Design of Mobile and Integrated Tyre Repair Tools for Motorcycle

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Abstract - Tyres are a very important component of a motorcycle. Not only vehicle driving components, tyres also play a role in safety, passenger comfort, fuel consumption efficiency, endurance components of car legs and so forth. So, the condition of the tyre must receive special attention from the owner of a motorized vehicle. When riding on a motorcycle, tyre leakage is one of the problems that is often encountered. Not only because of sharp objects, tyres can also leak due to several other reasons. If problems are not immediately sought, leaks in tyres can cause loss of control, endangering the safety of motorists and other road users. And the place and timing of leakage events that cannot be predicted are often a scourge for motorists. After a leak, motorists, especially motorcycle riders, are very dependent on the existence of patched tyre entrepreneurs. With helps from IoT application based in advance, the design of this tool will be an opportunity for tyre patch entrepreneurs to be able to "Pick Up the Ball" to every customer / driver who has a leak. The design of this tool is quite concise and integrated thru Programmable Logic Control (PLC) with each main component making easier for entrepreneurs for patching tyres and can reduce downtime repair / replacement of the tyre.

Keywords: Tyres, Automatic Controller, Market opportunity, Motorcycle, Repair.

1. INTRODUCTION

1.1 Market Analysis

The Indonesian motorcycles industry which providing primary private transport sector for people and goods, is currently world’s top three for the last two decades and six time bigger in size compared to any corelating industries. The industry hits its peak approximately 10 years ago with sales record at 8 million units that year. In 2017 the industry experienced progressive declining sales and hits the lowest record ever with only 5.8 million units sold. In 2018, this industry has showed a positive trend with 8.4% rise in sales with over 6 million units sold at the end of the year, fueled by a quite positive economic trend [1].

Based on DKI Jakarta Transportation Statistics data for 2018, passenger cars recorded the highest growth of 6.48% per year in the 2012-2016 period. In 2012 the number of passenger cars in Jakarta was 2.74 million units while in 2016 it increased to 3.52 million units. If it is assumed that the growth of passenger cars is still the same, the number of passenger cars in Jakarta in 2017 will reach 3.75 million units and 2018 will be 3.99 million units. Based on DKI Jakarta Transportation Statistics data for 2018,
passenger cars recorded the highest growth of 6.48% per year in the 2012-2016 period. In 2012 the number of passenger cars in Jakarta was 2.74 million units while in 2016 it increased to 3.52 million units. If it is assumed that the growth of passenger cars is still the same, the number of passenger cars in Jakarta in 2017 will reach 3.75 million units and 2018 will be 3.99 million units [2].

On the Length of Road perspective, the highway as a link between one region and another is one of the important infrastructures in land transportation. The road connects the production centers with the marketing area. Economic mobility relies heavily on the reliability and level of service of the road transport network. At present and in the future road infrastructure development is increasingly colored by aspects of regional development. This means that infrastructure development will be increasingly demanded to be able to support the movement of people, goods, and services within the framework of regional development perspective [3].

Table 1. Growth Motorcycle / Passenger Vehicle in DKI Jakarta until 2016

| Type of Vehicles   | 2012     | 2013     | 2014     | 2015     | 2016     | Growth per year (%) |
|--------------------|----------|----------|----------|----------|----------|---------------------|
| Motorcycle         | 10.825.973 | 11.949.280 | 13.084.372 | 13.989.590 | 13.310.672 | 5.30                |
| Passenger Vehicle  | 2.742.414  | 3.010.403  | 3.266.009  | 3.469.168  | 3.525.925  | 6.48                |
| Heavy Vehicle      | 561.918   | 619.027   | 673.661   | 706.014   | 689.561   | 5.25                |
| Bus                | 358.895   | 360.223   | 362.066   | 363.483   | 338.730   | -1.44               |
| Special Vehicle    | 129.113   | 133.936   | 137.859   | 139.801   | 141.516   | 2.32                |
| Total              | 14.618.313 | 16.072.869 | 17.523.967 | 18.668.056 | 18.006.404 | 5.35                |

1.2 Problem in Field

Tyre patching tool is one type of appropriate tools used by user in assisting the tyre filling process in a motorcycle. This tool consists of 4 main components, namely electric compressors, electric heating tyres, power generators and Human Machine Interface (HMI). The four components work in an integrated manner with each other so that it facilitates how to use and accelerates the time in tyre repair activities. Generally, currently the tyre patching equipment in the workshop still uses conventional tyre patching tools. So that the time of the tyre filling process cannot be ascertained, adjusting to the condition of the patching tools found in the workshop [4]. In the tyre filling process, the results of the tyre filling are stated to be good if the patching material and inner tyre are tightly integrated. This is possible if the tyre patch can determine the temperature and length of time patching. Therefore, to get the perfect tyre filling results, it is necessary to have a component that can regulate the temperature of the filling followed by the time of the filling process [5]. Small reciprocating compressors, as applied in the automotive industry for pneumatic suspension, vertically adjustable seats and tyre repair devices are produced in large quantities and so the effort for business companies to find cost-detailed solutions is very high. Especially the avoidance of oversized designs is an important point. To meet this demand without a cost explosion in field tests, simulation tools should be introduced [6]. In order to create opportunities for the operation of on-site power generation, new and well distributed small-scale of generators should present tendency to produce smaller power systems [7].

