Design and Development of In-motion Tyre Inflator

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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Approved by,

4/6/09

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June 2009

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Zainol Rashid B. Osman

ABSTRACT

This report contains the final prototype working principal and result gained from the experiment for the final year project, which is **The Design and Development of In-Motion Tyre Inflator**. The objective of the project is to design and fabricate a tyre inflator which can control the pressure of air inside the tyre while the vehicle is moving. The final result and analysis shown that the project is a success but can be modified for future improvement.

The challenge in this project is to design the rotary joint or seal bearing that will act as the connectors between the tubes of the tyre to the compressor. The design of the system and the test rig are completed and all the technical drawing done by AutoCAD software. The system comprises of an external compressor that will transfer air to the under inflated tyre via a rotary joint that have been designed. The rotary joint can effectively be the medium for air transfer and avoid hose tangling during the transfer.

The relationship between the air pressure and the tyre width are demonstrated by the relationship of pressure with the tyre footprints. The pressure range used for the experiment is 26 psi until 32 psi. The rotary joint was also tested to rotate at 25 Rpm for three minutes in order to detect any air leakage at 28 psi.

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The author wishes to take the opportunity to express his utmost gratitude to the individual that have taken the time and effort to assist the author in completing the project. Without the cooperation of these individuals, no doubt the author would have faced some minor complications through out the course.

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CHAPTER 1
INTRODUCTION

1. INTRODUCTION

Improperly inflated tyres are fairly common problems on passenger vehicles. In fact, 80% of passenger vehicles on the road have at least one under-inflated tyre [1] and 36% of passenger cars have at least one tyre that is 20% or more under-inflated [1]. Often pressure loss in tyres is a result of natural permeation of the gas through the elastic rubber, road conditions, and seasonal changes in temperature. Every drop of 10 °F, tyre pressure drops by 1 psi [2]).

When tyres are under inflated, the tread wears more quickly. According to Goodyear, this equates to 15 percent fewer miles you can drive on them for every 20 percent that they're under inflated. Under inflated tyres also overheat more quickly than properly inflated tyres, which cause more tyre damage.

There are also cases where the amount of air pressure inside of all four tyres are not the same and this will affect the alignment and produce uneven tyre wear which reduce the efficiency of vehicle mobility.

1.1 BACKGROUND OF STUDY

Friction between the tyre and the road surface is affected by the pressure inside the tyre. The hardness and evenness of the road surface is another factor in determining the optimal air pressure for the tyres. Besides that, the temperature of the environment and the humidity of the road surface are important as well as the presence of water, snow and ice. Tyre pressure will significantly affect the handling or mobility and the speed of the vehicle .Road safety also dependent on the tyre pressure. It has been found that incorrect air pressure has been a decisive contributing factor in many road accidents [1].

For the past few years, the in-motion tyre inflator have been design and develop for the used by the army vehicle for the convenience of the vehicle to be operate under various terrains.

The main reason for designing this system is to balanced between the speed and mobility of the vehicle. It will also reduce road damage done due to incorrect tyre pressure and also increase mobility of the vehicle according to the terrains. The system also solved the problem of uneven tyre wear due to different amount of air pressure in the each of the tyre by making sure same air pressure inside each tyre.

1.2 PROBLEM STATEMENT

Tyre pressure is important in determining the acceleration and the frictional forces on the car. Depending on the event or condition, acceleration can be increased by increasing the tyre pressure but reducing the grip of the tyre. While reducing the tyre pressure will increase the friction and the tyre will be wider for wet road condition and thus increase the vehicle mobility.

One has to stop at a service station and read the pressure with a special pressure gauge and then adjust it, if needed. It is recommended that this should be done every time you fill up the fuel tank but of course this will take an extra effort for the driver. The development of in-motion tyre inflator will make it more convenience for the driver to change the air pressure inside the tyre while the vehicle is in motion.

1.3 OBJECTIVE

The main objectives of this project are:

- To design the interface for in-motion tyre inflator
- To design and fabricate a test rig that can be integrated with the system and withstand the pressure transferred
- Testing and analyse the result.

1.4 SCOPE OF STUDY AND LIMITATION

The scope of this project is to experiment the existing tyre for the inflator mechanism and determine the effect of various pressure on the vehicle speed and mobility. The main scope is to design the mechanical part of the project which is the rotary joint at the wheel hub which functioned to avoid air tube from tangling during tyre rotation. The joint supposed to be able to withstand pressure of 28 until 32 Psi.

The project is limited to the used of car tyre and focused only onto one of the wheel and not all the four wheel of car tyres. The prototype will not be assembled onto a real car and will only be tested on the test rig to perfect the design and convenience to do maintenance and improvement. The exact spindle of a car is attached to the suspension component, hence the spindle function are replaced with a pipe that act as the housing to the driveshaft.

CHAPTER 2
LITERATURE REVIEW

2. TYRE REVIEW

Tyre is the only contact between the vehicle and the road, which means that tyre safety should be a prior concern to any driver. Under inflated tyre will cause huge impact on the tyre wear. The contact patch of the tyre will have a larger wave pattern , friction and the heat will increase because of the contact patch wear out more quickly than if the tyre were inflated correctly.

Goodyear have done the estimation that the average tyre tread life will drop to 68% of the expected tread life if the pressure dropped from 35psi to 17psi and remained there.

