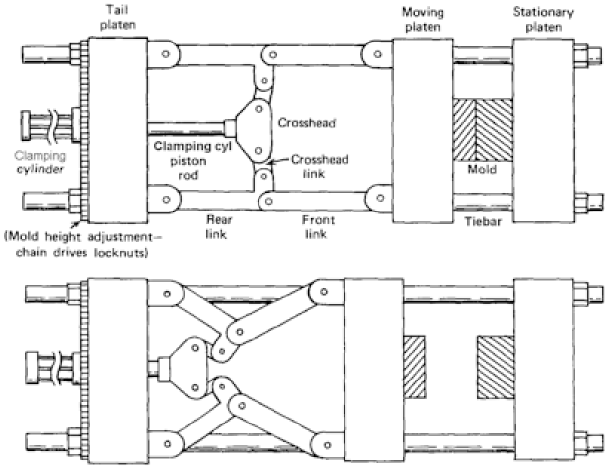


Figure 34: Clamping unit mechanism

4.2.1.4 Injection molding faults

Plastic moldings produced by the injection molding process are usually durable consumer goods whose suitability for the purpose in question depends not only on the properties of the finished part but also highly on the surface quality. The complex interplay among molding and mold design, processing conditions for the raw material and the parameters for the actual process require a great deal of experience for optimum results especially when focusing on the short-term removal of processing faults.

The surface faults occurring most commonly in styrene polymers are:

- Streaks
- Peeling/delamination
- Weld lines
- Air entrapments
- Bubble formation
- Sink marks
- Voids
- Glossy spots or differences in gloss/mat spots
- Microcracks, crazing, stress whitening
- Diesel effect
- Demolding problems
- Push marks (“tiger stripes”)

- Record effect
- Short shot
- Flash formation
- Jetting
- Cold slug
- Warpage
- Rainbow effect
- Read through

4.2.1.5 Cooling Fixtures

Cooling fixtures can be a significant value add to the overall molded product by eliminating part distortion and enhancing overall part dimensional accuracy by keeping key areas on the part supported post mold. Many times once a RIM[18] part, vacuum form part or structural foam part is molded it has a "cure" time for a few minutes after molding. If the part is not properly supported it can increase scrap rates and rework required to insure dimensionally accurate parts.

Cooling fixtures can be as simply constructed as a machined "buck" or surface to nest the part post mold or can be constructed from aluminum dependent on product volume. Some of the prior cooling fixture builds also incorporated water lines which allow circulation of cool water through the fixture to accelerate the cooling process while the part is being held into proper position.

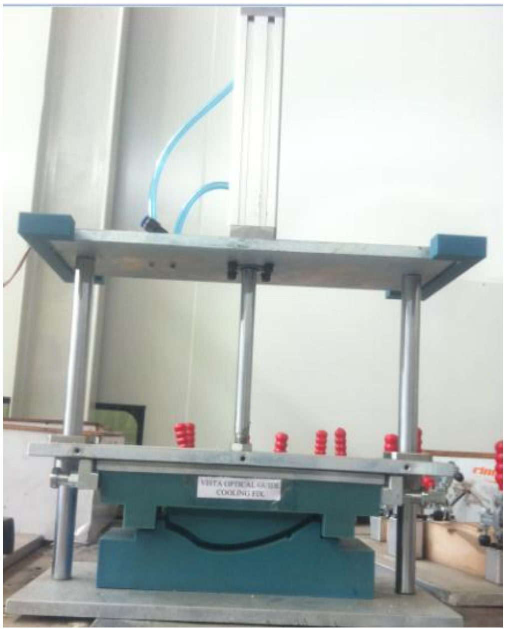


Figure 35: Cooling fixture of Tata Vista Optical guide

[18] *RIM*: Reaction injection molding. Process where two liquid materials, Polyol resin and Isocyanate are brought together in a mix head and injected into a single or multi-cavity mold.

4.2.2 Vibration welding

4.2.2.1 Introduction

In vibration welding, also called linear welding and linear friction welding, the surfaces to be joined are rubbed against each other, under pressure, in an oscillatory manner. The resulting frictional work causes the interfacial material to heat up and melt. Welding is then completed by allowing the molten film to cool under pressure. The main process parameters are:

- Weld frequency, n
- Amplitude of the vibratory motion, a
- Weld pressure
- Weld time

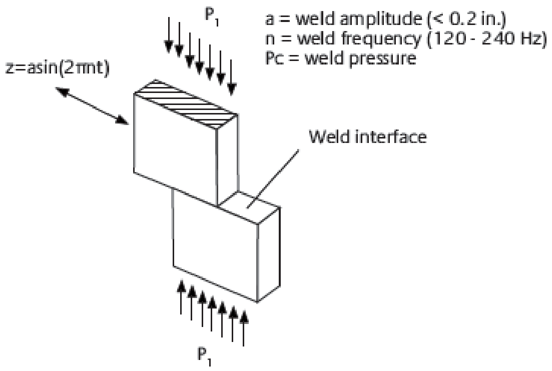


Figure 36: Schematic representation of vibration welding process

4.2.2.2 Advantages and shortcomings

The vibration welding process is ideally suited for welding of thermoplastic parts along flat seams. The process can also accommodate seams with small out-of-plane curvature. This technique has many potential advantages for joining large flat-seamed thermoplastic parts, relatively short cycle times, simple equipment and insensitivity of the process to weld surface preparation.

In contrast to adhesive bonding, no foreign material is introduced, so that the weld interface is of the same material as the parts to be welded. Also, in contrast to hot-tool welding, in which the interfaces to be welded are heated conductively by direct contact with a hot tool, the heating is very localized. Moreover, the vibration welding process is far more controllable and is much less likely to cause material degradation because of overheating at the interface.

The main disadvantage of this process is that it is limited to nearly flat-seamed parts, although stepped parallel seams can also be welded. Also, this process is not suited to welding low-modulus thermoplastics, such as some thermoplastic elastomers.

4.2.2.3 Vibration welding process

1) Part halves are placed into and securely gripped by precision holding fixtures which accurate alignment of the part halves throughout the vibration welding process.
2) The lower holding fixture rises upward to close against the upper holding fixture, compressing the part halves to be welded together.
3) Friction begins by vibration controlled by alternate energizing of electromagnets on the swing frame assembly. This pulsation propels the vibration platen and the upper tooling fixture alternately left and right, generating a peak to peak movement.
4) Vibration halts and the holding fixtures maintain clamping force, allowing the parts to cool under pressure.
5) When cooling is complete, the lower fixture lowers and the finished part may be unloaded.

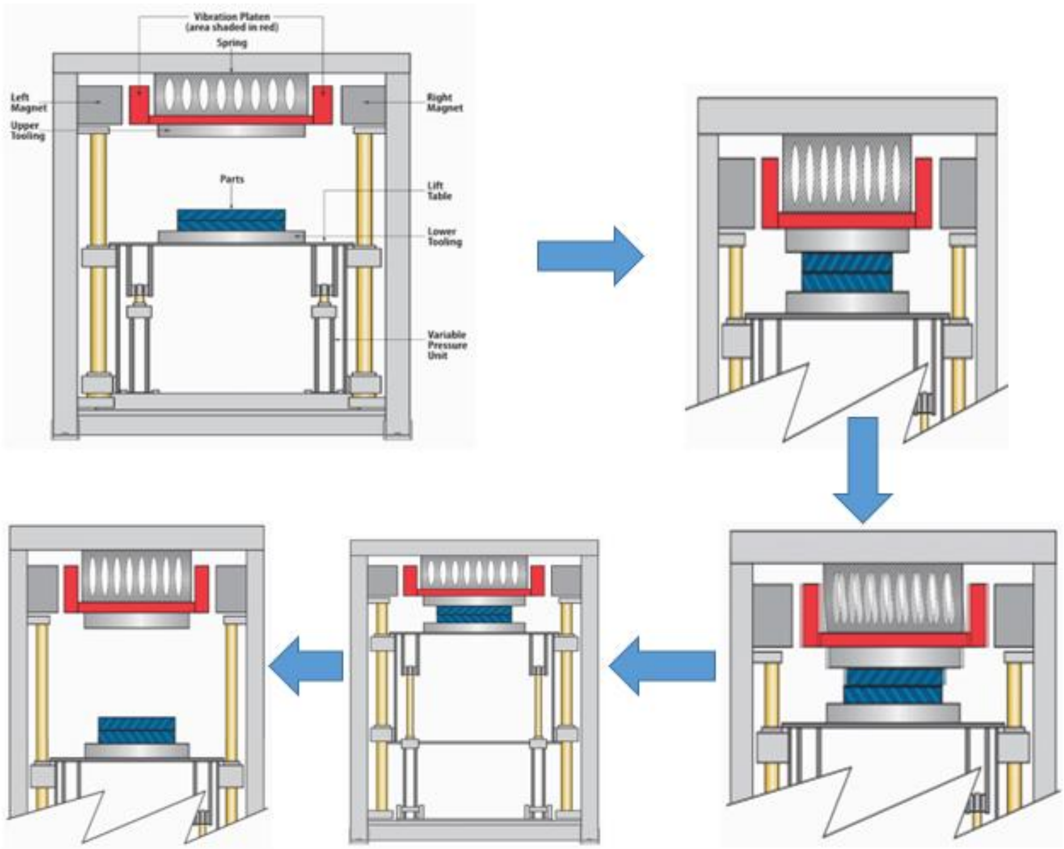


Figure 37: Vibration welding process

4.2.2.4 Vibration welder

A vibration welder is basically a vertical machine press, with one moving element, one fixed element and a tooling fixture on both.

The vibrator assembly (topside) is a moving element with no bearing surfaces and is driven by either hydraulic pistons or electromagnets. The vibration head and electrical drive deliver the power required to perform the frictional weld process. The ‘head’ is an electromechanical spring mass system, which typically has power delivered by electric coils acting upon opposing lamination stacks. With the tooling installed, the mass of the system determines its natural frequency. The drive sends power to the opposing drive coils switched at an electrical frequency tuned to match the natural frequency of the mechanical system, thus providing constant frequency vibratory motion. The amplitude (a) of the oscillation is a controllable parameter on the machine.

The fixed element is a lifting table (below) which brings the parts to be welded into contact, by raising the lower tooling and the part to meet those attached to the vibrator head. Guide rails ensure that horizontal positional accuracy is maintained. The lifting table controls the force (F) with which the parts are brought together and controls the penetration depth (s).

Both the vibrator head and lifting table are equipped with application-specific tooling fixture. The tooling must provide good support to ensure that an even pressure is applied to the weld interfaces during the welding. It is essential that there is no relative movement between the parts and tooling fixtures during welding, otherwise the amplitude between the weld interfaces will be reduced. If the amplitude falls below the threshold value, it will result in a poor weld.

The lifting table and hydraulic system are rigidly fixed to a machine frame and the vibration head is attached to the frame by means of isolation mounts, and therefore able to be moved by large forces. The mechanical system is surrounded by a sound enclosure with access doors to the working envelope for operation. A control cabinet houses the drive mechanism, electrical system and the PC control unit.

Figure 38: Vibration welding machine Branson M-502H

4.2.3 Annealing process

4.2.3.1 Introduction

In this process molded components are gradually heated just below its glass transition temperature after vibration welding for desired time & temperature to remove internal stress from molded component.

When any material is heated, it expands, when cooled, it will contract. Since most plastics are poor conductors of heat, any uneven or rapid heating and cooling can introduce "stress" into the material. These forces are already present on the parts due to injection process of thermoplastics and are increased during welding as they are under a certain temperature, pressure and specific time.

The reason why we need to remove stress is that sometimes some cracks appear in the area nearby the welding bond when the part contact with products, such as gasoline, solvent or break fluids. For the removal of the stress the parts must be introduced in a convection oven for a time and temperature which depend on the welding technology, substrates and part geometry. This controlled increase and decrease of the temperature allows the part to free the non-desired stress.

In some cases the stress removal makes a welding defect so it´s necessary to run 100% verification (Leak test) after the stabilization of the parts. In certain processes as ultrasonic welding there is a huge difference between controlling before or after stabilization. Nowadays, in vibration welding there is not enough data to reveal any influence on this process, so the verification must be done once the parts are taken out from oven.

4.2.3.2 Annealing process

The following are general guidelines for annealing automotive lighting products. Variation in the equipment used, rate of temperature rise per hour, part configuration, and degree of stress, preclude any exact predictions arising from these steps. Heavy cross sections and parts with high levels of stress may require longer holding times, or more than one intermediate annealing step. Thinner cross sections or lower stress parts can often be annealed in a faster cycle. Annealing is effected in three working steps:

1) Heating of the welded part to annealing temperature.
2) Keeping the temperature constant over a certain period of time.

Slow cooling down of the welded part. Slow-cooling will produce the best annealing after heating. Annealed parts should not be removed from the oven until the temperature reaches 50°C.

Sr No.	Sustrato A (Lens)	Sustrato B (Housing/Reflector)	Time (min)	Temperature (ºC)
1	PC Amber.	PC White	40	90
2	PC	PC White	40	90
3	PC	PC Black	25	75
4	PMMA Cl.	ABS Black	25	90
5	PMMA Cl.	ABS Black	25	90
6	PMMA Red	ABS Black	25	75
7	PMMA Red	ABS Black	25	75
8	PMMA Red	PC White	25	75
9	PMMA Amber	BAYBLEND White	40	90
10	PC Amber	PC Black	40	90

Table 6: Annealing parameters

4.2.4 Leak testing

4.2.4.1 Introduction

Leak testing consists in checking the part for leakages due to process flaws. The component is pressurized at 0.1 to 0.3 bars, depending on the part size.

4.2.4.2 Leak testing process

The complete cycle is as follows:

1) After the cycle start signal is provided, the air is filled into the part at the set pressure “P” (0.1 to 0.3 bar) for the set amount of time (FILL TIME), and then shut off.
2) After this, the filled air is allowed to “de-turbulate” for a short “STABILISATION TIME”.
3) The pressure monitoring starts after this stage. If the part is OK, the pressure remains constant (P1) and the cycle completes and a punch mark is made.
4) If there is a leak, the monitored pressure falls below “P1”, some air is injected again into the lamp to maintain the pressure “P1” the monitoring continues for the set “TEST TIME”.

In the case of leak, the flow rate of the injected air (in cc/min) is measured and displayed as the leak rate.

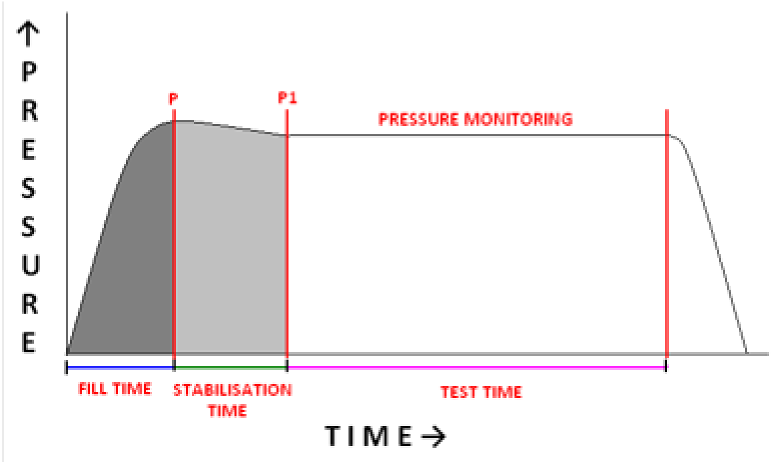


Figure 39: Leak testing pressure cycle

4.2.5 Light testing

4.2.5.1 Introduction

The Light test is designed to measure the light intensities of the item controlled. The machine used consists of:

- Box type structure.
- Keypad and HMI[19] on the front.

4.2.5.2 Light testing process

1) Take assembly from the previous stage and place it on light testing fixture.
2) Join female coupler of the lamp wiring harness to the male coupler of the light testing machine.
3) Press start button to check continuity.
4) Depending in the type of light regulated photometric test points are measured, the intensity must be in the required range.
5) If the intensity of light is in the range of set value then it will pass the part, otherwise it will get fail.
6) Remove the job from the fixture after the testing.
7) Check for poka yoke punch mark. If there is no mark the part is rejected.
8) Pass this assembly for final inspection.

[19] HMI: Human machine interface.

