1.1 Background

At present, the increase in the number of vehicles manufactured per year has created a higher demand for tires in the world market. Basically, tires can be divided into two main categories. They are Solid tires and Pneumatic tires. From the total pneumatic tire production in the world, 95% of tires are used for transportation. Other 5% is used for agricultural and farming purposes [1]. Tire manufacturing process is a long process which includes a number of hazardous operations. It involves lots of chemicals that are toxic to the human body. Compared to the solid tire manufacturing processes, pneumatic tire manufacturing involves more difficult processes. Pneumatic tire manufacturing process includes lots of human interacting hazardous operations like Tire building, Green tire painting and curing etc.

Basic steps in pneumatic tire manufacturing process are chemical mixing, Calendaring, Extruding, making beads, tire building and curing process [2]. “Green tire” is the industrial term used for a half-built tire before the curing process. Green tire is the output of the building machine. It is an uncuried cylinder shaped tire with two beads at the end. Before the curing process, some amount of paint need to be applied inside and outside of the green tire. Inside paint is used to reduce friction between green tire and curing press bladder [3], and outside paint is used to increase the flow properties of the green tire to form lugs accurately as in the mould [4]. These liquids are highly toxic to inhale. Therefore operators have to wear heavy safety equipments to prevent from inhaling the toxic paint [5]. However it is very difficult to wear such equipments in a hot environment and also the productivity is adversely affected. Also it is difficult to get a uniform paint application all over the tire, as it depends on the operator’s skill and ability. Thus, all above mentioned reasons urges to find a solution to increase the productivity, quality and to protect operators from the hazardous environment.
Green tire painting operation is the most hazardous operation among all the operations which involve with tire building and curing process [5]. It uses hazardous chemicals. Statistically, major reason for serious health damages related to the tire manufacturing process is inhaling of toxic chemicals by green tire painting operation [6]. Therefore prevention of this hazardous environment in the tire manufacturing process is highly important.

1.2 Tire manufacturing process

Figure 1.1 Pneumatic tire manufacturing process [2]

Pneumatic tire manufacturing process is shown in figure 1.1.

1. Mixing

As in the first step of tire manufacturing, it has to mix raw materials according to the recipe of each respective tire. The recipe is depending on the requirement of the
customer and the performance of the tire. Main raw materials used for tire manufacturing are Natural rubber, Synthetic rubber, Carbon filler, Chemicals and Oil.

2. Material Processing

Output compound of the mixture has to undergo several processing operations to make it suitable for tire building. Inner liner calendaring is used to make inner layer of tubeless tires. Also fabric calendaring process is used to coat rubber layers both side of the fabric which is used to build a tire. It uses Nylon or Polyester depending on the performance and price requirements. Separate steel wire coating operation is used to make steel beads and a rubber extrusion process to extrude outer layer (Tread) of the tire.

3. Tire building

Outputs of the material processing are send to the green tire building machine. The operator of the tire building machine winds each plies on expanded or collapse drum of the building machine according to the specified tire construction. It is basically started with inner liner, several plies from rubber coated fabric, then two bead rings at the two edges and finally the thread on the top.

4. Tire painting

Then green tire comes to the painting stage. At this stage it has to paint outside and inside of the green tire according to the requirements. Inside paint is acting as lubricant between green tire and the curing bladder. Outside paint is acting as an agent to increase the flow properties of the tread.

5. Tire curing

Next stage is the tire curing process. In this stage, the green tire is put over the bladder which is attached in the middle of the tire mould. Mould is fixed to the curing press heated platen. Steam is used to heat up the curing press platen. Firstly apply pre shaping steam pressure in to the bladder and then close the mould and apply high pressure steam in to the bladder. Then the curing bladder pushes the green tire in to the mould. Due to heated mould and bladder inside steam heat, the green tire stats to vulcanize. Normally it takes 30 to 60 minutes to cure the tire depending on the tire.
dimension and the compound [9]. In the cuing process green tire takes the shape of the mould and the lug pattern.