2.1 TYRE BASICS

A quick look at the side of the tyre will reveal a coded number apply on the tyre. The number represented as:

185 / 65 / H / R13

Table 2.1: Tyre coding description

Tyre Coding	Description
185	This is the width in mm of the tyre from sidewall to sidewall when it's unstressed and you're looking at it head on (or top-down). This is known as the section width.
65	This is the ratio of the height of the tyre sidewall, (section height), expressed as a percentage of the width. It is known as the aspect ratio.
H	This is the speed rating of the tyre.
R13	This is the diameter in *inches* of the rim of the wheel that the tyre has been designed to fit on. While symbol 'R' tells you that the tyre is a radial construction

(*sources taken from http://www.carbibles.com/tyre_bible_pg1.html)

2.2 TYRE TREAD

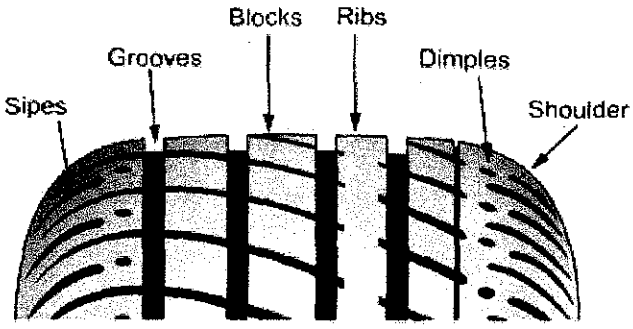


Figure 2.1: Tyre tread

Table 2.2: Tyre treads structure and function

Tyre structure	Function
Sipes	It is the small, slit-like grooves in the tread blocks. This added flexibility increases traction by creating an additional biting edge.
Grooves	The structure creates voids for better water channeling on wet road surfaces (like the Aqua channel tyres below. By designing grooves circumferentially, water has less distance to be channeled.
Blocks	Blocks are the segments that make up the majority of a tyre's tread. Their primary function is to provide traction
Ribs	It is the straight-lined row of blocks that create a circumferential contact
Dimples	The dimples are the indentations in the tread, normally towards the outer edge of the tyre. They improve cooling.
Shoulder	The structure provides continuous contact with the road while maneuvering. The shoulders wrap slightly over the inner and outer sidewall of a tyre.

(*sources taken from http://www.carbibles.com/tyre_bible_pg1.html)

2.3 TYRE PRESSURE

Tyre can lose pressure eventually based on time and temperature condition. Figure 2.2(a) shown that a tyre can lose pressure up to 10psi in 5 month [9]. In order to determine the correct tyre pressure, one will need a pressure gauge since tyre pressure cant be determine just by looking at the tyre as shown in figure 2.2(b).

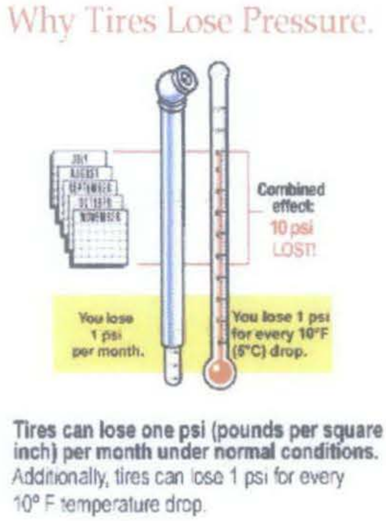


Figure 2.2(a): Tyre pressure loss

Figure 2.2(b): Visual comparison

The in-motion tyre inflator is the system that will provide pressure monitoring and the convenience of changing the tyre pressure while the vehicle is in motion. Hence, the system will ultimately tackle the entire problem encountered regarding tyre pressure.

Experiment were done by M.L.Groenewald and J. G-ouws [2] on an effect of the for 5-ton trucks carrying no cargo. The footprint area is more than doubles when the tyre pressure is dropped from 520 KPa to 140 KPa. This experiment already shows the significant effect of the tyre pressure.

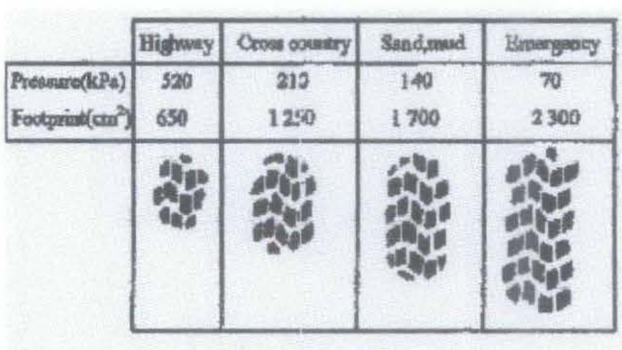


Figure 2.3: Experiment on the effect of pressure to tyre width (M.L. Groenewald & J.G-ouws,2006)

Table 2.3: Average pressure for vehicles

Vehicle	Pressure Range, psi	Average Pressure, psi
Car	28-32	30
Bicycle	50-60	55
Truck	20-25	23

Table 2.3 is based on the manual of basic vehicle used. The table showed the average pressure for the vehicle under normal condition. The pressure to be used in the experiment will vary slightly than the pressure range of the vehicle to determine the width of the tyre [6].

2.4 EXISTING IN-MOTION TYRE PRESSURE CONTROLLER

There is already few tyre motion inflators in the market, but are produced for trailer and also belong to a very expensive cars. Some of the system is the 'Tyre Maintenance System' and 'Airgo'.

2.4.1 AIRGO System

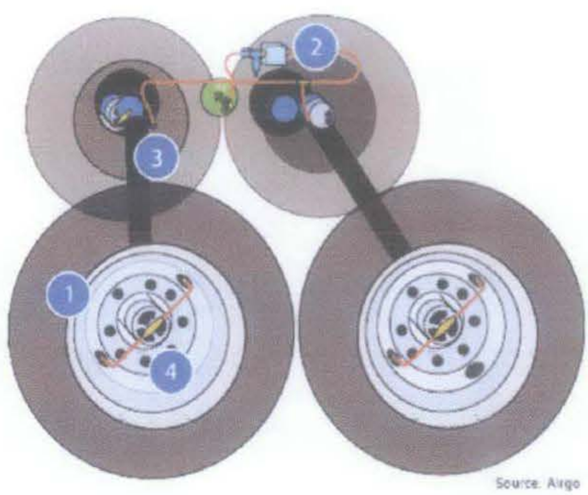


Figure 2.4: Flow of the AIRGO System

The AIRGO system is a constant monitoring system that uses a series of check valves to detect a loss in air pressure. Unlike some of the other systems, AIRGO doesn't use air from the vehicle's braking system. When air seepage has occurred at any of various points in the system (1), the system draws air (2) from the vehicle's pneumatic system (not shown) and sends it by way of the vehicle's axles (3) -- through the axles themselves if they're pressurized or by way of tubing if they're not -- through the hubcap assembly (4) and into the tyre requiring inflation [1].