Parameters	Value	Tolerance (+/-)
Output Voltage supplied by unit.	13.5 V	0.2 V
Current	0.76 A	0.05A

Table 7: Light testing unit parameters

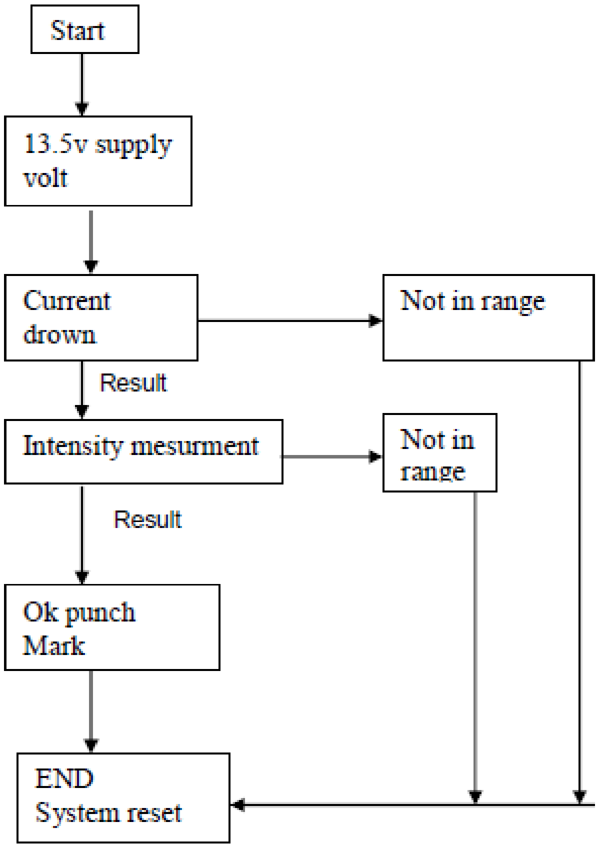


Figure 40: Light testing process diagram

4.3 Layout of the Vibration Cell

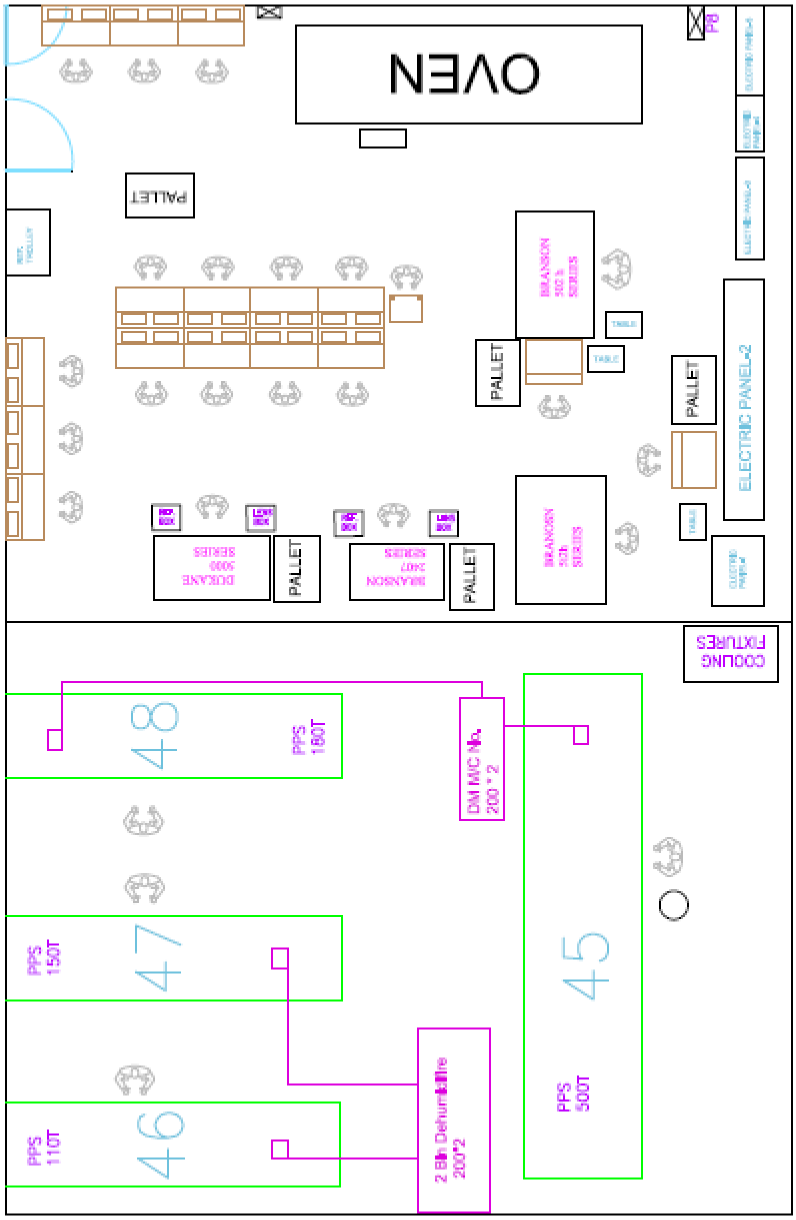


Figure 41: Initial layout of Vibration cell

The vibration cell is formed by two areas, one for injection molding and the other for welding, annealing and assembly. The surfaces and equipment are:

- Vibration cell surface: 304 m^2
  - Injection molding area surface: 149 m^2
  - Vibration welding area surface: 155 m^2
- Machinery:
  - Injection molding area:

- Molding machine Ferromatik Milacron Magna T Servo 500
- Molding machine Ferromatik Milacron Magna T Servo 150
- Molding machine Ferromatik Milacron Elektron 180
- Molding machine Ferromatik Milacron Elektron 110
- Dehumidifier Alfa dryer 110
- Dehumidifier Alfa dryer 200

- Vibration welding area:
    - Vibration welder Dukane 500 Series
    - Vibration welder Branson 2407 Series
    - Vibration welder 502 H Series
    - Vibration welder 5i2 H Series
    - Leak tester Paveway 01
    - Leak tester Paveway 02
    - Light tester Authentic 01
    - Light tester Venus 01
    - Leak Tester + Light tester Venus 02
    - Annealing oven

The main problem of the design of the initial lay-out is the configuration of all of the work stages. This configuration, along with other reasons, causes the appearance of different wastes like defects, accidents, increased transport times and wasted staff capacity.

As it is shown in the figure the molding zone is totally separated from the vibration welding zone. The molding zone has four injection molding machines, four dehumidifiers and one shelf for the cooling tools. The largest part of the products manufactured in the cell are small parts, but those of Isuzu and Fuso are bigger so they need a big moulding machine. The connection between the two areas is nonexistent. All the moulded parts comes to the vibration welding area in trays and boxes, which cause an increase of work in progress stock, waste of packaging boxes and increase the transportation time. This configuration makes the product flow non-continuous and nonproductive, generating unnecessary expenses of money and time.

The vibration welding area has the problem of lack of space. The equipment used are four vibration welding machines (Dukane 5000 Series, Branson 2407 Series, Branson 502 H Series and Branson 5i2 H Series), one oven and four assembly lines. The cell has also some electric panels that they are needed for the electrical supply of the machinery. The lay out is conditioned by the oven and the electric panels, one of the solutions for that is to replace them out of the cell, but it is very costly. In the future it will be necessary because the oven generates much heat and the electric panels could be dangerous for workers.

Due to an increase in demand from customers the plant was forced to create the cell. The cell installation was done very quickly and without a proper plan. None of the assembly lines had a specific function and that is the reason why during some days workers manufacture the same products in a different line each time. The stages of the assembly lines are not fixed, so each day the configuration of them change. Leak testers and light testers are always moving, causing space problems and making inefficient the assembly lines.

The assembly tables are bigger than is required and a number of them are not justified according to the needs and capacity calculation. One of the doors is blocked because one line is located near there. This problem cause that all the inputs, outputs, fixtures, tools and manpower flows converge in the same point thus making slower the transportation process.

4.4 Products manufactured in Vibration Cell

Customer	Project	Type of lamp
KAWASAKI	8943	Tail lamp
KAWASAKI	3524	Tail lamp
KAWASAKI	1169	Tail lamp
KAWASAKI	9080	Tail lamp
BAJAJ	JG TL	Tail lamp
BAJAJ	DT TL	Tail lamp
BAJAJ	KTO - 4	Front position lamp
BAJAJ	DT	Front position lamp
REML	NT51 TL	Tail lamp
PEUGEOT	721 TL	Tail lamp
PIAGGIO	SCARABEO TL	Tail lamp
TATA FICOSA	FIAT LINEA	Mirror blinker
TATA FICOSA	TATA VISTA	Mirror blinker
TVS	U157	Blinker
TVS	U157	Blinker
TVS	N112	Front position lamp
TVS	N112	Front position lamp
VW	REFLEX RR 250	Rear reflector
VW	REFLEX RR 251	Rear reflector
ISUZU	SIDE REPEATER	Side indicator
ISUZU	SIDE REPEATER	Side indicator
ISUZU	FPL RH	Front position lamp
ISUZU	FPL LH	Front position lamp
FUSO	FR & STL 24V LH	Side indicator
FUSO	FR & STL 24V RH	Side indicator

FUSO	FR & STL 12V LH	Garnish lamp
FUSO	FR & STL 12V RH	Garnish lamp

Table 8: Manufactures products in Vibration cell

The vibration cell is an area were Rinder manufactures a large amount of products for different customers. For that reason it is very difficult to standardize the processes and to design dedicated lines. As it is shown in the table there are tail lamps, front position lamps, mirror blinkers, rear reflectors and garnish lamps. Each type of lamp has different requirements and different stages in their manufacturing process.

Figure 42: Bajaj JG Tail Lamp

Figure 43: Fuso FR & STL 12V Garnish lamp

Figure 44: Bajaj Dt front position lamp

Figure 45: Tata Vista mirror blinker

Figure 46: Fuso FR & STL 24V Garnish

Figure 47: Bajaj KT-04 Front position lamp

Figure 48: VW Rear Reflector 250

Figure 49: VW Rear Reflector 251

Figure 50: Kawasaki 2189 Tail lamp

Figure 51: Kawasaki 1169 Tail lamp

Figure 52: REML NT51 Tail lamp

Figure 53: Bajaj DT Tail Lamp

Figure 54: TVS U157 Blinker

Figure 55: Fiat Linea Mirror blinker

Figure 56: Piaggio Scarabeo Tail lamp

Figure 57: Isuzu Side Indicator

Figure 58: Kawasaki 8943 Tail lamp

Figure 59: Kawasaki 9080 Tail lamp

Figure 60: Peugeot 721 Tail lamp

Figure 61: Isuzu Front position lamp

4.5 Capacity calculation

Customer	Project	Qty/month	molding mc29 (350 ABS)	molding mc45 (500 PMMA)	molding mc46 (110 PMMA)	molding mc48 (180 PMMA)	molding mc43 (150 PMMA)	molding mc47 (150 ABS)	molding mc13 (150 ABS)	molding mc10 (150 ABS)	M502H	M5i2H	2407	DUKANE	Annealing oven VIB	Leak tester 1	leak tester 2	leak tester 3	leak tester 4	Light tester 1	Light tester 2	Light tester 3	Light tester 4
KAWASAKI	8943	4000					55.55556		55.5556				70			55.556				55.56			
KAWASAKI	3524	4500					62.5		62.5				79			62.5				62.5			
KAWASAKI	1169	500					6.944444		6.94444					9		6.9444				6.944			
KAWASAKI	9080	840					11.66667		11.6667					15		11.667				11.67			
BAJAJ	JG	7000				97.22222			97.2222					123		58.333				106.9			
BAJAJ	DT	4000					55.55556	55.5556					70			55.556				55.56			
BAJAJ	KTO - 4	2000					27.77778	27.7778						35		27.778				27.78			
BAJAJ	DT	2000					27.77778	27.7778						35		27.778				27.78			
REML	NT51	4500					62.5			62.5			79			62.5				62.5			
PEUGEOT	721TL	500			9.25926						9				2			6.9444				6.944	
PIAGGIO	SCARABEO TL	900			9.72222									16	2	12.5				12.5			
TATA FICOSA	FIAT LINEA	2000			27.7778		27.77778	27.7778				35			2		27.778				27.78		
TATA FICOSA	TATA VISTA	9000			125	125			125			158			9		125				125		
TVS	U157	6500							90.2778				114						90.28				90.28
TVS	U157	6500					90.27778						114					90.278				90.28	
TVS	N112	10000				138.8889					175								138.9				138.9
TVS	N112	10000						138.889			175							138.89				138.9	
VW	REFLEX RR 250	3900				78.24074		78.2407						68	0		54.167				54.17		
VW	REFLEX RR 251	12000			240.741					240.741				211	20		166.67				166.7		
ISUZU	SIDE REPEATER	4500			90.2778							79			22				62.5				62.5
ISUZU	SIDE REPEATER	4500						90.2778				79			22				62.5				62.5
ISUZU	FPL RH	4500	118.056	118.056								79			67				62.5				62.5
ISUZU	FPLLH	4500	118.056	118.056								79			67				62.5				62.5
FUSO	FR & STL 24V LH	2025	53.125	53.125							36				30			28.125				28.13	
FUSO	FR & STL 24V RH	2025	53.125	53.125							36				30			28.125				28.13	
FUSO	FR & STL 12V LH	3000	78.7037	78.7037							53				45			41.667				41.67	
FUSO	FR & STL 12V LH	3000	78.7037	78.7037							53				45			41.667				41.67	
TOTAL			500	500	503	439	428	446	449	303	536	509	526	511	364	381	374	376	479	430	374	376	479
MONTHLY HOURS			0.91	0.91	0.91	0.80	0.78	0.81	0.82	0.55	0.97	0.93	0.96	0.93	0.66	0.69	0.68	0.68	0.87	0.78	0.68	0.68	0.87

As is it shown in the capacity calculation of the Vibration Cell the injection molding machines and the vibration welding machines are near 100% of their capacity. Production planning is performed without taking into account the process flows for each product. One example of this is that one pair of leak and light testers are allocated to products that have different assembly processes. One of the objectives of this project is to classify the products according to their process flow and allocate the existing equipment for each product group and to then reduce the cycle time (set up and assembly time).

5. Analisys of production processes

5.1 Goals of the chapter

The aim of this chapter is to analyze the times, production problems and all the aspects that affect to the low productivity of processes. The area of study will be the Vibration welding area.

5.2 Change of tool

The change of tool of the vibration welding machines is a very important process in the production plan of the cell. Before the realization of this project there was not a guideline and checklist. In each change, workers performed the process in a different way. In addition the current trolley is unsafe, unstable and it is not prepared to develop its function in a proper manner. The changeover time is at least one hour, making the production and the quality inconsistent. The longer it takes to change the tool, the cycle time increases and the delivery times are delayed.

5.2.1 Trolley

The existing trolley is used in an inefficient way. This trolley comes from another plant of Rinder and is not adjusted to the current necessities of the plant. The problems with this trolley are:

- It does not have the capacity to transport the most of the welding tools in safe conditions.
- Workers use it every time in a different way.
- Usually the welding tools are wider than the trolley.
- The maximum width that the trolley can permit is 60 centimeters, but the vibration welding machines have the capacity for tools with 102 centimeters of width.
- Four workers are required at least for the change of tool because the trolley is difficult to handle.
- Needs a counterweight and the strength of three workers to not overturn during the process.
- There is not a box for storing the required tools for the changeover.
- Maintenance is nonexistent.
- Dangerous for the safety of workers.
- The mobility of the trolley is limited.

Figure 62: Current Vibration Welding trolley

Figure 63: Top view of current trolley

Figure 64: Lateral view of current trolley

Figure 65: Front view of current trolley

Figure 66: The workers moving the trolley

Figure 67: Big tool in current trolley

5.2.2 Tools

The tools used for the change of the fixture are not defined. During the process workers need to search for the wrenches, interrupting the changeover because there is not a specific container box for the tools. Workers use inappropriate tools, screws and washers causing damage to the fixture.

Figure 68: Bent pipe used as tool

Figure 69: Wrench

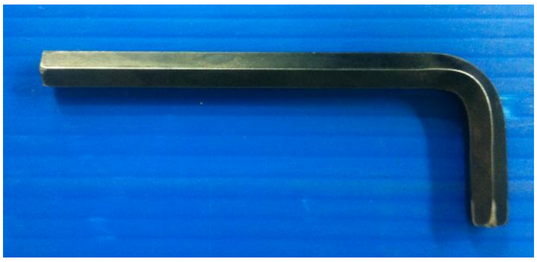


Figure 70: Hex wrench

Figure 71: Worker tightening the screws

5.2.3 Welding fixtures

There is no specific place to store the welding fixtures. When the production starts, many parts are rejected because the installation of the tool is not correct and a lot of tools are damaged.

Figure 72: Storage of vibration welding tools

Figure 73: Deformed washer with screw

5.3 Time study

Before taking any measurement regarding the optimization of the processes involved in the production of the parts, is important to know the real cycle time of each product and identify the bottleneck[20] of each product.

5.3.1 Times of reflectors (VW RR 250 & VW RR251)

Processes	Manpower	Subprocesses	n° Worker	Times (seg) Time 1	Time 2	Time 3	Time 4	Mean	Process time
Vibration Welding	2	Preassembly housing & lens	1	15.67	12	10	7.7	11.3	39.6
		Put housing & lens on the Vibration Welding Fixture	2	12.21	13.29	12.8	13.23	12.9	
		Welding	2	11	11	11	11	11.0	
		Place the part in the tray	2	3.38	5.42	4.23	4.35	4.3	
Annealing	3	Transport the tray to the annealing oven	3,4 & 5	450	450	450	450	450.0	2400.0
		Annealing	3	1500	1500	1500	1500	1500.0	
		Transport the tray to the checking line	3,4 & 5	450	450	450	450	450.0	
Inspection	2	Clean the part and visual check	3 & 4	12.35	7.94	9.69	17.18	11.8	31.6
		Check the proper fitment in the car part	3 & 4	12.92	14	12	15.04	13.5	
		Place the part in the tray with the sticker if it is Ok	3 & 4	8.93	4.38	3.98	7.94	6.3	
Packing	2	Place the stretch film on lens	4 & 5	10	16.6	16.2	44	21.7	23.5
		Place the part in the box	4 & 5	2	1.82	1.8	1.5	1.8	
		Flux time						2494.6	Seconds
		Cycle time						60	Seconds

Table 9: Times of reflectors

It is observed that the annealing process is the slowest process. We can deduce that it is because the products need one hundred and twenty minutes of annealing. Although there are some more aspects that affect that time:

- The oven is out of the vibration cell.
- There is no tool to transport the trays.