6. Quality inspection

Then it will move to the quality inspection section. If the quality does not meet the required level, those tires will be sent to the scrap yard. All the tires which have acceptable quality level are sending to packing and warehouse. Those tires will be shipped to various destinations according to the customer requirements.

The basic steps involved with the tire manufacturing process has mentioned as above. In this project it is mainly focused on the tire painting process to introduce new machine to overcome difficulties faced in the current tire painting manual system.

![Figure 1.2 Cross section of a tire [10]](image_url)
Figure 1.2 shows a completed green tire which is ready for curing. Figure 1.3 shows the green tire with wrapped protective cover over the beads. This is used to prevent contamination of the paint on the beads. The paint should not be touched with the beads as it will affect badly on the correct bead formation. This protective cover is mostly used for big tires. These covers are normally removed before the curing process.

Figure 1.4 Green tire with polyethylene wrap around the bead
Normally the bladder life time is around 150 tires. There is a separate bladder calculation which is used to select suitable bladder for a particular tire.
1.3 Present method of the green tire painting

To manufacture a good quality final tire, the attention given to the green tire is utterly important. Green tire quality directly determines the quality of the final result. This fact clearly shows that the green tire painting plays a significant role in tire manufacturing process. A number of inside and outside paint types are available in the market. But in this project it is focused on following paint types only.

<table>
<thead>
<tr>
<th>Paint Type</th>
<th>Manufacturer</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside paint</td>
<td>Darmex</td>
<td>1.25</td>
</tr>
<tr>
<td>Outside Paint</td>
<td>Darmex</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Paint quality is an important factor affecting the final tire quality [2]. The application method and the amount of usage is also affecting to the final outcome. The norm is to apply the inside paint as thin layer. It is water based mixture and has to be dry-off completely before curing. Otherwise the moisture inside the paint will expand in the curing process and will make inside air bubbles in the cured tire.

The existing method of inside painting is done using a manual operation. Operators apply paint according to the specifications as well as their experiences. Therefore it is very difficult to get a uniform output from existing method. It highly depends on the operators’ skill. Also the operator has to rotate the tire manually to apply the paint all over the tire, except the beads.

Figure 1.7 Manual green tire inside painting method
In this manual method, lots of paint particles are inhaled by the operators. It is very hazardous for health. Also this is not ergonomically suitable for long hour’s continuous working [11]. Figure 1.6 is showing the manual operation of present green tire inside painting method.

The existing method of outside painting system is also a manual operation. Operators use conventional painting brush to apply outside paint. The brush marks give a bad appearance on the final tire. The operator has to rotate the tire to apply paint all over the tire. Also the amount of paint and the quality of the painting process is highly depending on the operator’s skill. Figure 1.7 is showing the manual operation of the present green tire outside painting method.

Those two above mentioned operations create bottle necks, which need to overcome in order to get high production output. Even, the painting operators cannot work long hours as they get sick due to the harsh environment. Sophisticated safety equipments need to be used to prevent inhaling the paint. It is very difficult to work with wearing heavy safety equipments. This is the utmost requirement behind this project, which is to make a machine with capability to paint inside and outside at the same time with high production output in a safety environment.
1.4 Objective of the project

With the present system, the output is around 650 tires per 8 hour shift when the operators are working at their full capacity. In the 8 hour shift routine, they take ½ hour meal break. Therefore the painting output is 1.5 tires per minute. Company target for the year 2011 is 1500 tires per shift. This equals to 3.3 tires per minute. The possibility with the present method to meet that target is to increase the number of painting operators. But this will not overcome the safety problems and also not a solution for uniform quality output requirement and uniform paint consumption. Therefore the main objective of this project is to give permanent solution to fulfill all production capacity requirements, quality requirements and to create a safe environment to work with.

Main requirements of the new methodology are,

1. Efficiency (Maximum 6 to 8 tires per minute)
2. Easy loading and unloading
3. Protect operators from toxic paint
4. Simplify operation and use of standard components
5. Safety of the operation