2.4.2 Tyre Maintenance System

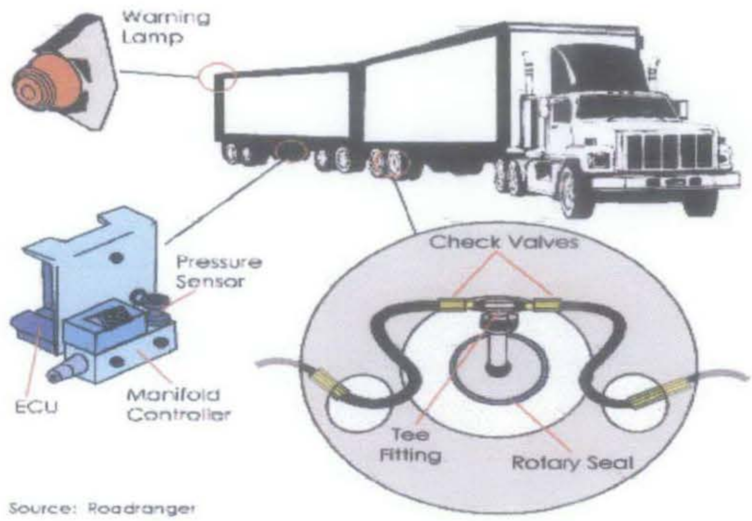


Figure 2.5: Working principle of Tyre Maintenance System

Dana Corporation's Tyre Maintenance System (TMS) is a "smart" system for tractor trailers that monitors tyre pressure and inflates tyres as necessary to keep pressure at the right level [1]. It uses air from the trailer's brake supply tank to inflate the tyres. The system has three main components:

- The tyre hose assembly provides the air route to inflate the tyre and has check valves so that the air lines and seals do not have to be pressurized when the system is not checking or inflating the tyres.
- The rotary joint is comprised of air and oil seals and bearings and connects the air hose from the non-rotating axle to the rotating hubcap.. The rotary hub also has a vent to release air pressure in the hubcap.
- The manifold houses the pressure protection valve, which makes sure the system doesn't pull air if the brakes' air supply is below 80 psi. It also houses an inlet filter to keep the air clean, a pressure sensor to measure tyre pressures and solenoids that control airflow to the tyres.

CHAPTER 3
METHODOLOGY

3. DESIGNING THE SYSTEM

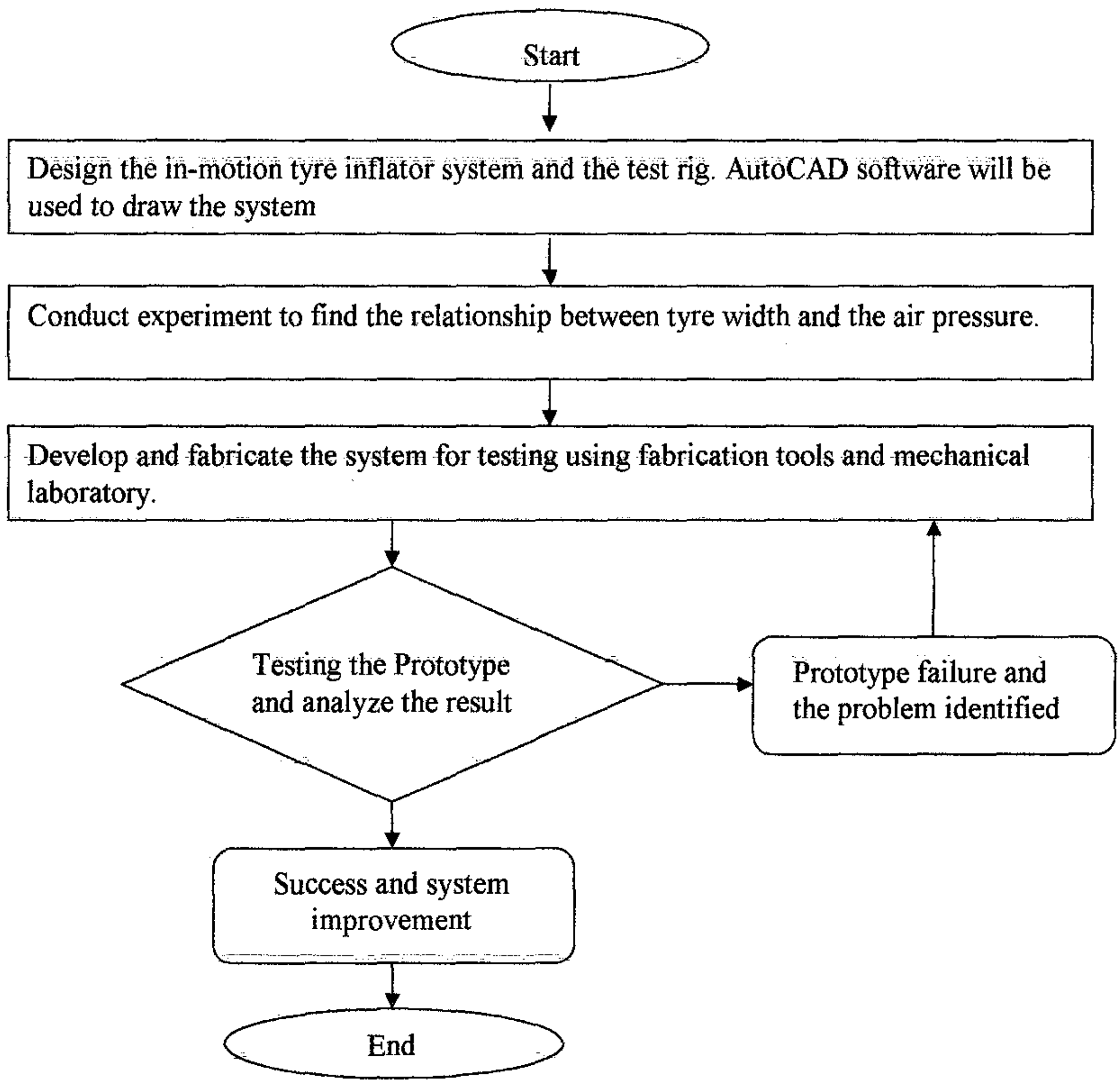
The methodology which is going to be used for this project is focused into designing the rotary joint which is the heart of the system. All the drawing design is using AutoCAD software. Experiment will be conduced to find the relationship between tyre width and the air pressure. The pressure used is in the range of 26 until 32 psi for the experiment. While the rotating joint designed are supposed to be able to withstand 28 until 32 psi.