[20] *Bottleneck:* Stage in a process that causes the entire process to slow down or stop.

- The workers of the plant use the area next to the oven to place boxes.
- The instructions of how to do the annealing process do not specify anything.
- The process requires few workers.
- Sometimes workers do not put the maximum number of trays in the oven.
- They transport five trays to the oven each time.

Inspection and Packing is slower than welding process. The aspects that affect that time are:

- The process is slower if two workers do the checking and packing.
- The process of how the products must be packed is detailed, but not the process.
- Sometimes the worker does not identify if it is the left or right product.
- Difficulties to extract the piece of the fixture during the checking.
- The process stops when the worker has to prepare the packaging box.
- Workers have to wait sometimes for the trays with annealed parts.

Vibration Welding

- Sometimes workers do not put the maximum number of reflex per tray.
- The worker does not know where to put the work instructions in the welding stage.

Figure 74: Oven placement

Figure 75: Current situation of identification labels

5.3.2 Time study of mirror blinkers (Tata Vista & Fiat Linea)

				Times (seg)					
Processes	**Manpower**	**Subprocesses**	**n° Worker**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Mean**	**Process time**
Vibration Welding	2	Take housing pre-assembly from tray and clean	2	3.7	4	3.7	3.8	3.8	26.8
		Place housing in machine	2	3.5	3.4	3.6	3.5	3.5	
		Take lens from box and clean	1	3.8	3.8	3.9	3.7	3.8	
		Welding	2	10	10	10	10	10.0	
		Place the job in tray	2	5.7	6	5.4	5.7	5.7	
Annealing	2	Transport the tray to the annealing oven	1	45	45	45	45	45.0	1567.0
		Annealing	0	1500	1500	1500	1500	1500.0	
		Transport the tray to the checking line	3	20	26	22	20	22.0	
Leak Testing	1	Place the two jobs in leak testing	3	8.6	10.15	7.17	8.8	8.7	36.6
		Leak testing	3	11	11	11	11	11.0	
		Fit the cap in the left job and place on tray	3	8	7.8	8.12	8	8.0	
		Fit the cap in the right job and place on tray	3	9.24	6.67	9.76	10.1	8.9	
Light Testing	1	Place the two jobs in light testing	4	8.04	9.6	7.16	12.3	9.3	25.0
		Light testing	4	7.8	7.76	7.8	7.8	7.8	
		Take right job and place on tray	4	4.28	3.63	4.17	3.93	4.0	
		Take left job and place on tray	4	4.33	3.71	3.9	3.8	3.9	
Visual Check and Packing	2	Take the job and visual check	5	5.21	5.5	3.9	4.94	4.9	16.3
		Paste the sticker and put in plastic bag	5	5.35	5.31	5.19	6.96	5.7	
		Packing	6	5.59	5.48	5.22	6.67	5.7	
		Flux time						**1671.7**	**Seconds**
		Cycle time						**36.6**	**Seconds**

Table 10: Times of mirror blinkers

It is observed that the annealing process is the slowest process. We can deduce this because the products need twenty five minutes of annealing. Although there are some more aspects that affect to that time:

- When the four vibration welding machines are working at the same time there is no place in the oven for all the welded parts.
- The route that the worker have to do is not defined.

- Sometimes they accumulate trays out of the oven because there is no worker nearby.

The second process that requires more time is the leak testing, this is because in the same stage the worker do the leak test and fit the caps in the blinkers. The caps do not have a box or a place and they are extended in the work table. It is observed that there are two workers involved in the last process making it much faster, but that does not affect the cycle time because the bottleneck is before that operation.

5.3.3 Time study of products that require potting[21]

The products that require potting and have the same cycle time are:

- Bajaj JG Tail lamp
- Piaggio Scarabeo Tail lamp
- Bajaj KT0-4 Front position lamp
- Bajaj DT Front position lamp

				Times (seg)					
Processes	**Manpower**	**Subprocesses**	**Worker nº**	Time 1	Time 2	Time 3	Time 4	Mean	Process time
Vibration Welding	1	Inspection of lens and housing	1	7.21	7.5	9.52	5.1	7.3	49.1
		Clean lens and housing with air and put in fixture	1	19.39	20	19.99	19.89	19.8	
		Welding	1	12.59	12	12.06	12.02	12.2	
		Remove welded part from fixture and place parts in tray	1	11.17	10.05	9	8.93	9.8	
Annealing	2	Transport the tray to the annealing oven	1	35.35	34.02	40.03	35	36.1	1570.7
		Annealing		1500	1500	1500	1500	1500.0	
		Remove the tray from the conveyor	2	30.1	36.3	40.11	32	34.6	
Potting	1	Potting with black hot melt	2	31.07	20.54	49.37	54.35	38.8	398.8
		Cure the potting		360	360	360	360	360.0	
Leakage testing	1	Put lamp on the Leakage Testing	3	9.07	7.73	18.08	12.01	11.7	38.3
		Leakage Testing	3	12.15	15.38	15.46	14.21	14.3	
		Remove the lamp from fixture and paste the Air Vent Filter	3	18.94	9.03	11.27	10.01	12.3	
Light testing	1	Put the lamp on the Light Testing fixture	4	9.4	11.37	14.27	9.62	11.2	35.5
		Take Wire connector and connect	4	5.2	7.57	8.8	6.56	7.0	
		Light testing	4	9.83	9.82	7.66	10.62	9.5	
		Remove the lamp from fixture	4	6.49	10.26	7.65	7.06	7.9	
Packing	1	Final check	5	17.11	15.28	14.48	11.56	14.6	19.6
		Packing	5	2.84	5.91	5.53	5.67	5.0	
		Throughput time						**2112.1**	**Seconds**
		Cycle time						**50.0**	**Seconds**

Table 11: Times of products that need potting

[21] *Potting*: Siliconized with hot melt of leaking risk areas.

As has been seen in the other products, the annealing is the process that requires the most time. Twenty five minutes are required for the annealing process, so as to reduce the time we need to optimize the process of transport. The worker has to stop his main task when he has to carry the tray to the oven.

The second process that requires more time is the potting, this is because six minutes are required to cure the potting. If the cooling time is not fulfilled the part could be rejected in the leakage test. Although there are some more aspects that affect to that time:

- There is not any specific system to cooling the potting.
- All the parts after potting are extended in the assembly table.
- The tools for potting does not have any specific place.
- The application time of potting is different each time.
- Potting stage is not in the same line of assembly.
- The worker has to stop the potting process when he goes to the over for taking the annealing parts.
- The potting gun is cleaned with cardboard.

The third process that requires more time is welding. The problems viewed in the process are:

- Trays after welding are in a table with a low height.
- Worker has to clean a lot the parts because they come from the warehouse and in this process they take a lot of dust.
- The most part of the parts that are rejected in this stage are for mould causes.
- There is only one rejection tray, products that can be restored with a simple process, go to the same big tray far from the worker.

Other problems that have been observed during the time study are:

- The complete process is not continuous, after each process the worker places the part in a tray.
- The workers are using an additional leak tester because the maintenance of the fixed leak testers is not adequate.
- Sometimes the temperature and humidity conditions are not good (Temperature 32.5°C and 28% of humidity).

Figure 76: Potting stage

Figure 77:Rejection tray in welding stage

5.3.4 Times of Royal Enfield NT51 Tail lamp

Processes	Manpower	Subprocesses	Manpower	Times (seg)				Average	Process time
				Time 1	Time 2	Time 3	Time 4		
Vibration Welding	1	Take housing sub assembly & put on vibration welding	1	18	17	15	16	16.5	
		Put lens on housing sub assembly	1	11	12	10	13	11.5	
		Welding	1	5.2	5.2	5.3	5.3	5.3	
		Remove welded part from fixture	1	22.5	23	21.1	22.3	22.2	55.5
Annealing	2	Transport the tray to the annealing oven	1	31.34	33	35	30	32.3	
		Annealing		1500	1500	1500	1500	1500.0	
		Remove the tray from the conveyor	2	45	45	41.2	46.2	44.4	1576.7
Potting	1	Potting with black hot melt	3	33.26	34.28	30.21	35.61	33.3	
		Cooling the potting	3	360	360	360	360	360.0	393.3
Leakage testing	1	Transport tray form potting stage	4	6	6	10	12	8.5	
		Put lamp on the Leakage Testing	4	15.12	16.03	15.31	15.59	15.5	
		Leakage Testing	4	14.83	15.08	15	14.9	15.0	
		Remove the lamp from fixture and paste the Air Vent Filter	4	18.1	19.21	18.5	19.3	18.8	57.7
Assembly	1	Put the cover	5	15	16	15	16	15.5	
		Put the Seal Body and screw	5	43.35	43.34	40.2	46.5	43.3	58.8
Light testing	1	Put the lamp on the Light Testing fixture and connect	6	9.04	10.1	10	9.5	9.7	
		Light testing	6	16	16	16	16	16.0	
		Remove the lamp from fixture	6	9.1	7	8	7	7.8	33.4
Final Inspection	1	Visual inspection and put sticker	7	21.02	22.03	20.02	26.04	22.3	
		Put part in bag	7	9.33	8.59	9.01	8.42	8.8	31.1
Packing	1	Pack in box	8	11.29	10.87	10.87	9.58	10.7	10.7
		Throughput time						**2217.3**	**seconds**
		Cycle time						**60**	**seconds**

Table 12: Time study of Royal Enfield NT51 Tail Lamp

As seen in the previous times, this product has in common many of the same problems. This particular product has two assembly stages between leak testing and light testing, this process conditions the cycle time because the next stages must wait the parts. In this process two workers are involved but one of them needs around fifteen seconds and the other around forty three seconds.

5.3.5 Time study of Garnish lamps

				Times (seg)					
Processes	**Manpower**	**Subprocesses**	**Manpower**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Mean**	**Process time**
Preassembly	1	Visual check of housing and put in fixture	1	10.3	10.55	13.95	13.7	12.1	44.8
		Take inner cup and put in fixture	1	5.83	4.26	4.5	3.78	4.6	
		Take deflector, visual check and put in fixture	1	3.58	7.71	10.21	17.03	9.6	
		Assembly deflector with inner cup	1	5.98	6.34	7.91	6.48	6.7	
		Assembly deflector preassembly with housing	1	7.13	11.64	8.08	6.58	8.4	
		Place the work in the next stage	1	3.84	2.36	3.6	3.77	3.4	
Vibration Welding	2	Clean the housing subassembly and place it in the machine	2	9.96	14.15	16.25	11.38	12.9	56.3
		Flaming lens	3	29.73	18.16	4.16	25.08	19.3	
		Clean lens	2	9.31	7.1	7.41	7.84	7.9	
		Place lens in machine	2	6.19	3.87	4.15	5.4	4.9	
		Welding	2	12	10	11.42	11.66	11.3	
Annealing	2	Transport work to the oven (3 works)	2	14.74	15.75	15.1	14.89	15.1	182.9
		Annealing		150	150	150	150	150.0	
		Transport work to assembly line	4	16.6	20.57	16.77	17.1	17.8	
Leak testing	1	Bulb fitment	4	10.91	6.1	14.44	9.08	10.1	24.4
		Leak testing	4	8.29	9.07	9.06	10.34	9.2	
		Fit the air vent in housing	4	3.71	6.26	4.67	5.58	5.1	
Light testing	1	Assembly 2 grommets with screws	5	15.16	14.06	16.27	16.77	15.6	34.1
		Assembly 2 brackets with housing during light testing	5	15.7	17.15	20.72	20.39	18.5	
Final Check	1	Visual check	6	27.36	36.65	15.06	29.61	27.2	27.2
Packing	1	Packing	7	37.06	24.51	26.46	27.87	29.0	29.0
		Flux time						**398.5**	**Seconds**
		Cycle time						**60**	**Seconds**

Table 13: Time study of Garnish lamps

Problems that have been observed during the time study are:

- The worker of preassembly sometimes does not have space to place the work when he finish.
- The worker of welding transport the welded parts in threes, he has to do two walks to the oven for that.

- The line of assembly usually have to wait a lot of time the works that come from the oven.
- The worker that packs usually cut the packaging tape with his teeth.
- The assembly process is not continuous because the leak test stage and the assembly stage are placed in the wrong order.
- The packing box are big and they hinder the passage.
- The products take up much space in the oven.
- They need to use two tables for the light testing
- Flaming the lens with the hot air gun is an inconsistent process because the cycle time goes from 4.16 to 29.73 seconds.

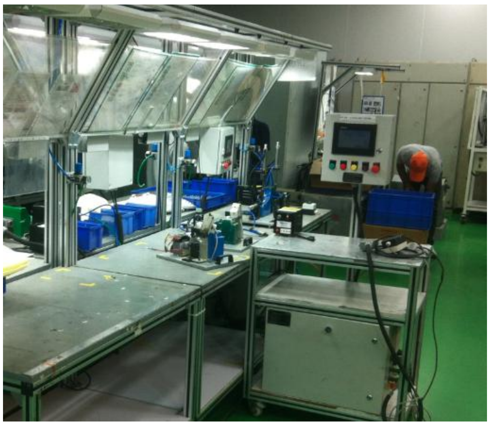


Figure 78: Added table for light testing

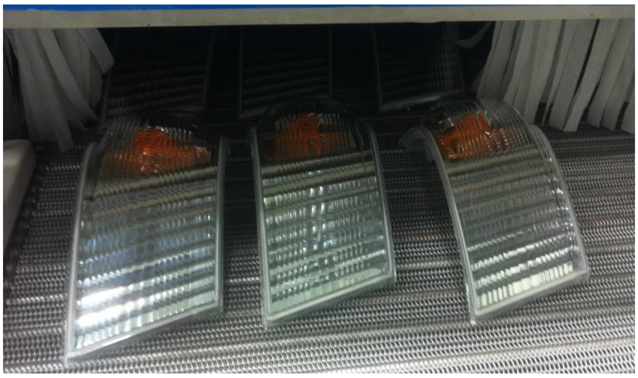


Figure 79: Garnish lamps places in the oven

Figure 80: Initial assembly table of garnish lamps

Figure 81: Air gun

5.3.6 Takt time calculation

First of all, to know which are the actions that should be undertaken, the calculation of the takt time must be performed. As it is explained in chapter three the takt time is the time available divided by customer requirement. In a shift of eight hours the available time is seven hours. The requirements that were considered in this calculation are from May and April daily production planning.

Assly line	Project	Parts/shift	Takt time (seg)	Cycle time
Vibration 1 (502)	Fuso Trasfer_Japan LH	500	50.4	60
	Garnish Lamp LH	500	50.4	60
	Garnish Lamp RH	500	50.4	60
	Fuso Trasfer_Portugal LH	500	50.4	60
	Fuso Trasfer_Japan RH	500	50.4	60
	Fuso Trasfer_Portugal RH	500	50.4	60
Vibration 2 (Dukane)	TATA VISTA BLK LH	500	50.4	36.6
	TATA VISTA BLK RH	500	50.4	36.6
	SIDE MIRROR BLINKER ASSLY.LH (TATA FICOSA-FIAT)	500	50.4	36.6
	SIDE MIRROR BLINKER ASSLY.RH (TATA FICOSA-FIAT)	500	50.4	36.6
	VW POLO GP REAR REFLEX LH	500	50.4	60
	VW POLO GP REAR REFLEX RH	500	50.4	60
	Rear Reflector 251 LH	500	50.4	31.6
	Rear Reflector 251 RH	500	50.4	31.6
	DT Tail Lamp Assly	300	84	65
	KT04 FPL	500	50.4	50
Vibration 3 (2407)	NT 51 Tail Lamp Assembly	650	38.76	60
	JG Tail Lamp assly	650	38.76	50
	JG Tail Lamp assly (SPD)	650	38.76	50
	2189 TL	600	42	50
	1169 TL	250	100.8	50
Vibration 4 (5i2H)	Peugeot Tail Lamp RH	250	100.8	50

Table 14: Comparison between Takt time and cycle time

5.4 Workers and materials flow

The initial layout of the plant is designed dividing the cell in two areas, the injection moulding area and the vibration welding area. The material flow goes from the left side to the right side.

Firstly, the raw material is placed in the left side of the plant and the workers take it from there to the dehumidifiers that are connected to the injection machines. Once the material is injected the worker puts the part in the cooling fixture to prevent undesired deformations. When the molding process is finished the material flow stops because the parts are packed and transported to the warehouse.

The production process continues in the vibration welding area. In this step of the process the worker at the vibration welding machine receives preassembly, metallized and moulded parts. The metallizing cells are producing parts for all the lines of the plant, so to modify the flow of materials that come from there is quite difficult. However the transport process of the parts that come from molding and preassembly area can be optimized. The preassembly area where the PCB with the electronic parts are mounted is in the export cell, so the route that the material has to follow for going to the vibration cell is so long and most of the times those parts go first to the warehouse.