With the imbalance in the volume of motorized vehicles with a lot and the length of the road that can be passed by the motorized vehicle, the chances of a tyre leak occurring in become very large, for example in DKI Jakarta. This phenomenon is an opportunity for tyre patching businesses. Most of the
tyre patch workers use the "Wait for the Ball" principle, but the principle is inversely proportional to the expectations of motorized motorists. Tyre leaks when driving is often a scourge for motorists, the uncertainty in the distance where tyre patches and the time and energy spent looking for them is an opportunity to design compact and practical tyre patches and can be developed with online request-based applications. make it easy for businesses to meet customers and change the principle of "Wait for the Ball" to "Pick Up the Ball" and be an answer to the fear of motorists when experiencing a tyre leak. This condition creates business opportunities for the existence of the mobile and integrated tyre repair

2. METHODS
The design of this tool is done by carrying out several steps. The step of this design starts with the Reference Theory and Problem Identification by raising some statistics from the growth of the number of motorized vehicles and the growth of the number of roads available in Indonesia to show the business scale and identifying cases that often occur in motor vehicle users, especially the occurrence of leaks tyres on motorized vehicles. With the above considerations, this tool is designed through a control philosophy based on real activities carried out by conventional tyre patch entrepreneurs.

![Methodology Diagram](image)

**Figure 1. Methodology Diagram**

2.1 Control Philosophy
This tool is designed using PLC and uses Human Machine Interface (HMI). PLC and HMI are used to integrate these 3 major components, namely the Heating Element, Air Compressor and Power Generator Set. This tool is also equipped with transmitters as safety devices when operating. This tool can be used in 2 modes, Automatic Mode and Manual Mode. Manual Mode can turn on and off the Compressor and Heater individually.

2.1.1 Automatic Mode. In this mode, the device is designed to run automatically between Heating Element (HE01) and Air Compressor (AC02). Both tools will get electric power from the Diesel Engine Generator (DEG03). The entire process of this tool will be ordered via HMI (HMI04). The tyre will first be dismantled by a technician and look for the hole that caused the leak. After the tyre has been dismantled and the hole has been found, the tyre is ready to be patched. By pressing the Automatic Push Button (PB00), HMI04 will command HE01 to heat the element. The heating time of the element takes 3 minutes and the length of the filling process on the heating element is 3 minutes. After 3 minutes of patching, HMI04 will order HE01 to stop. After the tyre has been completely patched, the technician will immediately replace the tyre on the vehicle. A moment HE01 stops, then HMI04 will give a message that is accompanied by a buzzer sound to be able to technician order HMI04 to run AC02. The compressor will automatically turn OFF if the message is ignored by the technician for 15 minutes. Compressors need 1-2 minutes to fill 1 tyre of a motorcycle tyre. HMI04 will order AC02 to stop when the desired tyre pressure has been read by a Pressure Transmitter (PT02).

2.1.2 Manual Mode. In this mode it can be used according to the actual conditions required by a tyre. Technicians can turn HE01 and AC02 on or off by pressing the Push Button Heater (PB01) and Push Button Compressor (PB02). The process in this mode, Safety Devices and Regulator Switch continues to function.
2.1.3 **Safety Devices.** This tool is designed with a Safety Device equipped with a transmitter sensor. In addition, there is a Timer Command from HMI04 as a switch function on this tool, the Temperature Transmitter on the Heating Element (TT01) also functions as a Switch and as an indicator on the HMI. TT01 also provides warning protection if the temperature of the element reaches 75 °C and provides shutdown protection that can turn off automatically HE01 when the temperature of the element reaches 80 °C. Pressure Transmitter on the Air Compressor (PT02) functions as a switch when the pressure in the tyre reaches a set pressure which are desired. In addition, PT02 also provides warning protection when the pressure in the tyre reaches 35 psig and provides shutdown protection that can automatically turn off AC02 when the pressure in the tyre reaches 40 psig. The Level Transmitter in DEG03 (LT03) serves as a warning and shutdown protection when the fuel level of the device touches the specified threshold. All Analog Signals from each transmitter will be sent to HMI04.