3.1 TEST RIG

The test rig for the experiment setup will be design so that it can provide the simulation of the real road condition and the tyre pressure while the vehicle is in motion. A 4inch steel angle will be used to construct the support for the rig and equipped with a shaft on top of it for the attachment of the tyre.

The shaft is to be equipping with a handle to rotate it so that it will simulate the motion of tyre while it is moving. The shaft used is taken from Proton Saga and it comes with original wheel hub to best fit the real condition of real vehicle. The rotating joint are attached to wheel hub and tested for the air transfer mechanism.

3.2 FLOW CHART



3.3 TYRE PRESSURE MONITORING

The tyre pressure monitoring system will be implemented onto the wheel to inform the driver on the current tyre pressure and determine whether the tyre should be inflate or deflate. In each of the tyre, a route from compressor to the tyre will be connected to each other and this will be the platform to install the pressure sensor. Figure 3.1 show the digital tyre pressure monitoring equipment to be used in the inflator system.

The pressure sensor is to be put into the route from compressor to the wheel and it will monitor the pressure of the tyre constantly. The pressure sensor will produce a radio signal to be received by a radio transmitter signal receiver and display it on the dashboard of the driver seat. The value shown the current tyre pressure and will warn the driver if the tyre pressure is too low and needed adjustment. The in-motion tyre inflator will then be activated by the driver to increase the tyre pressure to its recommended air pressure.

Figure 3.1: Digital tyre pressure monitoring equipment

3.4 COMPRESSOR

The compressor that is suitable for the usage in the system is Campbell Hausfield CC2300 12V compressor. According to the manufacturer, it can produce pressures up to 230psi. Its cordless capabilities will allow greater ease of use to be combined with the system.

Product Description

- Perfect For Emergency Roadside Tire Inflation
- Plugs into Cigarette Lighter
- Inflates Car & Bike Tires, Beach Balls

Figure 3.2: Campbell Hausfield CC2300 12V compressor

3.5 CALCULATION

Assuming an adiabatic compressor, air as an ideal gas, stagnant inlet velocity of air, inlet air temperature and pressure at atmospheric conditions, negligible pressure losses through joints and tubing, and a rough estimate of outlet air temperature; the first law of thermodynamic is employed to determine outlet velocity of air.

By rearranging parameters in the first law of thermodynamics, the outlet velocity (V_2) can be found by the equation below, where w represents the work done on the compressor, h_1 and h_2 represent inlet and outlet enthalpies respectively, and Cp represents constant heat capacity. The value taken is from the Campbell Hausfield CC2300 12V compressor. Cp=1kj/kg-k / w = 10kj/kg

$$V_2 = \sqrt{2 \times w \times (h_2 - h_1)}$$

$$h_2 - h_1 = 20kj/kg$$

$$V_2 = 20m/s$$

Flow rate (Q) of air is dictated by the cross section area of the air hose which is 3/8 inch, and the velocity of the flow,

$$Q_2 = \pi \times (0.00953\ m)^2 \times V_2$$

$$Q_2 = 0.0057\ m^3/s$$

The first item needed to calculate the angular velocity of the tyre is the radius of the tyre. Knowing the grade of the tyre for this application which is 175/70/R13, the radius can simply be found by

$$r_{tire} = 0.7w_{tire} + \frac{1}{2}d_{rim}$$

$$r_{tire} = 0.7(175mm)(\frac{1inch}{25.4mm}) + \frac{1}{2}13inch$$

$$r_{tire} = 11.32inch$$

Where 'w' tyre refers to the width of the tyre in inches,'d' rim refers to the diameter of the rim in inches, and 'r' tyre refers to the radius of the tyre in inches. Note that the coefficient of the 'w' tyre term is merely the aspect ratio relating of the height and width of the tyre, which is stated in the tyre grade.

The angular velocity of the tyre is then expressed as the following:

$$\omega_{tire} = \frac{V_{tire}}{r_{tire}}$$

$$\omega_{tire} = \frac{31mph(\frac{5280\ ft}{mile})(\frac{12\,inch}{ft})(\frac{1hr}{60\ min})}{11.32\,inch}(\frac{1rev}{2\pi rad})$$

$$\omega_{tire} = 460.26\,rpm$$

Where 'V' tyre is the velocity of the tyre in mph, 'r' tyre is the radius of the tyre in inches, and 'ω' tyre is the angular velocity of the tyre in rpm. Note that the speed constraint for the design is 50km/h.

In determining the critical speed of the rotary joint-shaft system, the first step is to determine the stiffness of the shaft. This quantity can be found by

$$k = \frac{EA_{shaft}}{L_{shaft}}$$

$$k = \frac{(30000\,kpsi)(\frac{1000\,psi}{1kpsi})(\frac{\pi}{4})(0.75inch)^2}{22.8inch}$$

$$k = 581297.98lbf\,/\,inch$$

Where 'E' is the elastic modulus of the shaft in Kpsi, A shaft is the cross-sectional area of the shaft in in^2, 'L' shaft is the length of the shaft in inches, and 'k' is the stiffness of the shaft in lbf/in. Note that E=30,000 kpsi since the shaft is considered as solid steel cylinder and l shaft=22.8 in.