The vibration welding area has two doors, but only one is available because the other is blocked by one assembly line. All the workers and materials flow must go through the same door. The input and output flow is the same.

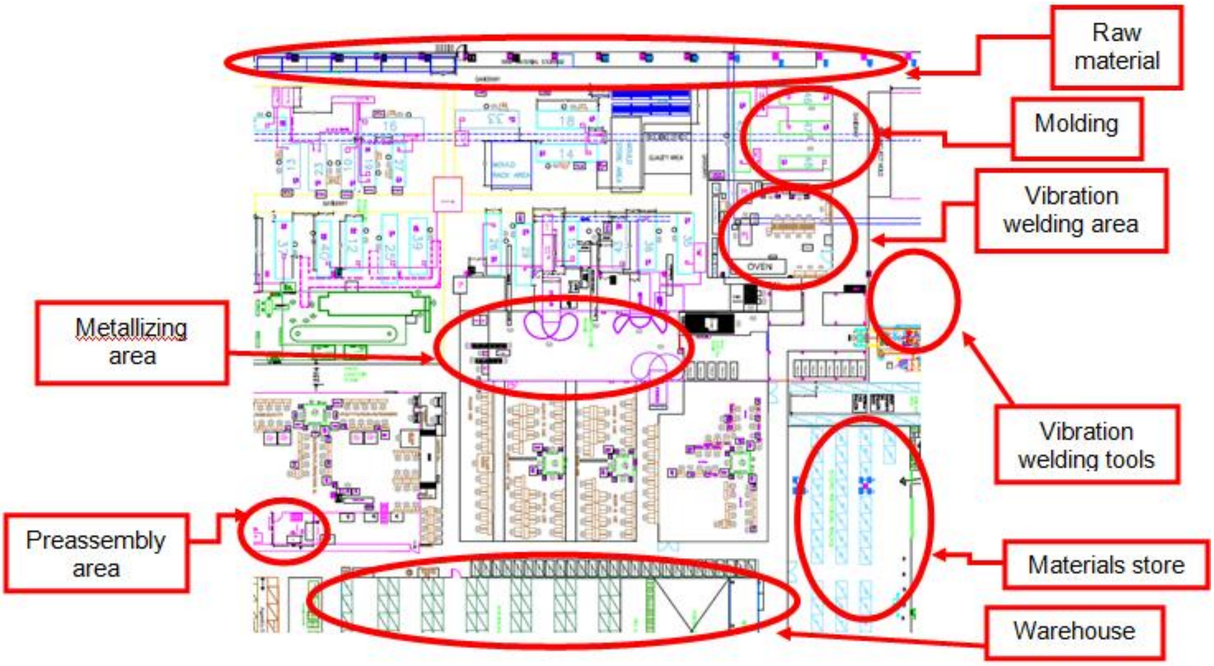


Figure 82: Areas implicated in production of parts of the Vibration Cell

6. Design of new assembly lines

6.1 Goals of the chapter

Is important to define and classify the products produced at the cell, know their process flow and the necessary manpower to achieve the customer demand. Before the realization of this project, the Rinder production team did not follow a guideline and in each shift the organization of the production plan was different. The goal of this chapter is to design the new assembly lines according to the needs of each product.

6.2 Classification of products

Products will be divided according to their manufacturing process. According to the manufacturing process in the assembly line, three different groups are defined. In the first group there are the lamps that after annealing only need final testing (Leak test, light test and visual inspection), in the second group products that need potting and in the third, products that need assembly and final testing (fit the bulb, assembly with screws, leak test, light test, visual inspection…).

6.2.1 Group 1

6.2.1.1 Products

In this group there are two kinds of products according to their process flow; the ones that need a visual check and packing (Reflectors), and the others that need leak testing, light testing, visual check and packing. The quantities of these products are huge, cycle times are low and the production must be fast.

Customer	Project	Qty/month
VOLKSWAGEN	RR 250	10000
VOLKSWAGEN	RR 251	12000
TATA FICOSA	VISTA	9000
TATA FICOSA	LINEA	2000
KAWASAKI	9080 TL	2500
BAJAJ	K03 TL	500
TVS	N112 FPL	10000

Table 15: Group 1 products to be produced

The first step is to analyze and define what the process flow of each product is and which requirements of each stage are. With the cycle time measured and the assembly stages defined, the design of the line would made.

6.2.1.2 Process flow and required tools

Group 1.1:

- VW RR 250
- VWRR 251

Description of Operation	Tools required
Stage 1: Final Inspection	Assembly table & bumper
Stage 2: Packing	Assembly Table, film & box

Table 16: Process flow of Group 1.1

Group 1.2:

- KAWASAKI 9080 TL
- KAWASAKI 2189 TL
- TATA FICOSA LINEA
- TATA FICOSA VISTA
- BAJAJ K03 TL
- TVS N112 FPL

Description of Operation	Tools required
Stage 1: Leak Testing & putting Leak tester Cap	Leak Tester, fixture & caps
Stage 2: Light testing of Lamp	Light Tester & fixture
Stage 3: Final Inspection	Assembly table
Stage 4: Packing	Assembly table, bags and boxes

Table 17: Process flow of Group 1.2

6.2.1.3 Capacity calculation

SR. NO	L E NO.	LINE DEFINATION	PRODUCT PART NO.	PART NAME	HAN	PRO PER MONT	CYCL TIME (Sec)	NO. OF STAGE	No of shifts (12 Hrs shift)	Time Req for change (12 Hrs shift)	Total Time in sec	No. of shifts (12 Hrs)	Total Shifts/ Line	% Utilization
1	1	VIBRATION WELDING G1	64024.01	VW 250	2	10000	40	2	10.10	16666.67	419753.09	10.60	47.57	91.48%
2			64015.01	VW 251	2	12000	40	2	12.12	20000.00	503703.70	12.72		
3			64028.01	N112 FPL	2	10000	35	4	8.84	14583.33	367283.95	9.27		
4			62010.01	K03 TL	1	500	35	4	0.44	729.17	21100.00	0.53		
5			90530.01	VISTA BL	2	8000	30	5	6.06	10000.00	251851.85	6.36		
6			90531.01	LINEA BL	2	2000	30	5	1.52	2500.00	62962.96	1.59		
7				Peugeot TL	2	2000	60	5	3.03	5000.00	125925.93	3.18		
8			90522.01	9080 TL	1	2500	50		3.16	5208.33	131172.84	3.31		

Table 18: Capacity calculation of Group 1

The capacity calculation was made according to the current customer requirements. The cycle times are theoretical and maximized so the calculation may be considered realistic. The number of projects that need vibration welding is increasing and the expectation is that this trend will not stop.

6.2.1.4 Final structure of line 1

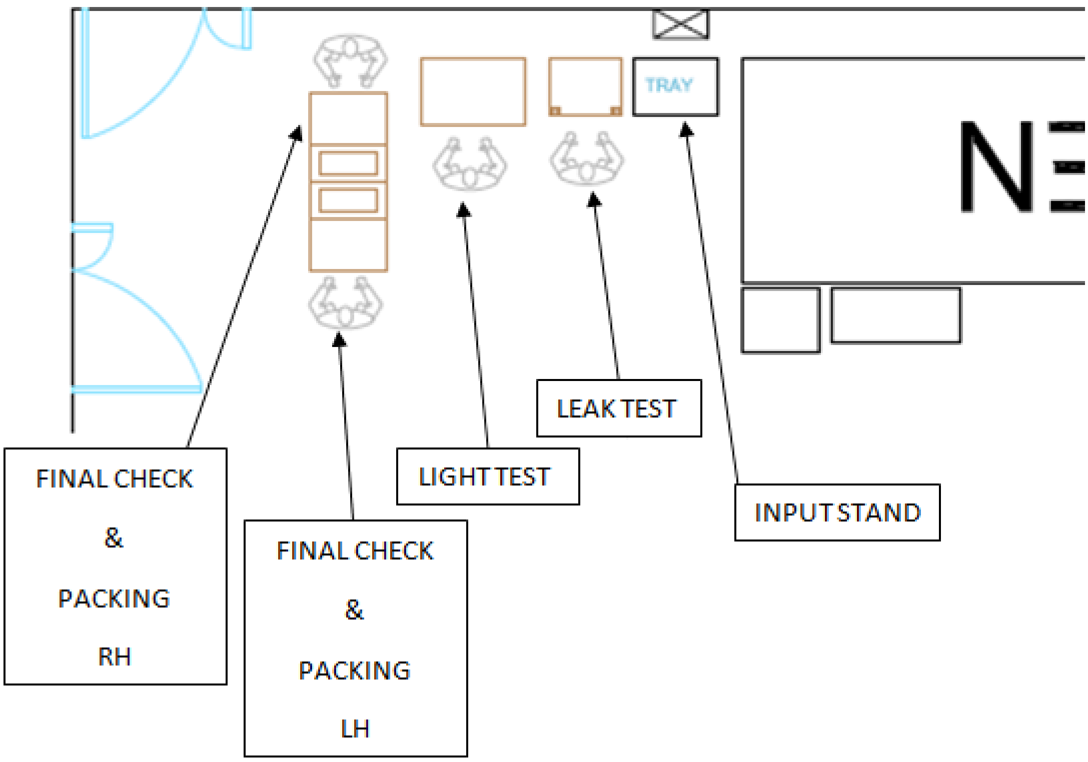


Figure 83: Final structure of line 1

The new structure is provided only with the necessary stages so the workers cannot occupy more space than that which is necessary. The line will be fixed so the setup of the assembly process will be faster. Fixing the stages that are required forces workers to make the process fluid. The assembly stages will be placed one in front of another so the worker will not mix left and right products.

Leak and light testers: The current light and leak testers must be modified because present microcontrollers in the tables do not adequately locate the fixture. The solution is to replace them.

Figure 84: Microcontrollers in testers

New assembly table: The current assembly tables must be modified, dividing them in two and adding a shelf for placing the required trays and tools. Currently there is not a location for the tray with products so the idea is to optimize the space using a shelf slightly inclined so that the parts do not bunch up on one side of the tray. The requirements are:

- Shelf for putting trays with a suitable high
- Good illumination
- Suitable height of the work table
- Space for all tools required
- Space for the assembly process

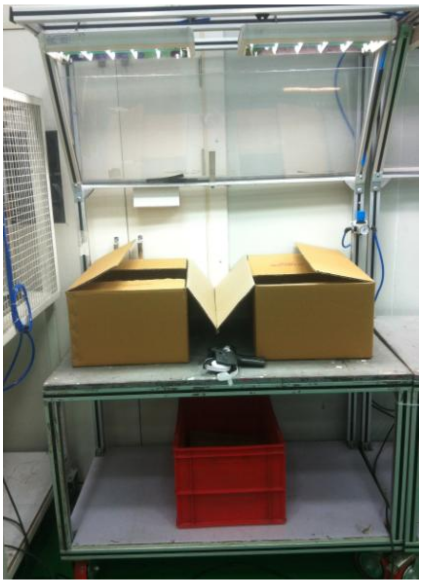


Figure 85: Current assembly table

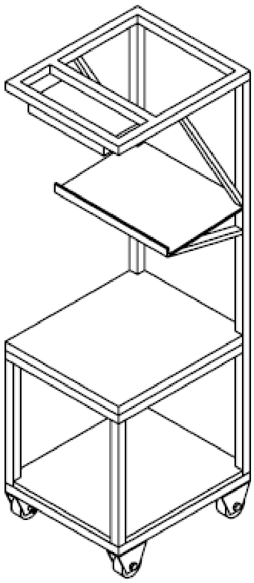


Figure 86: New assembly table

6.2.2 Group 2

6.2.2.1 Products

In this group there are three kinds of products according to each process flow; the ones that need potting, leak test, light test, final inspection and packing, others that need potting, leak testing, assembly, light testing, final inspection and packing and the ones that need pre-assembly, potting, leak test, light test, final inspection and packing. In these products the process of cooling for potting is a process that conditions the cycle because it needs six minutes. In the following table the products that are producing at the moment and the projects that will be produced.

Customer	Project	Qty/month
KAWASAKI	8943 TL	4000
KAWASAKI	3524 TL	4500
KAWASAKI	1169 TL	500
KAWASAKI	2189 TL	20
BAJAJ	JG TL	7000
BAJAJ	DT FPL	4000
BAJAJ	KTO - 4 FPL	2000
BAJAJ	DT TL	2000
REML	NT51 TL	4500
PIAGGIO	SCARABEO TL	900

Table 19: Group 2 products to be produced

6.2.2.2 Process flow and required tools

Group 2.1:

- BAJAJ KT-04 FPL
- PIAGGIO SCARABEO TL
- BAJAJ JG TL
- BAJAJ DT FPL

Description of Operation	Tools required
Stage 1: Adding potting compound in Wire harness and screw	Assembly Fixture & glue gun
Stage 2: Leak Testing & putting Leak tester Cap	Leak Tester & fixture
Stage 3: Light testing of Lamp	Light Tester & fixture
Stage 4: Final Inspection	Inspection table
Stage 5: Packing	Assembly Table, bags & boxes

Table 20: Process flow of Group 2.1

<u>Group 2.2:</u>

- KAWASAKI 8943 TL
- KAWASAKI 3524 TL
- KAWASAKI 1169 TL
- KAWASAKI 2189 TL
- REML TL

Description of Operation	Tools required
Stage 1: Adding potting compound in Wire harness and screw	Assembly Fixture & glue gun
Stage 2: Leak Testing & putting Leak tester Cap	Leak Tester & fixture
Stage 3: • Fitting Coupler to wiring Harness (KAWASAKI PRODUCTS) • Assembly of Outer housing + Cover + Seal Body With 02 nos Screws (REML)	Assembly Table
Stage 4: Light testing of Lamp	Light Tester & fixture
Stage 5: Final Inspection	Inspection table

Stage 6: Packing	Assembly Table, bags & boxes

Table 21: Process flow of Group 2.2

Group 2.3:

- BAJAJ DT TL

Description of Operation	Tools required
Stage 1 : Back Cover Sealing & screwing on back cover	Assembly Fixture & glue gun
Stage 2 : Potting on screw area	Fixture & glue gun
Stage 3: Leakage Testing.	Leak Tester & fixture
Stage 4 : Light Testing of Tail lamp	Light Tester & fixture
Stage 5 : Final Inspection	Inspection table
Stage 6 : Packing	Assembly Table, bags & boxes

Table 22: Process flow of Group 2.3

6.2.2.3 Capacity calculation

SR. NO	LINE NO.	LINE DEFINATION	PRODUCT		HAN	PRO PER MONT	CYCL TIME (Sec)	NO. OF STAGE	No of shifts (12 Hrs shift)	Time Req for change (12 Hrs shift)	Total Time in sec	No. of shifts (12 Hrs)	Total Shifts/ Line	% Utilization
			PART NO.	PART NAME										
1	2	VIBRATION WELDING G2		U157 TL	1	0	1		0.00	0.00	3600.00	0.09	31.89	61.33%
2				SCARABEO TL INNER HSG	1	900	44	6	1.00	1650.00	41555.56	1.05		
3				2189 TL	1	20	35		0.02	29.17	4300.00	0.11		
4			90573.01	KT04 FPL	1	2000	55	8	2.78	4583.33	115432.10	2.91		
5			90515.01	DT TL	1	4000	35	7	3.54	5833.33	146913.58	3.71		
6			90431.02	8943 TL	1	2000	45	6	2.27	3750.00	94444.44	2.38		
7			90288.01	3524 TL	1	500	45	8	0.57	937.50	26100.00	0.66		
8			90288.03	1169 TL ASSY	1	700	45	7	0.80	1312.50	33055.56	0.83		
9			90341.01	JG TL	1	7000	45	7	7.95	13125.00	330555.56	8.35		
10			90494.00	REML TL	1	4500	50	8	5.68	9375.00	236111.11	5.96		
11				721 TL	2	0	120	6	0.00	0.00	3600.00	0.09		
12				2189 TL	1	20	60	6	0.03	50.00	4800.00	0.12		
13			90517.02	DT FPL	2	4000	50	4	5.05	8333.33	209876.54	5.30		
14			90451.01	3154 FPL	1	300	30	7	0.23	375.00	12600.00	0.32		

Table 23: Capacity calculation of Group 2

6.2.2.4 Final structure of line 2

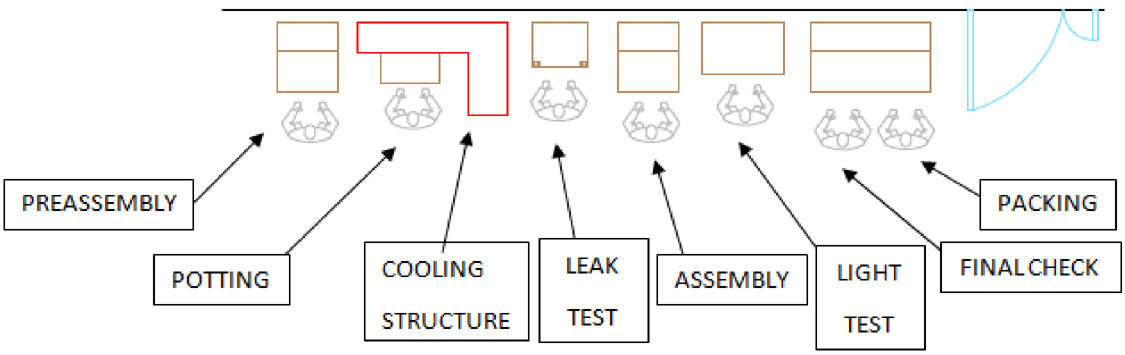


Figure 87: Structure of line 2

The new line structure has solved all the required stages, and also has included a cooling structure for the potting. Before this improvement parts were cooled in an incorrect way, operators did not know which of the products were t be cooled first and what was the cause of rejection. This structure reduces the area for cooling of the potting parts and optimizes the space available.