![Figure 2. Process Flow Diagram](image)

2.2 **Main Component**

2.2.1 **Heating Element.** Electric heating is a process where heat energy is produced through electrical energy conversion. An electric heater is an electrical device that converts an electric current into heat. The heating element that works on the principle of Joule heating, inside every electric heater is an electrical resistor. Electric current that passing through the resistor will convert the electrical energy into heat energy. The example of using electric heating is on electric tyre system. The heating plate is part of a heat system that encounters the tyres. This plate is used in patching process as a medium of heat transfer from heater to tyre.

The design of a tyre patch equipment system that is sourced from electricity is designed to be environmentally friendly, because it does not cause air pollution, such as the system of tyre patches generally. The design of the heating system of the tyre patch tool consists of several major components and supporting components. The main component consists of a voltmeter that serves to know the large voltage used in the filling process [8]. Amperemeter is used to determine the current strength in the series of tyre patches [9]. The Rise of Thermo-Electric effect will be produced by the combination of 2 different conductors in thermocouple as the tools to measure the temperature. [10].
In the process of working system of electric tyre patches will be obtained data that can be used to determine the rate of heat transfer on the heating plate and tyres based on the formula of conduction heat transfer [11]. The heat transfer rate Data (Q) on the heater plate is obtained from the Iron heat conductivity (K), the area of the cross section (A) and the plate thickness (L) of the heater plate as well as the temperature difference between T1 dan T2. So that in the Q counting on the heating plate applies the formula (1) [12] as follows:

\[ Q = k \cdot A \cdot \frac{T_1 - T_2}{L} \]  

(1)

Description:
- \( Q \) = Heat transfer rate (Watt)
- \( k \) = Iron heat conductivity (W/m·°C)
- \( A \) = Area of the heating plate section (m²)
- \( T_1 \) = Heater temperature (°C)
- \( T_2 \) = Heating plate temperature (°C)
- \( L \) = Thick heating plate (m)

Acquisition of Q data on tyres is an advanced calculation of the Q calculation on the heater plate. The difference in Q calculation on tyres based on K and ΔT. Where K is used is K of tyres and ΔT comes from the temperature difference between T2 and T3. So in the Q counting on tyres apply formula (2) [13],[15] follows:

\[ Q = k \cdot A \cdot \frac{T_2 - T_3}{L} \]  

(2)

Description:
- \( Q \) = Heat transfer rate (Watt)
- \( k \) = Rubber heat conductivity (W/m·°C)
- \( A \) = Area of the heating plate section (m²)
- \( T_2 \) = Heating plate temperature (°C)
- \( T_1 \) = Tyre temperature (°C)
- \( L \) = Tyre thickness (m)

Power (P) is obtained from the magnitude of the voltage and the current strong into the system. In this case the voltage (V) of electricity entered into the system amounted to 220 volts, as per the power provided by PLN. For the current strong (I) obtained from the heater capability to transmit the amount of electrical current. So in the Q counting based on the voltage and current apply the formula [12] follows:

\[ P = V \cdot I \cdot \cos \Phi \]  

(3)

Description:
- \( P \) = Power (Watt)
- \( V \) = Voltage (Volt)
- \( I \) = Current (Ampere)
- \( \cos \Phi \) = Power Factor

2.2.2 Air Compressor. Air Compressor used is reciprocating type. A reciprocating compressor also known as piston compressor is a positive-displacement compressor type by using forces of pistons driven through a crankshaft to deliver pressurized gasses. The intake gas enters the suction filters into inlet manifold, enters the chamber cylinder and later compressed by piston driven in a reciprocating motion via a crankshaft, and then discharged [14].

Bicycle form is the simplest reciprocating type. Dynamic piston will suction the air into the cylinder and then compressed it. If only one piston used is called a single-acting compressor. If both pistons on top and undersides are used, the compressor is double acting. Relationship of the absolute pressure on Outlet and Inlet nozzle is called Pressure Ratio. Accordingly, Compressor Chamber draws in air at atmospheric pressure (1 bar(a) and compresses it into 7 bar working pressure at a pressure ratio of (7 + 1)/1 = 8 [14].
At Suction Stage, Stroke volume is a volumetric capacity of the cylinder. Clearance volume is a volumetric capacity below inlet and outlet valve and should be above the piston. Gap between those volumetric capacities will produce pressurized free air delivery, p/V diagram and the actual diagram show the practical characteristic of volumetric compressor. For Reciprocating Compressor, there is always a gap between piston and cylinder, valves are never completely sealed. Valves cannot 100% full open and close then minimum delay will always be occurred, which causes a pressure drop when the air suction and compressed through the chambers. Because of this design, the gas will also have temperature rises when flowing into the cylinder.