Finally, the critical speed of the rotary joint-shaft system can be determined by

$$\omega_{crit} = \sqrt{\frac{k}{m}}$$

$$\omega_{crit} = \frac{\sqrt{(\frac{581297.98lbs}{inch})(\frac{12inch}{ft})}}{8.16lbs}(\frac{1rev}{2\pi rad})(\frac{60s}{\min})$$

$$\omega_{crit} = 8829rpm$$

The critical speed of the rotary joint need to be higher than the speed of the rotating tyre to avoid danger from over speeding the rotary joint. Air transfer between the rotating joint to the tyre will be smooth if the critical speed of the rotary joint can endure the speed of the rotating tyre. As shown from the calculation, the rotating joint can withstand the speed of the rotating tyre.

CHAPTER 4
RESULTS AND DISCUSSION

4. TECHNICAL DRAWING OF THE SYSTEM

The result gained so far is the design of the full system and the working principle of the rotary joint and also the full working prototype of the system. All the fabrication work has been completed. However, there are various problem encountered during fabrication which will be explain in the discussion section.

4.1 DESIGNING THE INFLATOR SYSTEM

The system require the use of a centralized air compressor that is placed in the engine as a compartment of a vehicle. This compressor are attached to a valve used to control the amount of inflation pressure. The air travels via ¼" diameter hoses to a rotary joint located at the wheel. This rotary joint allows the system to pass air from the vehicle chassis to the rotating tyre. Flexible tube will be use in the design as the air transportation method. The design is to be implemented for all 4 tyres of the car but for the early design purpose, the system will be focused onto only one wheel . The whole system are shown in figure 4.1

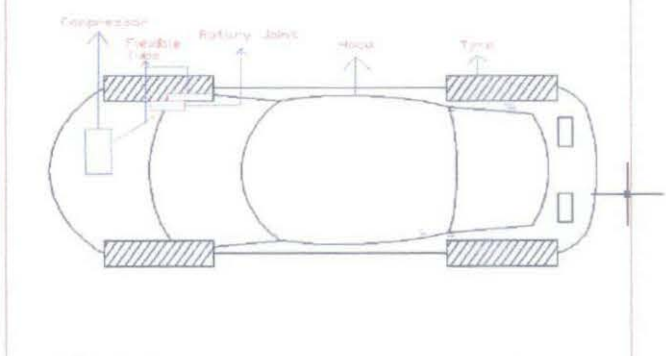


Figure 4.1: Sketch View of the system

4.2 DESIGN OF THE TEST RIG

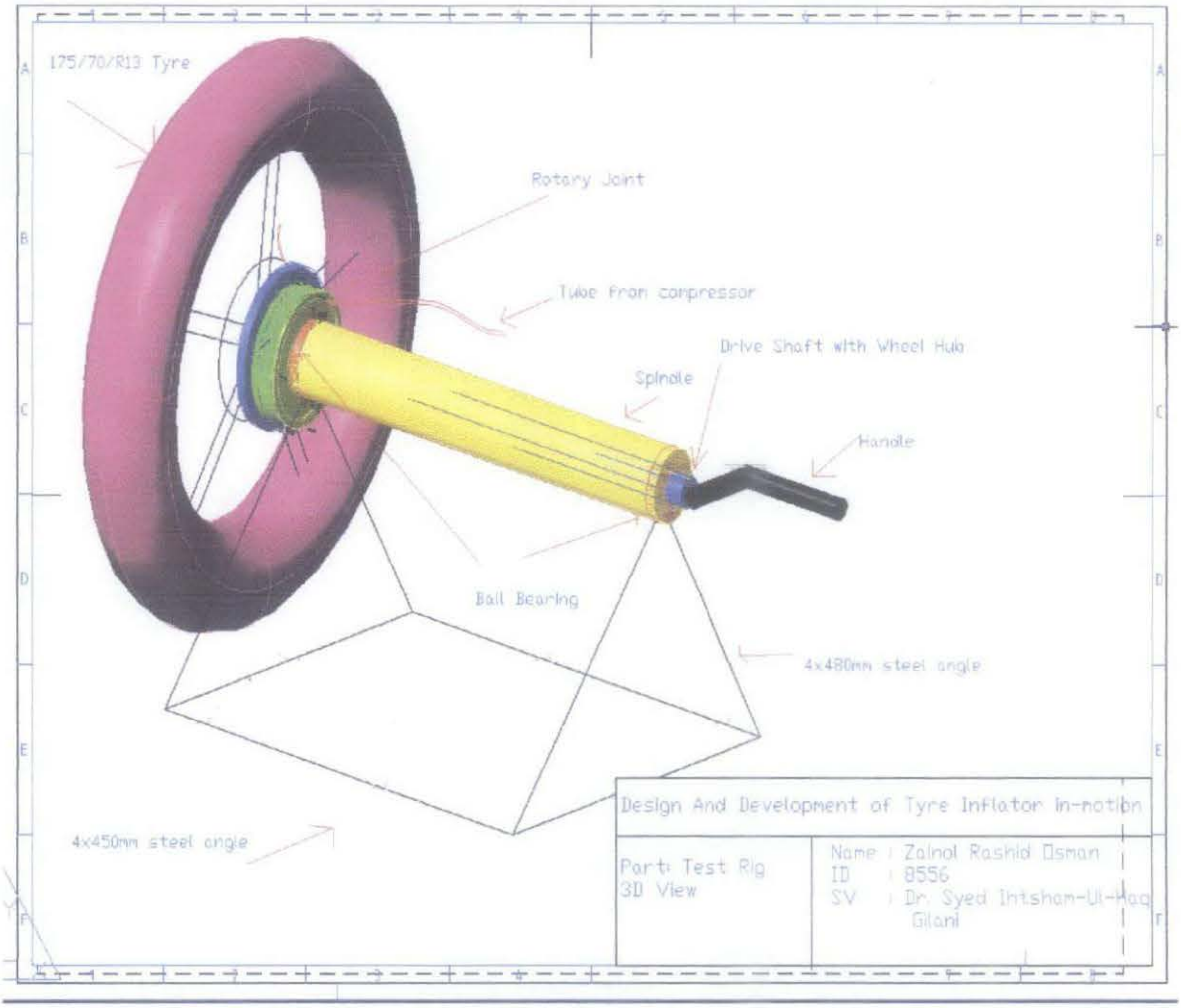


Figure 4.2: Test Rig Drawing

The test rig as shown in figure 4.2 which has been design is to simulate the real tyre motion; hence a handle will be attached to the shaft to rotate the tyre. The spindle has been replaced with a hollow pipe to resemble the exact spindle that attached to the suspension component of the car.