Cooling structure: The new cooling structure solves the problem of having all the potting parts extended in the assembly tables. The cooling structure is designed taking into account all the sizes of the products that need potting. The idea is that once the potting is applied, the part is placed in a box with adjustable dividers. We know that the time of cooling is six minutes, and the time for applying the potting is twenty seconds, so we need to have eighteen products in the structure to feed the next stage. The structure has a mechanical system so in the case of power failure the line does not stop.

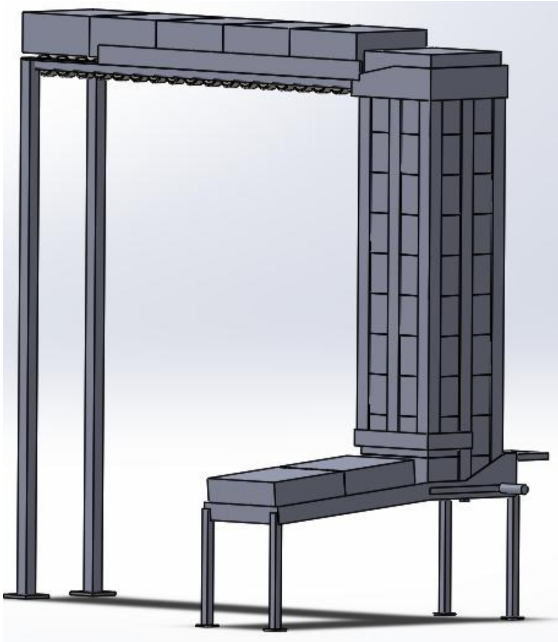


Figure 88: Cooling structure with boxes

Figure 89: Cooling structure

6.2.3 Group 3

6.2.3.1 Products

In this group the products need more than one assembly stage for the manufacturing process. The majority of the products are large because they are lamps for trucks, so the space required is larger. The fixtures are individual, so the production of the parts of the right side must be produced in the left side.

Customer	Project	Qty/month
FUSO	FR & STL 24V RH	2025
FUSO	FR & STL 24V LH	2025
FUSO	FR & STL 12V RH	3000
FUSO	FR & STL 12V LH	3000
ISUZU	SIDE REPEATER	4500
ISUZU	SIDE REPEATER	4500
ISUZU	FPL RH	4500
ISUZU	FPL LH	4500

Table 24: Group 3 products to be produced

6.2.3.2 Process flow and required tools

Description of Operation	Tools required
Stage 1: 24V 21 W Bulb fitment in socket & Socket fitment in sealed sub assembly And Leak Testing Of lens Housing sealed assembly. & Cover Hole (Air Vent) fitment with housing	Assembly Fixture & leak testing fixture
Stage 2 : Assembly of Grommet with Bracket 4.2 X 14 by self-tapping screw 01 No.	Fixture & electric screw driver
Stage 3: Assembly of Bracket assembly with housing by M4 X 19 Screw. & Light Testing Of Lamp	Light Tester, light tester fixture & electric screw driver
Stage 4 : Final Inspection	Inspection table

Stage 5 : Packing	Assembly Table, bags & boxes

Table 25: Process flow of group 3

6.2.3.3 Capacity calculation

SR. NO	LINE NO.	LINE DEFINATION	PRODUCT		HAN	PRO PER MONT	CYCL TIME (Sec)	NO. OF STAGE	No of shifts (12 Hrs shift)	Time Req for change (12 Hrs shift)	Total Time in sec	No. of shifts (12 Hrs)	Total Shifts/ Line	% Utilization
			PART NO.	PART NAME										
1	3	VIBRATION WELDING G3	63002.01	FUSO TRANSFER LAMP ASLY	2	5000	50	5	6.31	10416.67	262345.68	6.62	47.18	90.72%
2			63001.01	FUSO GARNISH LAMP	2	3000	50	6	3.79	6250.00	157407.41	3.97		
3				1015 TL	1	5500	60	5	8.33	13750.00	346296.30	8.74		
4				U157 BLK	2	0	50	5	0.00	0.00	3600.00	0.09		
5				U221 BLK	2	0	50	5	0.00	0.00	3600.00	0.09		
6				9694 TL	1	0	50	5	0.00	0.00	3600.00	0.09		
7			63008.01	ISUZU FSTSL LAMP	2	8000	60	5	12.12	20000.00	503703.70	12.72		
8			64009.01	ISUZU SIDE INDICATOR LAMP	2	8000	70	5	14.14	23333.33	587654.32	14.84		

Table 26: Capacity calculation of Group 3

6.2.3.4 Final structure of liner 3 and 4

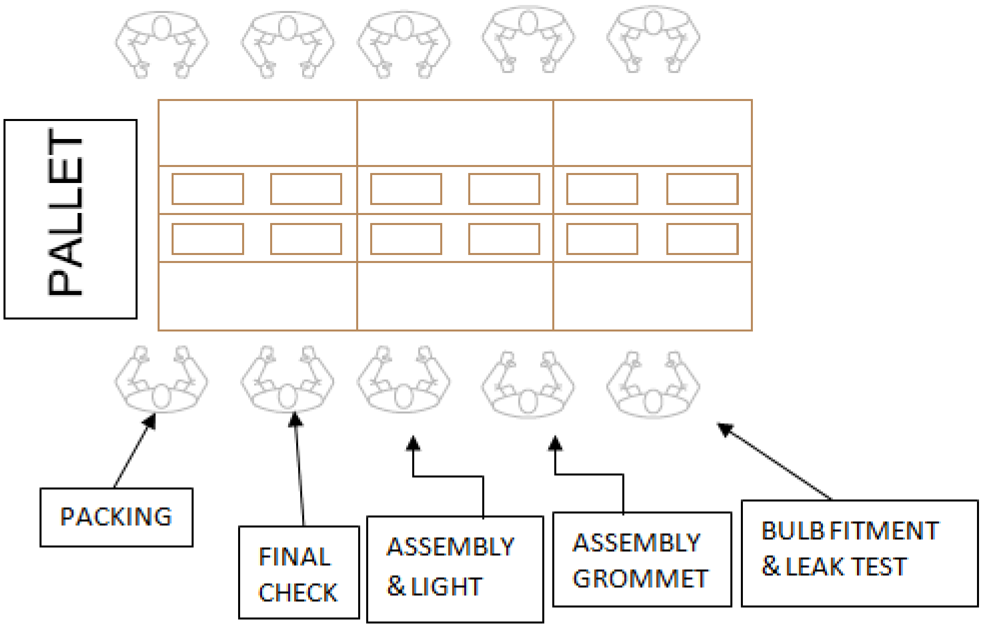


Figure 90: Structure of line 3

The design of these two lines is made by taking into account that the projects of the third group are larger than those of the other groups. The assembly processes are performed in the assembly line, so large assembly tables are required. The leak and light testers are integrated in the tables and so will be the combo (leak and light testers that can provide the two lines at the same time). The new lines can function with the current assembly tables but another solution, however more efficient but more expensive, is to install conveyors between the lines to make the process more fluid.

Figure 91: Assembly line with conveyor

6.3 Material bins

Every stage that requires an area for storing screws, gaskets, silicone rods, washers, caps will be provided with plastic bins.

Figure 92: Plastic bin

PRODUCT		SIZE OF BIN (cm)			
PART NO.	PART NAME	LENGTH	WIDTH	HEIGHT	Qty/Bin
48008.01	Bulb 12V 21W LL Clear Osram				420
48005.02	Bulb 24V 21W LL Amber Osram				420
95074.00	Bulb 12V 21/5W Osram	34	25	25	420
95069.00	Bulb 12V 10W Osram				420
95039.00	Bulb 12V 21/5W Phillips				420
92609.00	Air Vent Cap With Breather 307T HL				300
91694.00	Screw 3.5x11				400
55039.01	Grommet				300
55038.01	Bracket				125
40063.01	Screw M4 X 14 MFZn8	24	15	13	400
40064.01	Screw M4 X 19 MFZn8				400
55040.01	Self locking Nut				375
44001.01	Socket				200
40025.01	Self locking Nut				375

42023.01	Nitto Denko Blue Air Breather				300
42021.01	Grommet PA 6.6				300
40026.01	Screw 5 X 28 HHB Steel				400
42027.01	Gasket				300
91665.00	Screw M4 X 16				400
92609.00	Air Vent Cap With Breather 307T HL				300
42040.01	K03 TL Air Breather				300
92547.00	RBR Cap Leak tester				300
91727.00	Screw 2.9 x 9.5 Black				400
44065.01	Bulb Holder	30	21	16	120
44047.01	Bulb Holder				120

Table 27: Sizes of bins

7. Machine stages

The machines needed for the fabrication process will be distributed according to the group classification of products. The stages will be designed with all the necessary tools, with the aim of eliminating all unnecessary wastes, and it will be provided only with the required tools.

7.1 Vibration welding machines calculation

Customer	Project	Qty/month	DUKANE	M502H	M5i2H	2407
TVS	N112	5000		175		
TVS	N112	5000		175		
VW	REFLEX RR 250	3900	68			
VW	REFLEX RR 251	12000	211			
TATA FICOSA	FIAT LINEA	2000	35			
TATA FICOSA	TATA VISTA	9000	158			
KAWASAKI	8943	4000				70
KAWASAKI	3524	4500				79
KAWASAKI	1169	500				9
BAJAJ	JG	7000			123	
BAJAJ	DT	4000				70
BAJAJ	KTO - 4	2000			35	
BAJAJ	DT	2000			35	
REML	NT51	4500				79
PIAGGIO	SCARABEO TL	900			16	
TVS	U157	6500				114
TVS	U157	6500				114
KAWASAKI	9080	840			15	
PEUGEOT	721TL	500				9
ISUZU	SIDE REPEATER	4500			79	
ISUZU	SIDE REPEATER	4500			79	
ISUZU	FPL RH	4500			79	
ISUZU	FPL LH	4500			79	
FUSO	FR & STL 24V LH	2025		36		
FUSO	FR & STL 24V RH	2025		36		
FUSO	FR & STL 12V LH	3000		53		
FUSO	FR & STL 12V RH	3000		53		
TOTAL HOURS			472	528	540	544
MONTHLY HOURS			0.85818%	0.96%	0.981818%	0.989091%

Table 28: Capacity of vibration welding machines

The vibration welding machines have been distributed taking into account that the products of one group must be produced in two machines at the most. This calculation can be a modified in case of unexpected situations or machine problems.

7.2 Welding stages

The Vibration cell is provided with four vibration welding machines. According to the group classification the machines are distributed. With this distribution the products of one group will be always welded at the same machine or in some cases in the same two machines. In case of unexpected problems, the parts can be welded in any machine of the cell. The new vibration welding machines (Dukane 500 Series) has the same capacity of the other three machines that are going to be in the cell, so all vibration welding tools can be placed in any machine.

7.2.1 Standard welding stage

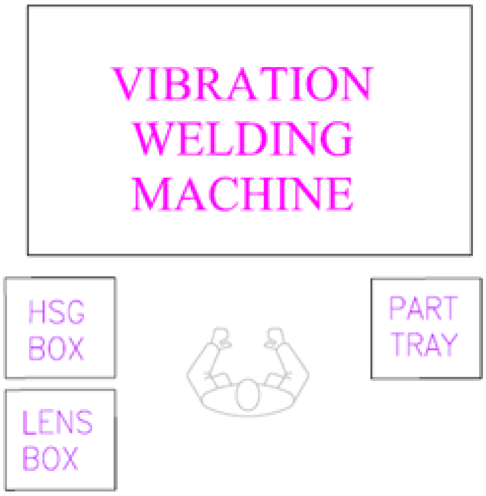
Most of the products welded in the vibration welding machines have a standardized process. Currently when they start to produce a different product the operators change the configuration of the stages using new tables, trays and bins, making the process very inefficient.

The equipment requirements for the welding stage are:

- Table for the preassembly parts
- Table for the lenses
- Table for the welded part
- Box for plastic bags (bags of the lenses and preassembly parts)
- Rejection tray
- Rejection tray for parts that can be reworked (Example: Parts that have a bad cut of the runner)
- Air gun for cleaning the parts (will be in the machine)

Table	Length (cm)	Width (cm)	Height (cm)
Preassembly	65	45	55
Lenses	65	45	55
Welded parts	65	45	70

Table 29: Tables of standard welding stage



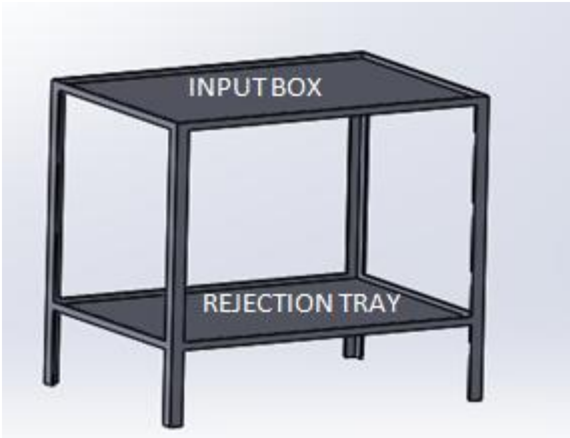


Figure 93: Standard welding stage Figure 94: Table for lenses and preassembly parts

7.2.2 Welding stage for products that need the process of flaming lens

The Branson machines will be dedicated for Fuso and Isuzu products, those products need the process of flaming the lenses and this is a restriction that we have to take into account for designing the stages.

The equipment requirements for the stage are:

- Table for the preassembly parts
- Table for flaming the lenses
- Table for the welded part
- Rejection tray
- Rejection tray for parts that can be reused, for example parts that have a bad cut of the runner
- Air gun for cleaning the parts (placed in the machine)

Table	Length (cm)	Width (cm)	Height (cm)
Preassembly	65	45	55
Flaming lenses	65	45	70
Welded parts	65	45	70

Table 30: Stands specifications

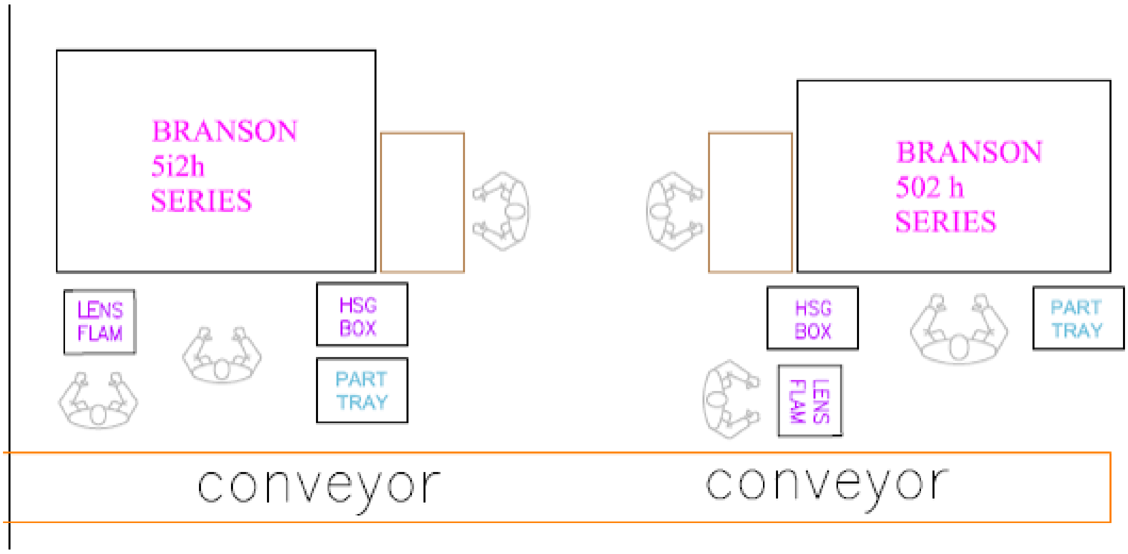


Figure 95: Vibration welding stages for products that need flaming lens

7.2.2.1 Flaming system

The current process of flaming the lenses is not safe and inconsistent. The new system provides the process flow continuity and security. Only the welding channel must be heated so the fixture must be a heat insulator except for the channel. The idea is to make one table with controlled emitting heat resistances so that when worker actives them, the welding channel of lens will be heated during the required time. The fixture of each product will be like a housing so the lens will fit perfectly.