Compression work with isothermal compression:
\[ W = \ln\left(\frac{P_2}{P_1}\right) \cdot (P_1V_1) \]  
(4)

Compression work with isentropic compression:
\[ W = \frac{K}{K-1} \cdot (P_2V_2 - P_1V_1) \]  
(5)

\[ W = \text{compression work (J)} \]
\[ P_1 = \text{initial pressure (Pa)} \]
\[ V_1 = \text{initial volume (m}^3) \]
\[ P_2 = \text{final pressure (Pa)} \]
\[ K = \text{isentropic exponent: } K \approx 1.3 - 1.4 \]

These relations show that more work is required for isentropic compression than for isothermal compression [14].

2.2.3 Diesel Engine Power Generator. Genset (generator set) is a device that functions to produce electricity. The set is equipped with a combination of two different devices, namely engine and generator or alternator. Engine will work as a rotating device while the generator or alternator as a power generation device. The engine can be a diesel engine or gasoline engine, while the generator or alternator is a copper coil or coil consisting of a stator (static coil) and rotor (rotating coil).

In a simple method it can be explained that the engine rotates the rotor on the generator so that a magnetic field arises on the generator stator coil, the magnetic field arising on the stator and interacting with the rotating rotor will produce an electric current. The electric current generated by the generator will have a voltage difference between the two poles of the generator so that when connected to a load it will produce electric power [16].

2.2.4 Programmable Logic Controller/PLC. A programmable logic controller (PLC) or programmable controller is an digital computerized control has been ruggedized and adapted for the control for any kind of manufacturing processes, such as assembly lines, or robotic devices, Packaged
System or any activity that requires high reliability control and ease of programming and process fault diagnosis for safety reasons. [17]

To emulate the functions of electro-mechanical relay is the basic function of a programmable controller. Variable inputs are given a unique code, and specific PLC instructions can test whether the input states of activity or inactivity. A logical “AND” function performed by relay contacts will not allow current to pass unless all contacts are checked. A series of “EXAMINE IF ON” instructions will energize its output storage bit if all the input bits are on, meanwhile a parallel set of instructions will perform a logical “OR” function as well. On the wiring diagram of electro-mechanical relay, a group of contacts controlling one coil is called a “rung” of a “ladder diagram”, this concept is also used to describe PLC logic.[18]. Some models of PLC limit the number of series and parallel instructions in one “rung” of logic. The output of each rung sets or clears a storage bit, that can be associated with a physical output address or an “internal coil” with no physical connection.[19] These internal coils can be used as a common element in multiple separate rungs. Unlike physical relays, there is no limit for number of inputs, outputs or internal coils referenced in a PLC program.

3. RESULT AND DISCUSSION

3.1 Main Component Selection

The selection process of several main tools such as the Heating Element, Air Compressor and Diesel Engine Power Generator above are based on the control philosophy described earlier. The control philosophy of this tool also has an important role in determining the type of PLC will be used. In order to achieve target time in filling the tire within 10 minutes using working temperature 70°C, the design requires supply power minimum 650 watts, 8 bar(g) working discharge pressure and minimum 110 Liters per minutes (lpm) free air delivery capacity. Brands currently available on market are considered to use as tools.

| Heating Element (HE01) | Air Compressor (AC02) | Diesel Engine Power Generator (DEG03) | PLC (EMD04) |
|------------------------|-----------------------|--------------------------------------|-------------|
| Brand: GAO | Brand: CHI | Brand: Yamaha | Brand: Schneider |
| Power Required: 600 Watt | Type: GA-61.9 | Type: EF 1000FW | Type: TM/18 |
| Voltage: 220/50 | COO: China | COO: Japan | Voltage: 120/50 |
| Design Temp: 90 DegC | Power Required: 500 Watt | Capacity: 8 bar(g) | Capacity: Max 800 Watt |
| Working Temp: 70 DegC | Voltage: 220/50 | Working Pressure: 6 bar(g) | Weight: 28 |
| Capacity: 2.3 Minutes/litre | LxWxD(mm): 130x150x200 | LxWxD(mm): 480x440x350 | Weight: 27 |
| LxWxD(mm): 300x150x200 | Weight(Kg): 10 | Weight(Kg): 40 |

3.2 Product Designed Drawing

The tool is designed to be compact and easy handling for the end user. Design is divided into compartments for Air Compressor, Heating Element, Diesel Engine Generator and tools. Design is limited on height by 1,000 mm to ease the tyre patching handling during transportation. Diesel Engine Generator and Compressor are located on one compartment to maintain the centre of gravity (COG). Design has maximum 65 kgs in weight.
4. CONCLUSION
The concept design of this tool can make things easier for patching tyre businesses to fulfill the needs of consumers. In the other side, customers / motorbike rider’s problems when a tyre leak occurs will be quickly solved. Later in the future, this market can be combined with online / IoT based applications and Artificial Intelligence to be able to know the whereabouts of consumers. It is concluded that this product could be useful for motorcycle in order to prevent tyre puncture during transportation.

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