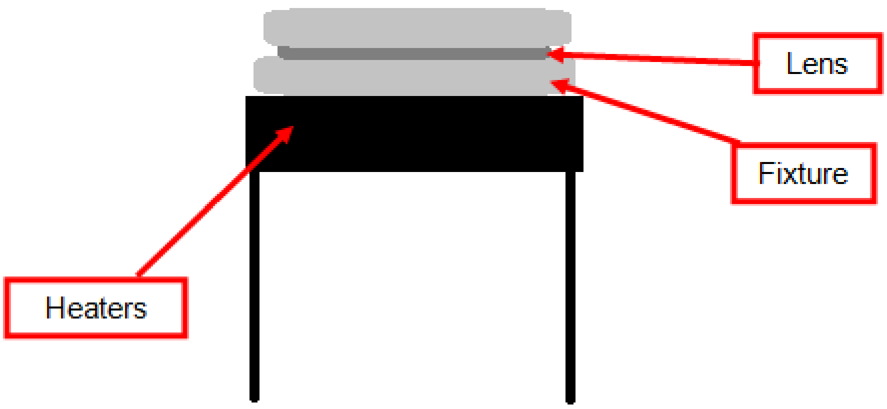


Figure 96: Flaming lens system

7.3 Oven

Annealing is a critical juncture in the manufacturing process because when the four machines are working the oven does not have the capacity to absorb all the parts that come from the welding machines. The oven operates using a convection system so the part can be placed in trays without touching the conveyor. Currently, the space is not being used properly because the oven has capacity for annealing more parts. This waste can be eliminated by an optimization of the space.

Solutions to optimize the space are simple and with the proposed changes the capacity can be the double. The garnish lamps are placed horizontally but if they are placed vertically, where there are three parts, there can be four. As has been mentioned before, the oven uses a convection system so the trays can be placed one above the other. One worker must collect two trays from the welding machines and then place them at the same time in the oven. The work instructions of the parts placement are in the appendix.

Figure 97: Optimization of the space of the oven

In the time study of Volkswagen products the annealing process was detected as the bottle neck. At first, due to the customer specifications parts were annealed during two hours in a box oven that was placed outside the cell. The solution proposed to this problem was to transfer this annealing process to the oven placed inside the cell. The limitation of that oven is that the annealing process takes twenty five minutes so before this change in the process flow of the product a test of residual stress in VW RR 250 was made. The result was successful and the annealing process was reduced in ninety-five minutes. The performance test report is in the appendix.

8. Change of tool

8.1 Goals of the chapter

This chapter deals with the cycle time reduction in mass production of automotive lighting systems. As it had been explained in previous chapters the mass production will be possible while we reduce the production time. This work has been formulated to suit the requirement of the present existing machine setup. The objectives are to improve the production of lamps, reduce the time in changeover of fixture and decrease the cost of production.

8.2 Restrictions

Before the design of the new process of change of tool we have to know what the restrictions are. The parameters that we have to take into account are:

- Width of vibration welding tools
- Weight of vibration welding tools
- Length of vibration welding tools
- Width of vibration welding machines (60cm-105cm)
- Height of vibration welding machines
- Workspace in the vibration cell
- Current design of trolley
- Mobility of trolley
- Stability
- Economic cost
- Safety
- Manpower
- Time
- Space in the cell

8.3 Solutions

The main problem is that for the change of tool there is not a guideline. In every change workers do the process in a different way. In addition the current trolley is unsafe, unstable and it is not prepared to develop his function.

8.3.1 New trolley

The idea is to use a trolley like the Dukane[22] Vibration Welding Cart, but adapted to the needs of Rinder. The needed trolley for the current requirements must have elevation system for picking up the tool from the storage area, but this alternative is very expensive. For doing the change of tool in the machines, the trolley does not

[22] *Dukane:* manufacturer and marketer of advanced technology products.

need an elevation system because the welding table is mobile. For the change of tool the height of the four machines will be the same and the height of the storage shelf will be the appropriate. To use this trolley the machine needs two brackets for the cart union and two centralizers for centering the tool during the process of loading and unloading.

Figure 98: Vibration welding cart

Figure 99: Cart union

Figure 100: Tool in cart

Figure 101: Cart centralizers

Figure 102: Machine centralizers

8.3.2 Modification of current trolley

The current trolley as it was explained in the chapter five is unsafety and unstable, the cheaper option, but not the best, is to modify the trolley adding to the structure two metal inserts with wheels. The overhang will be reduced and the trolley would be more stable.

Figure 103: Modification of current trolley

Figure 104: Frontal view of trolley with drawer

8.3.3 Tools required

The tools that are necessary for the changeover are a pneumatic gun and the screws with washers required for each tool. One container box for store the tools in the trolley will be necessary so in every change the tools will be the same and the loss of time when workers search the tools will be eliminated.

Is important to use the washers in the installation of the tool because if not the machine and the welding tool can be damaged. The tooling bolts must be all M12-1.75 and have to be tightened to a torque of 135 N*m. Always all bolts must be used, when possible, to secure the upper tooling. This is necessary to provide optimum acoustical coupling between the tooling and springs.

8.3.4 Storage of tools

The idea is to store each tool in the same place always. Each tool must have the same storage place and a checklist with the information of the number of screws that needs and where to tightening them.

Before the realization of this project, the vibration welding tools were stored in the floor without taking care about them. The setup of the welding was not efficient because the most part of the tools were damaged. The solution to this problem is to make a specific place for all the tools with a shelving provided with roller bearings. This way the change will be faster and the tools will not be damaged.

Figure 105: Shelving for storing the tools

8.3.5 Guidelines

GUIDELINE: VIBRATION WELDING CHANGE OF TOOL **WITH DUKANE TROLLEY**					
S.No	Operator 1	Operator 2	From	To	Time (seg)
1	Last Batch OK component		0	0	0
2	Bring cart with the pneumatic		0	12	12

	gun				
3	Place the front centralizers	Place the rear centralizers	12	22	10
4	Raise table to up position		22	32	10
5		Open the rear doors	32	42	10
6	Remove front upper screws	Remove rear upper screws	42	102	60
7	Lower table to home position		102	112	10
8	Remove front lower screws	Remove rear lower screws	112	172	60
9		Unattach quick connect electrical	172	182	10
10		Unattach pneumatics from tool	182	202	20
11	Position cart against alignment locater post		202	212	10
12	Position rails between cart and table		212	222	10
13	Block the cart wheels		222	232	10
14	Replace the tool in cart from the front position	Replace the tool in cart from the rear position	232	247	15
15	Remove rails from the table		247	257	10
16	Unblock the cart wheels		257	267	10
17	Transport the cart to the tools warehouse		267	387	120
18	Replace the tool in the warehouse	Replace the tool in the warehouse	387	447	60
19	Place the new tool in the cart	Place the new tool in the cart	447	507	60
20	Transport the cart to the vibration welding machine		507	627	120
21	Position cart against alignment locater post		627	637	10
22	Position rails between cart and table		637	647	10
23	Block the cart wheels		647	657	10
24	Replace the tool in machine from the front position	Replace the tool in machine from the rear position	657	672	15
25	Remove rails from the table		672	682	10
26	Unblock the cart wheels		682	692	10
27	Transport the cart to his place in vibration cell	Tightening the lower screws	692	752	60
28		Attach quick connect electrical	752	762	10
29		Attach pneumatic to tool	762	782	20
30	Raise table to up position		782	792	10
31	Tightening the front upper	Tightening the rear upper	792	852	60

	screws	screws			
32	Lower table to home position	Place the pneumatic gun in the cart	852	862	10
33	Place front centralizers in stock fixture	Place rear centralizers in stock fixture	862	872	10
TOTAL TIME				14.53	Minutes

Table 31: Guideline for the change of tool with Dukane trolley

GUIDELINE: VIBRATION WELDING CHANGE OF TOOL **WITH MODIFIED TROLLEY**					
S.No	Operator 1	Operator 2	From	To	Time (seg)
1	Last Batch OK component		0	0	0
2	Bring cart with the pneumatic gun		0	30	30
3	Place the front centralizers	Place the rear centralizers	30	40	10
4	Raise table to up position		40	50	10
5		Open the rear doors	50	60	10
6	Remove front upper screws	Remove rear upper screws	60	120	60
7	Lower table to home position		120	130	10
8	Remove front lower screws	Remove rear lower screws	130	190	60
9		Unattach quick connect electrical	190	200	10
10		Unattach pneumatics from tool	200	220	20
11	Raise the trolley up to the table		220	230	10
12	Place the trolley in position		230	240	10
13	Block the cart wheels		240	250	10
14	Replace the tool in cart from the front position	Replace the tool in cart from the rear position	250	275	25
15	Remove the trolley from the table		275	285	10
16	Lower the trolley		285	295	10
17	Unblock the cart wheels		295	305	10
18	Transport the cart to the tools warehouse		305	425	120

19	Replace the tool in the warehouse	Replace the tool in the warehouse	425	505	80
20	Place the new tool in the cart	Place the new tool in the cart	505	585	80
21	Transport the cart to the vibration welding machine		585	705	120
22	Raise the trolley up to the table		705	715	10
23	Place the trolley in position		715	725	10
24	Block the cart wheels		725	735	10
25	Replace the tool in machine from the front position	Replace the tool in machine from the rear position	735	760	25
26	Remove rails from the table		760	770	10
27	Unblock the cart wheels		770	780	10
28	Transport the cart to his place in vibration cell	Tightening the lower screws	780	840	60
29		Attach quick connect electrical	840	850	10
30		Attach pneumatic to tool	850	870	20
31	Raise table to up position		870	880	10
32	Tightening the front upper screws	Tightening the rear upper screws	880	940	60
33	Lower table to home position	Place the pneumatic gun in the cart	940	950	10
34	Place front centralizers in stock fixture	Place rear centralizers in stock fixture	950	960	10
TOTAL TIME				16	Minutes

Table 32: Change of tool Guideline with modified trolley

9. MRM Supermarket

9.1 Goal of the chapter

The aim of the chapter is to define a material store of boughtouts inside the Vibration cell. The idea of include one store with regular materials such as screws, bulbs, bulb holders and air vent caps leads in the necessity of reducing the supply times. The assembly line must be always running and each stage always must have to be provided of all the materials required at the moment.

9.2 Materials of the store

Depending on the customer requirements the material needed is different, so is important to know which materials are necessary in each shift. The following table is prepared in Excel and depending on the shift requirement the quantity of material is calculated. Moreover materials as finger cuts, Rinder tapes, white gloves, glue stick sealant and dispensable caps are also included.

PRODUCT			SIZE OF BOX (cm)				
PART NO.	PART NAME	Qty/Shift	LENGTH	WIDTH	HEIGHT	Qty/Box	Boxes/Shift
63002.01	FUSO TRANSFER LAMP ASLY	500					
48008.01	Bulb 12V 21W LL Clear Osram	500	34	25	25	420	2
92609.00	Air Vent Cap With Breather 307T HL	500	Plastic bag			100	5
91694.00	Screw 3.5x11	2000	Plastic bag			1000	2
55039.01	Grommet	500	Plastic bag			1500	1
55038.01	Bracket	1000	Plastic bag			250	4
40063.01	Screw M4 X 14 MFZn8	1000	Plastic bag			1000	1
40064.01	Screw M4 X 19 MFZn8	1000	Plastic bag			1000	1
55040.01	Self locking Nut	1000	Plastic bag			2600	1
44001.01	Socket	500	Plastic bag			200	3
63001.01	FUSO GARNISH LAMP	500					

48005.01	Bulb 24V 21W LL Clear Osram	500	34	25	25	420	2
92609.00	Air Vent Cap With Breather 307T HL	500	Plastic bag			100	5
91694.00	Screw 3.5x11	2000	Plastic bag			1000	2
55039.01	Grommet	500	Plastic bag			1500	1
55038.01	Bracket	1000	Plastic bag			250	4
40063.01	Screw M4 X 14 MFZn8	1000	Plastic bag			1000	1
40064.01	Screw M4 X 19 MFZn8	1000	Plastic bag			1000	1
55040.01	Self locking Nut	1000	Plastic bag			2600	1
44001.01	Socket	500	Plastic bag			200	3
63008.01	ISUZU FSTSL LAMP	500					
48005.02	Bulb 24V 21W LL Amber Osram	500	34	25	25	420	2
44065.01	Bulb Holder	500	Plastic bag			200	3
40025.01	Self locking Nut	1000	Plastic bag			2600	1
42023.01	Nitto Denko Blue Air Breather	500	Plastic bag			100	5
42021.01	Grommet PA 6.6	1000	Plastic bag			1500	1
40026.01	Screw 5 X 28 HHB Steel	1000	Plastic bag			1000	1
64009.01	ISUZU SIDE INDICATOR LAMP	500					
48005.02	Bulb 24V 21W LL Amber Osram	500	34	25	25	420	2
44047.01	Bulb Holder	500	Plastic bag			200	3
42027.01	Gasket	500	Plastic bag			200	3
42023.01	Nitto Denko Blue Air Breather	500	Plastic bag			100	5

90453.01	1015 TL	500					
95074.00	Bulb 12V 21/5W Osram	500	34	25	25	420	2
90285.03	9694 TL	500					
95069.00	Bulb 12V 10W Osram	500	34	25	25	420	2
91665.00	Screw M4 X 16	1000	Plastic bag			1000	1
64028.01	N112 FPL	500					
92609.00	Air Vent Cap With Breather 307T HL	500	Plastic bag			100	5
62010.01	K03 TL	500					
42040.01	K03 TL Air Breather	500	Plastic bag			1000	1
90530.01	VISTA Blk	500					
92547.00	RBR Cap Leak tester	500	Plastic bag			1000	1
90531.01	LINEA Blk	500					
92547.00	RBR Cap Leak tester	500	Plastic bag			1000	1
90335.01	Peugeot TL	250					
95039.00	Bulb 12V 21/5W Phillips	250	34	25	25	420	1
90535.03	SCARABEO TL INNER HSG	500					
92547.00	RBR Cap Leak tester	500	Plastic bag			1000	1
90573.01	KT04 FPL	500					
92547.00	RBR Cap Leak tester	500	Plastic bag			1000	1
90515.01	DT TL Assly	300					
91727.00	Screw 2.9 x 9.5 Black	300	Plastic bag			1000	1
90517.01	DT FPL	500					
92547.00	RBR Cap Leak tester	500	Plastic bag			1000	1
95505.02	Glue Stick Black Sealent	50					

98593.00	Dispensable cap	50
96210.00	Rinder tape	10
98572.00	Nylon hand gloves white	50
87001.63	Finguer cots	100

Table 33: Materials of the MRM Supermarket

9.3 Design of the stand

According to the necessities and to the space that occupies each material the measures of the stand were calculated. The design was made taking into account the maximum requirements (Three lines working with products that need bulbs, bulb holders, gasckets…). The container boxes that will be on the stand are the standard bins that Rinder use in the store of material 40x60x32 (Width x Length x Height).

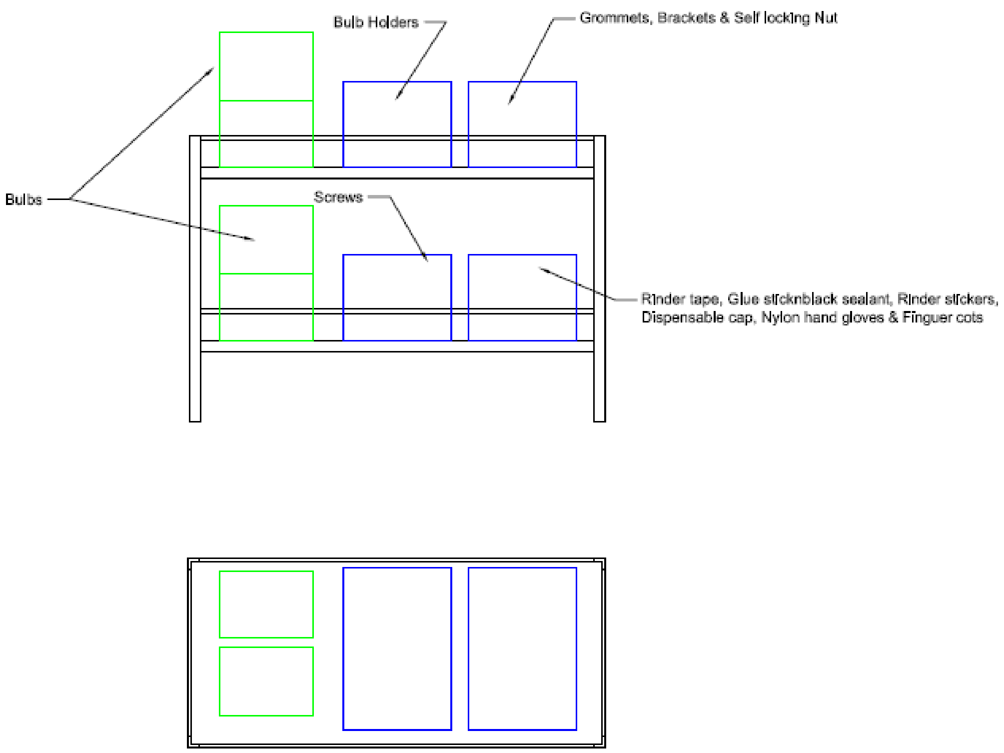


Figure 106: Stand of the MRM Supermarket

10. Visual control

10.1 Goal of the chapter

The aim of this chapter is to define a visual control system for detect elements that affect to the production. The information must be clear only with a code of visual signals making the processes more efficient and intuitive. The aim of this system is to give clear information for the workers and eliminate as much as possible the text information. One of the problems in India is communication because it is a country that has around two thousand languages and not all the workers know how to read in English or Hindi. The training phase in this field is essential because the workers have to understand and know with any doubt what the visual code is.

10.2 Trays

Currently they are using trays of three colors, red one for rejection and blue and orange for parts that are in working process. The new color code of trays wants to identify the trays by relating the function with color. The trays proposed are three, work in progress, rejection and reworked.

Tray function	Color
Work in progress	
Rejection	
Reworked	

Table 34: Colors of trays

10.3 Marking tapes for visual work place

Once the work stages are defined and approved the work places must to be marked with a color tape. Rinder use yellow tape for marking all the work, material and equipment places. The idea is to use in the cell two colors, one for fixed stages and another one for movable stages. Is important to not abuse about color codes because the use of lot of colors may confuse workers.

Tapes are an effective replacement for paint, ensure the reduction of unnecessary mistakes and increase the safety and productivity. One of the current problems is that in every set up workers change the configuration of lines. With the implementation of this system set up time will be reduced and stages fixed.

Stage	Color tape
Fixed	
Movable	

Table 35: Marking tapes in work places

10.4 Safety signals

Nowadays in India the safety aspect is not as important as others because the legal consequences of safety mistakes are not like in developed countries. Safety is another aspect very important in the productivity of the plant. Reduce the risks and the potential accidents, has direct repercussions in the productivity of workers. A lot of accidents can be avoided with simply preventive actions. The safety signals in the Vibration cell can be applied to protective measures, dangers signaling, security equipment signaling and emergency actions.

Place	Meaning	Signal	Color meaning
Fire extinguisher	Fire extinguisher		Fire fighting
Vibration welding machines	Wear ear protectors		Obligation
Electric panels	High voltage		Warning
Exit door	Emergency exit		Safety
Electric panels	No passing		Delimitation

Table 36: Safety signals

11. Layout

11.1 Goal of the chapter

The aim of this chapter is to propose the new layout of the Vibration cell. Changes in the layout would be necessaries because one more vibration welding machine (Dukane 500 series) of another plant of Spain will be installed in the Chakan plant. With the new machine, five vibration welding machines will be in plant, currently are not required but it is expected that in the future will be necessary.

The connection between the injection molding area and the vibration welding area will be studied because the two areas are working in an independent way. As is explained in the chapter five the preassembly area is so far from the Vibration cell, one place for those stages next to the cell will be submitted. In this chapter two alternatives of layout will be proposed.

11.2 First alternative of layout

The first alternative will be to place the new vibration welding machine in the cell with the other four existing. Currently the cell does not have place for that but if they replace the electric panels outside the cell, the space for the new machine will be available. This option is very expensive but is more secure because in case of a fire emergency in the electric panels the cell will not be affected. A conveyor will be placed between the two bigger Brandson machines, and the lenses of the Fuso products will come directly from the injection molding machine. There is no necessary economic investment for buying conveyors because there are available in plant. This alternative is not possible if the five machines are going to work at the same time because the oven has not capacity for annealing all the welded parts.

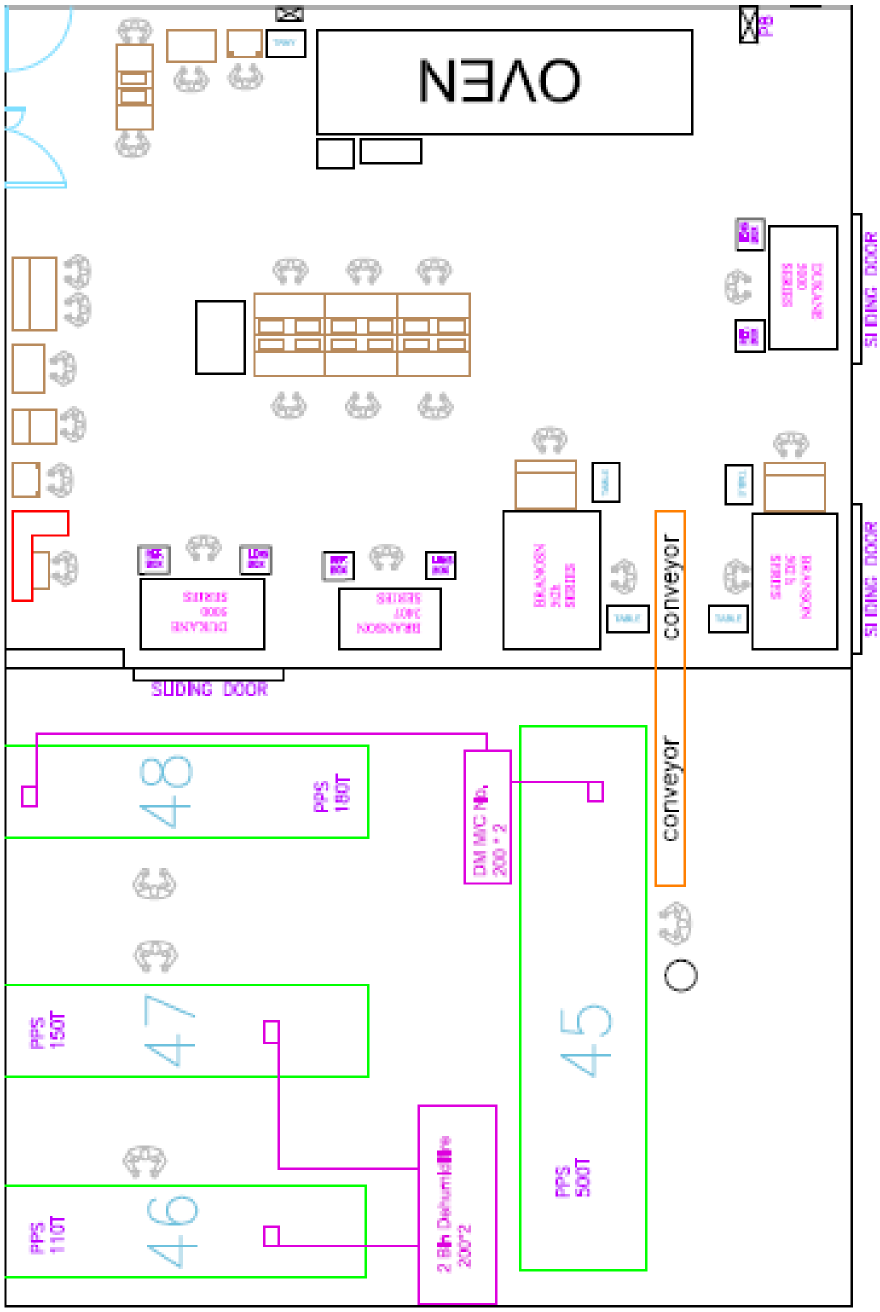


Figure 107: First alternative of layout

11.3 Second alternative of layout

The second alternative is to replace the Brandson 2407 Series in the Export cell and the new machine in Vibration cell. This option will standardize the processes because the capacity of all the machines will be the same and in case of one unexpected problems the welding tools will fit in all the machines. A conveyor will be placed for feeding the Brandson machines of the Fuso and Isuzu lenses.

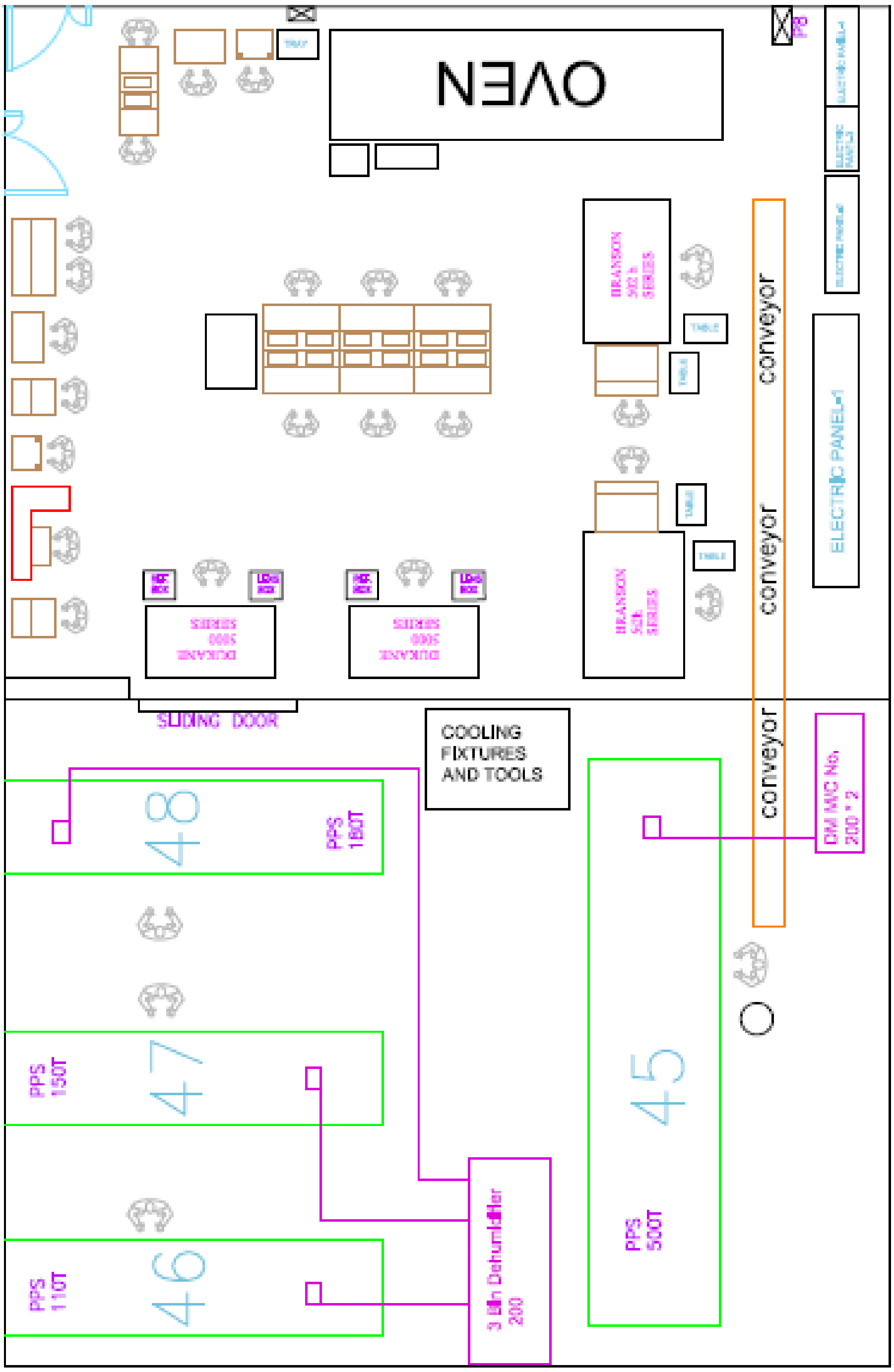


Figure 108: Second alternative of layout

11.4 New preassembly area

Future requirements of the cell demand a pre-assembly area near the cell. Currently the pre-assembly of electronic parts with the housing is made in export cell and when the process is completed the parts are packed and placed in the warehouse. The current process increases the flow of material in the plant, the time and the economic costs. The area destined to the preassembly stages is occupied by boxes and pallets making it a warehouse of unnecessary stuff.

The new preassembly area will be placed in front of the vibration cell so when parts are preassembled will go directly to the welding stage. It will be closed and equipped with the necessary equipment to meet the requirements. The cell must meet the following ESD[23] preventive rules:

Work area:

- Static-safe workstations to prevent yield loss (through catastrophic damage) or, worse, potential reliability failures in the field (through latent damage).
- Avoid bringing sources of static electricity within one meter of a static-safe work bench.
- Where it is necessary to use air-guns, use special models that do not generate static charges in the air stream.

Personnel:

- Any accumulated charge on the body of the human operator should be discharged first before opening the protective container with ESDS devices inside.
- Antistatic smock for each worker.
- Workers must have training on ESD preventive.

Packaging and Transportation:

- ESDS devices should be contained in a static protective bag or container at all times during storage or transportation.

Figure 109: New preassembly area

[23] *ESD*: Electrostatic discharge, is the sudden flow of electricity between two electrically charged objects caused by contact.

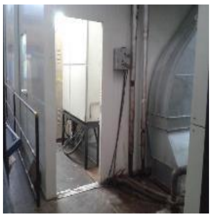
12. Safety

12.1 Goal of the chapter

The aim of this chapter is the realization of an audit where the deficiencies in the safety of the cell were identified and the measures to be taken for solving the problems will be proposed.

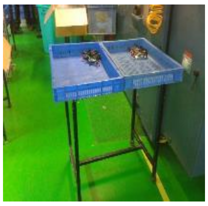
12.2 Safety audit

Sr. No.	Location	Photo(Before)	Observation	Actions to be taken	UC/ UA or Legal	Department
1	Front side of the entry		The floor in the entry is damage. Trolleys have difficulties for passing	Repair the floor with concrete	Unsafe conditi on	HR & Admin
2	Entire cell		Inside the cell there is no fire extinguisher.	Provide the fire extinguisher inside the cell	Unsafe conditi on	Safety
3	In exit door		Exit door is opened inside way. In emergency situation the exit will be blocked	Change the door with an antipanic door	Legal	Assembly: Production
4	Emergen cy exit door		Secondary emergency exit door is blocked by machine.	Replace the machine keeping the area unblocked.	Legal	Assembly: Production

5	Back side of the electric panel		Dust is entering inside the vibration cell through this cut out at backside of the panel.	Provide the door to close this area and then only authorized people can access to the area.	Unsafe condition	Assembly: Production
6	Dukane m/c back side		Dust is entering inside the vibration cell through this cut out at backside of the machine.	Provide the door to close this area.	Unsafe condition	Assembly: Production
7	Dukane m/c, Branson M 5i2H back side		No space provided between m/c & wall. Not possible to do repairing activity.	Provide 1.5 meters between m/c's and adjacent walls.	Legal	PE
8	In exit door		Emergency exit signal with light is not available.	Provide the emergency exit signage with light with glow with emergency backup.	Legal	Maintenance
9	Branson M 502 H		Ear protection is not available for the operator.	Provide the ear muff to all the welding operators.	Legal	Assembly: Production
10	All electrical panels		On the electrical panels danger warning signals are not available.	Provide the electric danger signal in all the electric panels.	Legal	Maintenance

11	Electrical panel		Product material boxes placed next to the electrical panels.	Provide floor signage in front of electrical panels.	Unsafe condition	Maintenance
12	Assly. Line		Fan used in assembly lines. Ventilation system is not effective. Worker cannot work properly.	Check the effectiveness of ventilation system to maintain the working temperature.	Unsafe condition	Maintenance
13	Assly. Line		Wires of the fans in the walking way.	Proper cabling and remove this fan after AHU system run effectively.	Unsafe condition	Maintenance
14	Branson M 502 H		Back side door can be opened while machine is running. Door interlock limit switch is not working.	Provide the door limit switch with interlock so the m/c will stops while running.	Legal	Maintenance
15	Branson M 5i2H		Back side door can be opened while machine is running. Door interlock limit switch is not working.	Provide the door limit switch with interlock to the m/c stop while running.	Legal	Maintenance

16	Electrical cable trench		At many places in the floor there are small openings. This leads to foot injury due to trapping & slipping.	Close all the floor holes.	Legal	Maintenance
17	Branson M 502 H		The trolley is unstable during the change of tool. Trolley with fixture may fall down. This leads to major foot injury.	Modify the trolley.	Unsafe condition	Assembly: Production
18	Assembly table		Worker is not using the safety glasses, mask and hand gloves during potting operation. Hands of worker can be injured with hot melt.	Provide the personnel protective equipment (PPE).	Unsafe condition	Assembly: Production
19	Assembly table		Working table supply board at wall side is inaccessible to switch off supply. Chance to hit this board & damage leads to electrical short circuit.	Relocate the position of supply board at front side. Easy to access.	Unsafe condition	Maintenance

20	Assembly table		Cables are in the floor being able to deteriorate.	All m/c electrical supply cabling done through cable rail.	Unsafe condition	Maintenance
22	Dukane m/c		Two trays are placed in a small table. Chances of falling down leads to foot injury.	Provide the stand for the two trays.	Unsafe condition	Assembly: Production
23	Branson M 502 H m/c back side		Electric panel door open and cable rail is not provided. Wires are in scattered form.	Provide the cable rail and lock the panel door.	Legal	Maintenance
24	Light testing m/c below area		Electrical panel door is open. Unauthorized person has easy access to this panel.	Lock the panel door and proper cabling routing done so that door to be lock properly.	Legal	Maintenance
25	In front of LT panel		The cables are cut due to direct contact with the metal sheet. Possibility of short circuit.	Provide the cable rail and lock the panel door.	Unsafe condition	Maintenance

28	LT panel		Electric panel doors are opened. Unauthorized person has easy access.	Lock all the electric panel doors (LT & m/c's) inside the cell.	Legal	Maintenance
29	Flaming m/c at second exit door		During operation there is the chance of hand trap causing amputation hand injury.	Provide the photo sensor with interlock to punch so m/c stops while any interception.	Legal	Maintenance
30	Assembl y table		Glue sticks material safety data sheet (MSDS) is not available at work station.	Provide the material safety data sheet (MSDS) at work station and train operators about chemical handling as per MSDS.	Legal	Assembly: Production

Table 37: Safety audit of Vibration cell

13. Implementation

13.1 Flaming lens tool

Figure 110: Flaming lens machine

This new system for flaming the lenses the time and temperature can be fixed. The fixture is designed for heat only the welding channel of the lens and protect the rest of the lens. For the implementation there are only fixtures for the Isuzu front side indicator. If the results during the trial month are good, new fixtures for products like Fuso will be made.

This system was designed by the supplier that provides to Rinder all kind of fixtures for different processes. The requirements and the measures of the lens were given and with that information the system and fixtures were manufactured by the supplier.

13.2 Assembly line for VW products

Figure 111: VW assembly line

The new configuration of the line was designed only for Volkswagen products (RR250 & RR251). The two stages were place one in front of each other because if not there are a lot of confusions between products of the right and left hands. Times were taken and the positive results are shown.

Processes	Manpower	Subprocesses	n° Worker	Times (seg) Time 1	Time 2	Time 3	Time 4	Mean	Process time
Inspection & Packing	2	Clean the part and visual check	3 & 4	12.35	7.94	9.69	17.18	11.8	49.1
		Check the proper fitment in the car part	3 & 4	12.92	14	12	15.04	13.5	
		Place the part in the tray with the sticker if it is Ok	3 & 4	8.93	4.38	3.98	7.94	6.3	
		Paly the stretch film on lens	3 & 4	10	16.6	16.2	20	15.7	
		Place the part in the box	3 & 4	2	1.82	1.8	1.5	1.8	

Table 38: Assembly times VW RR251 (05/03/2015)

Processes	Manpower	Subprocesses	n° Worker	Times (seg) Time 1	Time 2	Time 3	Time 4	Mean	Process time
Inspection & Packing	2	Clean the part and visual check	3 & 4	8.88	10.04	12.05	13.59	11.1	20.7
		Place the part in the tray with the sticker if it is Ok	3 & 4	2.91	4.9	4.62	3.65	4.0	
		Paly the stretch film on lens	3 & 4	4.02	3.61	4.24	4.59	4.1	
		Place the part in the box	3 & 4	1.51	1.95	1.14	1.29	1.5	

Table 39: Assembly times VW RR251 (01/06/2015)

As it is shown in the tables the time has been reduced from 49.1 seconds to 20.7 seconds. Although the process of check the proper fitment in the car bumper it has been removed, the new configuration increase the productivity.

13.3 Space optimization in work stages

In order to reduce unnecessary movements and not occupy more space than the required the poly bag bins and the rejection trays will be always placed under stands and assembly tables. All the stands of the cell were modified because they had a metallic bar disabling the placement of trays. The preassembly table was provided with a shelf for putting the screw boxes.

Figure 112: Poly bags boxes under stands

Figure 113: New pre-assembly table

14. Production and economic impact

14.1 Goal of the chapter

The goal of this project was to increase the productivity and reduce costs, for that reason is necessary to study the viability of the actions to be taken that has been proposed. The calculation of the production and economic impact was made with estimate data, because the process of implementation has not finished. In this chapter the new design of lines and the change of tool are taken into account, but other actions as security and visual signals are difficult to quantify.

14.2 Impact of the new configuration of Vibration Cell

Calculating the economic benefits of the optimization is a difficult task, because in Rinder India Pvt. Ltd. there is no standard way to do it. The following is a simplified way for calculate the economic impact of the actions proposed in the report. The economic result of each single action is not so big, but it is all the proposed improvements functioning together which will give to the company the biggest economic benefits.

Lean manufacturing techniques are used in this report with the aim of obtain a higher productivity and flexibility. The new design of lines, stages, MRM supermarket and change of tool eliminates wastes and non-value adding time, reduce changeover times and increases the quality of products. The benefit of have flexible assembly lines, effective changeovers, safe environment and a good supplying system is a consistent production without waste making it easier to fulfill the customer requirements. Rinder India Pvt. Ltd. till the moment had not considered those factors as key values when they had evaluated benefits of implementations, in addition those factors are difficult to measure since no records exist in Rinder data base facilitating these types of estimations.

When the project was finished, the implementation of the proposed changes was in an initial stage. In the following calculations it is assumed that the cycle time is reduced till the takt time. The cost of the products that need to be purchased was estimated with the help of the supplier. Products like the new conveyor and trays are available in the factory, so is not necessary to purchase.

Product	Quantity	Cost (INR)
Assembly table shelf	4	5000
Stands	10	2000
Cooling structure	1	5000
Bins	20	4000
Store stand	1	2500
Total (INR)		
18500		

Table 40: Purchases

The calculation of the cost was made knowing that the salary of each operator is 700 INR[24] per hour. Each month has 50 shifts of 12 hours. To calculate the manpower cost of each product, the number of workers, shifts and salary was taken into account.

Product	Before cycle time (s)	N° shifts/month (before)	New cycle time (s)	N° shifts/month (after)	N° operators before	N° operators after	Monthly Cost before (INR)	Monthly Cost after (INR)
Fuso Trasfer Japan LH	60	6.25	50.4	5.25	6	5	26250.00	18375.00
Garnish Lamp LH	60	6.94	50.4	5.83	6	5	29166.67	20416.67
Garnish Lamp RH	60	6.94	50.4	5.83	6	5	29166.67	20416.67
Fuso Trasfer Portugal LH	60	1.11	50.4	0.93	6	5	4666.67	3266.67
Fuso Trasfer Japan RH	60	4.24	50.4	3.56	6	5	17791.67	12454.17
Fuso Trasfer Portugal RH	60	1.11	50.4	0.93	6	5	4666.67	3266.67
VW Polo GP Rear Reflex LH	60	4.17	37	2.57	2	1	5833.33	1798.61
VW Polo GP Rear Reflex RH	60	4.17	37	2.57	2	1	5833.33	1798.61
NT 51 Tail Lamp Assembly	60	6.25	38.76	4.04	6	6	26250.00	16957.50
JG Tail Lamp assly	50	5.21	38.76	4.04	5	5	18229.17	14131.25
2189 TL	50	0.69	42	0.58	6	6	2916.67	2450.00
Tata Vista Blinker LH	36.6	6.78	32	5.93	5	3	23722.22	12444.44
Tata Vista Blinker RH	36.6	6.78	32	5.93	5	3	23722.22	12444.44
Fiat Linea Blinker LH	36.6	0.85	32	0.74	5	3	2965.28	1555.56
Fiat Linea Blinker RH	36.6	0.85	32	0.74	5	3	2965.28	1555.56
DT Tail	65	3.01	60	2.78	6	6	12638.89	11666.67

[24] *INR:* Official currency of the republic of India. 1€ = 68 INR.

Lamp Assly								
KT04 FPL	50	4.63	45	4.17	6	6	19444.44	17500.00
1169 TL	50	0.69	45	0.63	6	6	2916.67	2625.00
Peugeot Tail Lamp RH	50	0.84	45	0.76	6	6	3524.31	3171.88
TOTAL (INR)							262670.14	178295.35

Table 41: Manpower cost

1st Year Savings: 65874.79 INR

Productivity increase: 19.17%

14.3 Change of tool

The aim of the new proposal is to reduce the changeover time. Reducing the changeover time was a priority because the process must be flexible. The average of changes of tool per month are 40 and in the past the time required for the process was 60 minutes, so 40 hours per month. The benefits of this proposal is the reduction of non-value adding time, manpower and damage in tools. This benefits affects to the quality of the production and in the maintenance of tools and machines.

CHANGE OF TOOL		
Parameters	Before	After
Manpower	4	2
Time	60	16
Manpower cost/change (INR)	2800	373.33
Cost/month (INR)	112000.00	14933.33
Cost year (INR)	1344000	179200
Investment (INR)	0	4000
Benefit/1st year (INR)	1160800	
Productivity increase	73.33%	

Table 42: Productivity and economic impact of new change of tool

15. Conclusions

This project was borne out of the necessity to optimize and improve the production output of the Vibration Cell. For this end it was determined, mainly with Lean Manufacturing techniques, how it would be possible to increase productivity while meeting the customer's requirements. Afterwards, the products and their associated processes which are manufactured in the cell were studied during their production cycle.

Once all of the theoretical concepts of techniques of improvement were acquired regarding manufactured processes and products, the cell analysis was then initiated. A major difference between other production plants in developed countries and the one in this study is that the plant under analysis suffers from production deficiencies due to the Indian philosophy of mass production, which is based chiefly upon manpower. After studying the workstations, cycle times and process flows, the conclusion arrived to was that each operator worked independently and without following guidelines. Each station was equipped with the basic tools that each process required, but without being designed for the operator in mind, nor to produce the largest amount of parts in the shortest time possible.

The most critical problem of the cell are the high cycle times which condition the throughput and downward flow of production, increasing delivery times. For this, cycle times were taken for each product and a bottleneck was detected for each case. Therefore, we conclude that in the majority of the processes there was a lack of consistency because of bad assembly-line design. For example, one distinct product was observed undergoing the same manufacturing processes, but in different assembly lines. The assembly lines were redesigned according to product groups and their respective processes. The work stations were then standardized for the different product groups so as to reduce the number of changeovers.

Another important topic which was studied was rapid tool changeover. The trolley used in this process did not count with the minimum required design features so that the changeover could be done in a safe and effective manner. It was determined that this was the cause of high set-up times, tool damage, and part rejection. For this end, a new trolley and guidelines were proposed and tool change was standardized. To gauge the effect of these proposals, a tool-change was simulated with the new procedures and showed reduction in set-up times by 73.33%

Work safety was also studied because during the course of this project, a total disregard for workplace safety and prevention measures were observed. In India, workplace safety is not given much importance, but these measures proposed will have a positive impact in the cell production. Finally another important aspect of this study is the supply of parts to the cell. In order to ensure the continuous flow of the production lines, it was proposed that a conveyor belt be placed between the moulding area and the vibration cell, as well as a preassembly stage in front of the vibration cell and a mini-store area for items such as screws and bulbs.

All of the above-mentioned measures will improve the cell in the following ways:

- Reduction in the number of shifts: In reducing set-up and cycle times, it was observed that the number of shifts were reduced. It is difficult to quantify and compare each month to one another because production schedules of the 20+ products of the cell vary month by month, always according to customer and production demand.
- Improvements in working conditions and environment: The system designed takes into account workplace ergonomics and its environment, and when coupled with process standardization and training of personnel, it shall make the workplace more secure and comfortable, reducing the number of workplace accidents.
- Cost reduction: A robust, repeatable, and standardized process such as the one designed, united with continuous improvements for reducing rejection, and shall reduce waste until waste is eliminated. It is estimated that in the first year a savings of 1,226,674.79 INR will be achieved.
- Reducing machine downtime: The new procedure for tool changing and the immobilization of the leak and light testers shall reduce machine downtimes, eliminating unnecessary movements of machines and tools.
- Reduction in inventory levels: The desired implantation of these procedures is the reduction of inventory levels, both in Finished Goods (FG) and Work in Progress (WIP) and the possibility of breakage, and also a wide variety of other related costs (inventory costs, direct purchasing costs, obsolescence costs, etc…)
- Response to demand: The system is designed to be able to respond to changes in demand in a progressive manner, and to respond to variations and fluctuations which occur in time.
- Decrease in operating times: The lay-out design proposed necessarily implies a shorter distance between work-stations and material, which will result in a considerable reduction in the time utilized in the transport and movement of parts used in the manufacturing processes.
- Change in plant culture mindset: The adoption of these Lean Techniques shall induce a change in plant worker culture, demonstrating that by following these same workplace measures in other areas of the plant the Company shall obtain noticeable benefits.

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Appendix

	WORK INSTRUCTION	CODE:	D-09-01-M(Rev-02)
PRODUCT	FUSO FR STSL (TRANSFER LAMP) 12V LH ASSEMBLY		
PART NO.	63002.01/02/03/04		
WORK STATION NO.	STAGE - 04 (PFD NO - 60 D)	Language	English

Task: Annealing of Welded Assly

ANNEALING OVEN

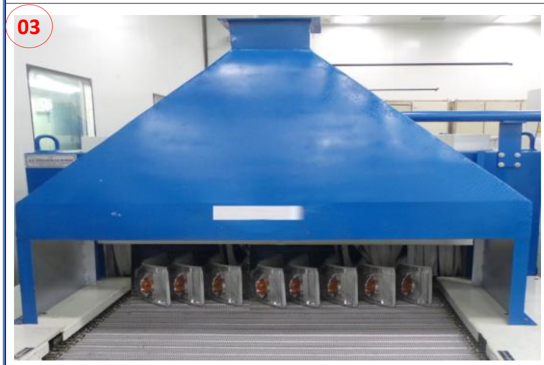
01

AFTER FILLING PICK UP THE PART TRAY BY BOTH HANDS & TAKE THE PART TRAY TO THE ANNEALING OVEN

02

PICK UP THE SEALED ASSLY ONE BY ONE & PLACE ON ANNEALING OVEN CONVEYOR AS SHOWN FOR ANNEALING

03



PLACE THE 8 NO.S OF PARTS ON THE CONVEYOR AS SHOWN IN PHOTO TO USEFUL CAPACITY OF THE OVEN

Bought Out Parts :

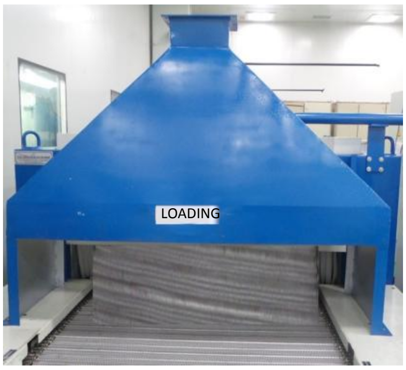
ANNEALING PROCESS PARAMETERS:
Annealing Temp: 75 °C ± 5 °C
Annealing Time: 25 Min
Conveyor Frequency : 22 Hz

LEGEND
S Special Characteristics
Customer Complaint
C Critical Operation
Safety

Rev No & Date	Reason for change	Prepaired by	Checked by	Approved by
0 - 1/ 12/ 2014	First Issue	Vivek	Manoj K.	D. R. Mallik
1 - 8/ 06/ 2015	Capacity issue	Alejandro	Zaheer	S.P. Naik

	WORK INSTRUCTION		CODE:	D-09-01-M(Rev-02)
PRODUCT	FUSO GARNISH LAMP ASSEMBLY (LH & RH)			
PART NO.	63001.01/02			
WORK STATION NO.	STAGE - 04 (PFD NO - 60 D)		Language	English

Task: Annealing of Welded Assly



01

ANNEALING OVEN

AFTER FILLING PICK UP THE PART TRAY BY BOTH HANDS & TAKE THE PART TRAY TO THE ANNEALING OVEN

02

PICK UP THE SEALED ASSLY ONE BY ONE & PLACE ON ANNEALING OVEN CONVEYOR AS SHOWN FOR ANNEALING

03

PLACE THE 8 NO.S OF PARTS ON THE CONVEYOR AS SHOWN IN PHOTO TO USEFUL CAPACITY OF THE OVEN

Bought Out Parts :

ANNEALING PROCESS PARAMETERS:
Annealing Temp: 75 °C ± 5 °C
Annealing Time: 25 Min
Conveyor Frequency : 22 Hz

LEGEND
S Special Characteristics
Customer Complaint
C Critical Operation
Safety

Rev No & Date	Reason for change	Prepaired by	Checked by	Approved by
0 - 1/ 12/ 2014	First Issue	Vivek	Manoj K.	D. R. Mallik
1 - 8/ 06/ 2015	Capacity issue	Alejandro	Zaheer	S.P. Naik

	Performance Test Report	**Code :- D-02-02-E REV.03**
		Date : 27.02.2015
		Page :- 1 Of 1

Report No:-	15B54	**Test Std.Used:- As per Requirement**
Customer:-	VW	**Sample Qty:- 10LH 10 RH**
Part Description:-	VW RR 250 Assy (RR LH & RR RH)	**Part No. -**
Supplier (If BOP Test):-		

Testing Purpose:	**VA/VE Proposal**	
Test Name	**Residual stress Test**	
Test Specifications Test Method	**Test procedure** **Immersion 24hrs, positioned horizontally, lens facing downwards.** **Subsequently drying for 30 min in static air (positioned horizontally, lens facing upwards). Subsequently leak tightness test by means of over-pressure acc. to Section 4.1.** **Reagent Ethanol/water mixture 90 : 10**	
Lighting ON/ OFF Mode	**OFF.**	
Test Start Date / Time Test End Date / Time	**26.02.2015 11.00AM 27.02.2015 11.00AM**	
Acceptance Criteria	**Immediately after drying. No stress cracks (continuous cracks) must occur.**	
Actual Test Conditions:	**24hrs. Dip in ethanol**	
Observations	**Before Test Sample is OK**	
Conclusion	**Accepted.**	
	During Test	**After Test**
Photo If Any		

Tested By:-	Approved By