4.3 DESIGNING THE ROTARY JOINT

The in-motion tyre inflator were to be used by the local passenger vehicle ,hence the main challenge is the presence of the axle shaft that runs straight into the center of the wheel which required other mechanicsm to route the air to the tyre. The solution to this problem is by placing a rotary joint that has one half spinning with the drive axle hub and the other half stationary with the spindle. There will be an air chamber that allows air to be transfer from the stationary joint to the rotating joint.

The main specification for the rotary joint :

- Must have a 43mm hole in the center to allow for the axle to either pass through or support the joint.
- Air inlets and outlets must be located at the outer radius to allow the hoses on the outside of the joint to clear the vehicle spindle and hub.
- Overall thickness of the joint must be no greater than 40mm to so as not to interfere with the vehicle driveline or suspension components.
- Ball bearing system must be used to reduce contact friction between the two rotating halves both axial and planar.
- A locking plate will be attached to hold the plate together and endure the pressure applied during the air transfer.

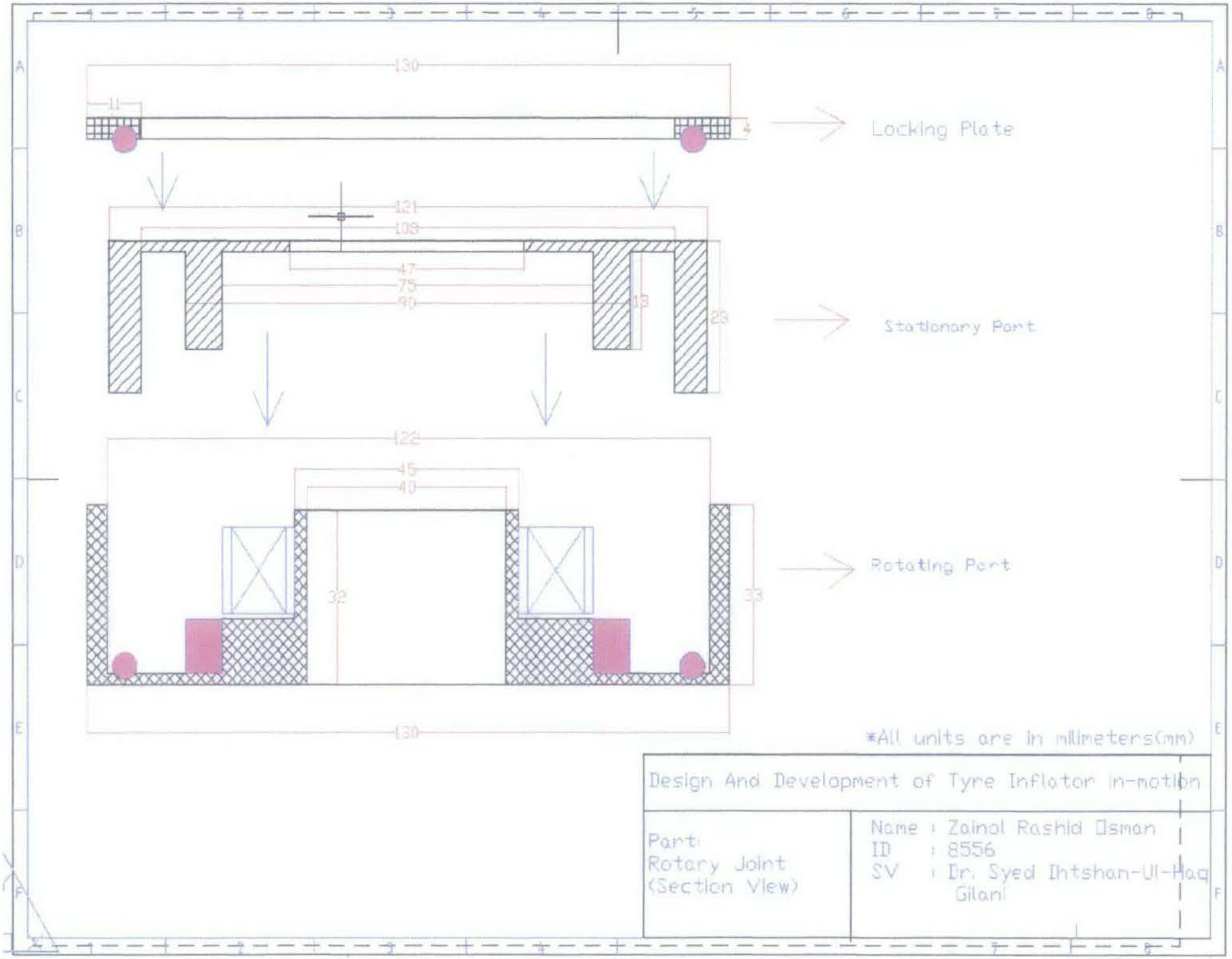


Figure 4.3 : Assembly view of rotary joint

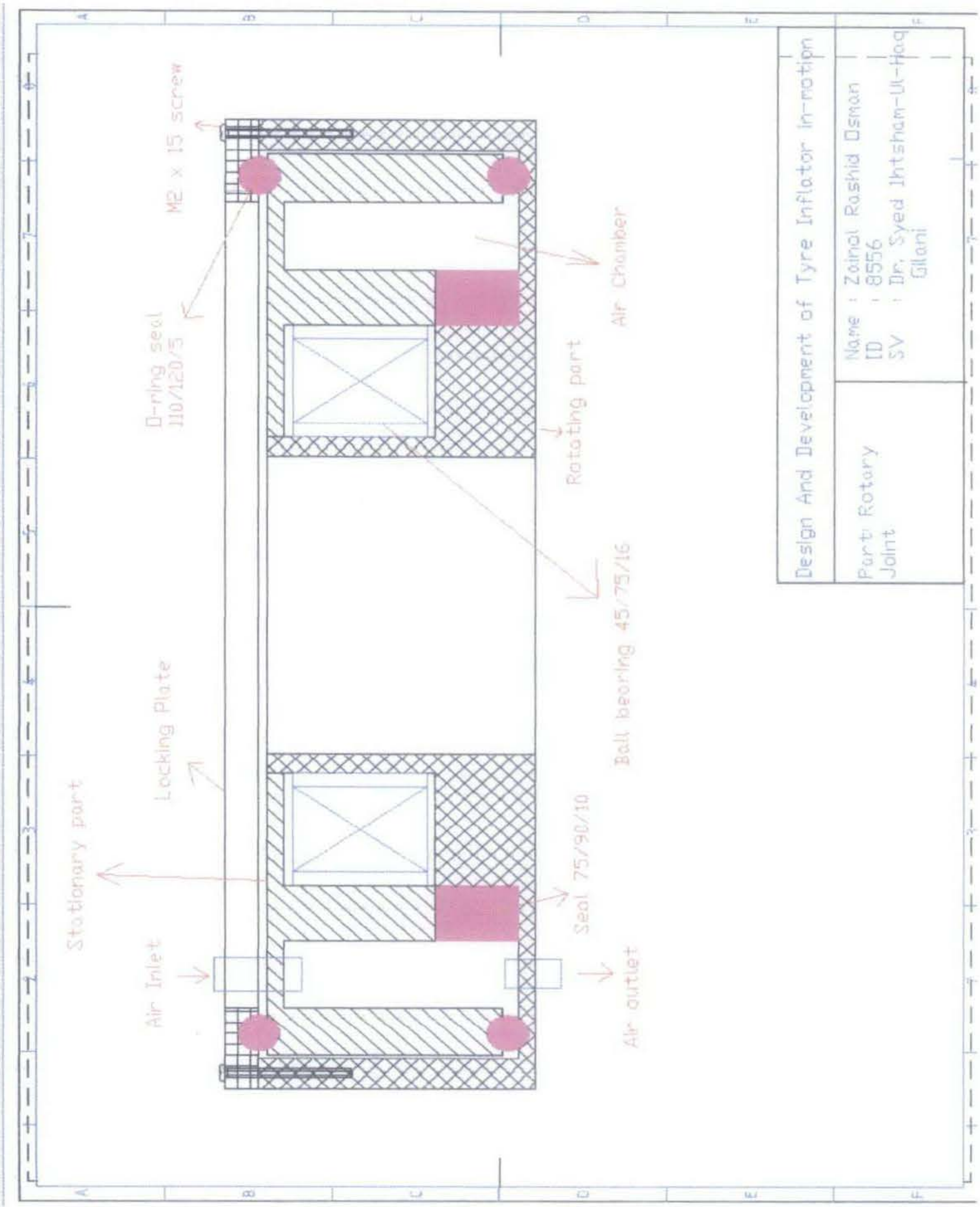


Figure 4.4 : Section view of rotary joint

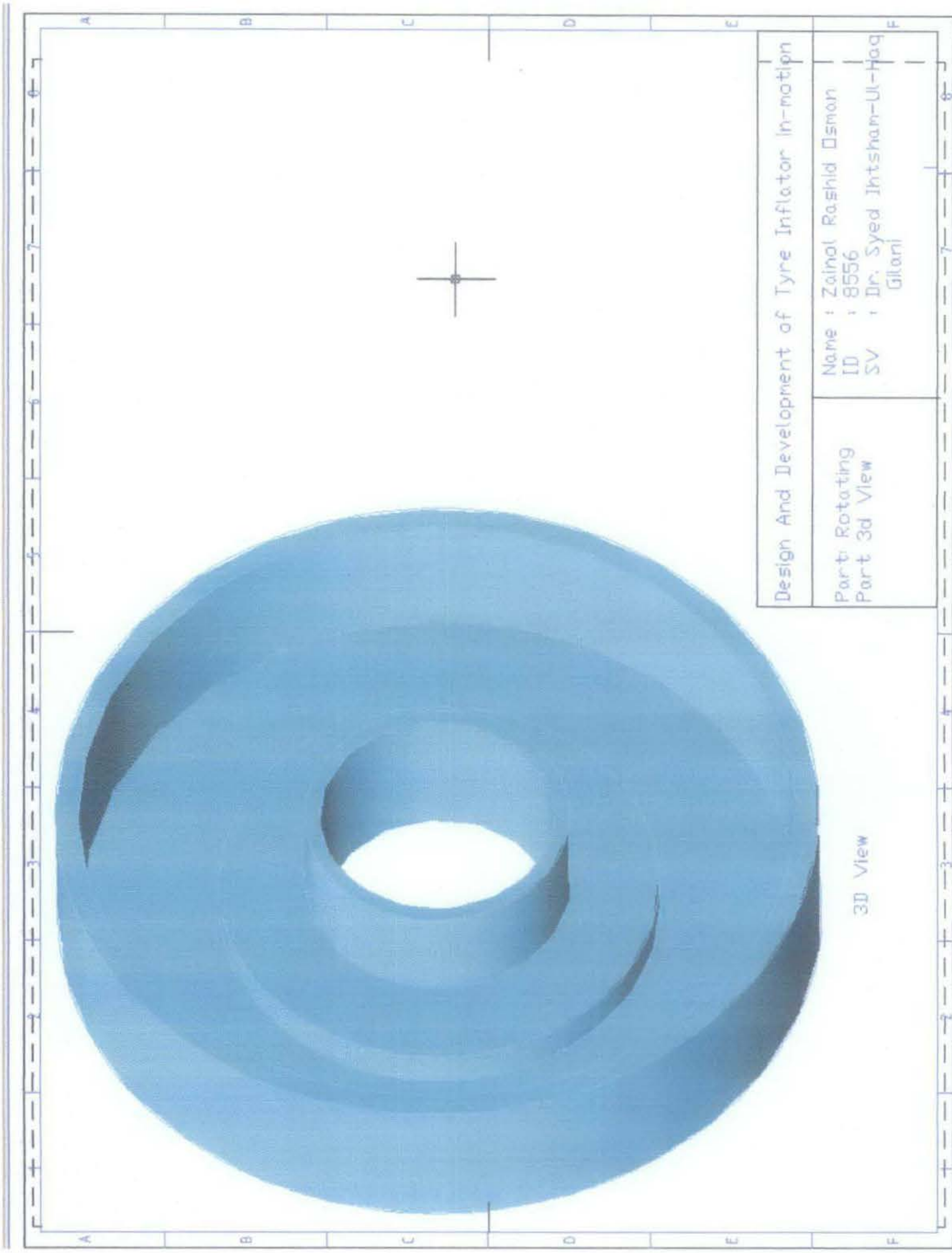


Figure 4.5: Rotating side of the rotary joint

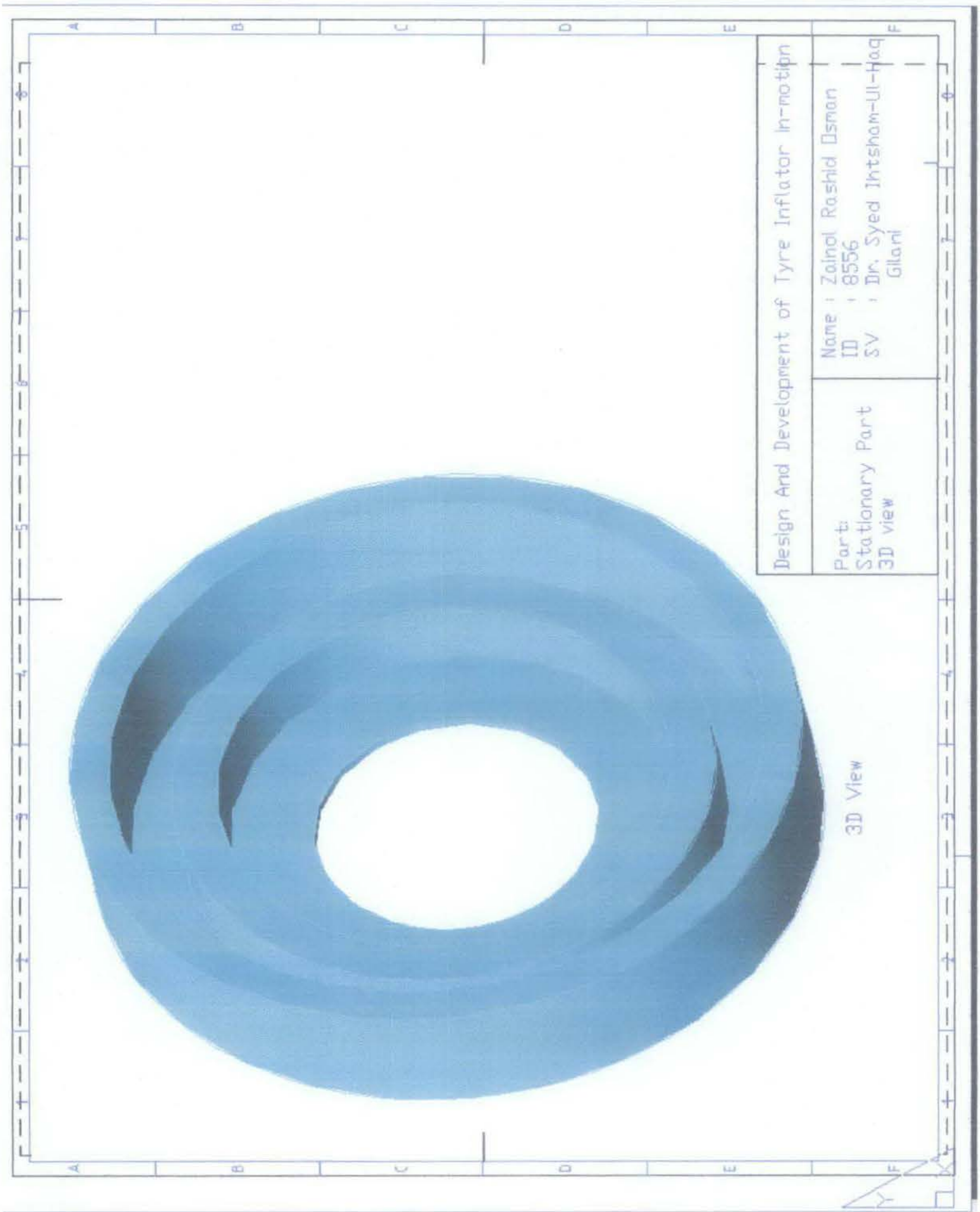


Figure 4.6: Stationary side of the rotating joint

The design of the rotary joint incorporates a 43mm bore in the center that allows the rotating half to completely rest on the drive axle while the stationary side rests above it and does not contact the rotating axle at all. The loose ball bearing system with "diagonally oriented" contact races allow the two halves to rotate relative to each other with minimal radial and planar friction. It is also exactly 37mm in thickness and 130mm in diameter.

This allows it to fit within the driveline constraints and brake components.The joint will be equipped with an air seal to prevent air leakage as shown in figure 4.4. The air chamber are designed to reduce as much pressure loss as possible without sacrificing friction when the joint rotates. This has been obtained by use of stepped features on one half that insert into the slots on the other half of the joint. These walls create a more complex passage for the air to escape, hence increasing the resistance.

The spinning side of the rotary joint will be lock onto the wheel hub to ensure it will not slip from its original place .The stationary side on the other hand will be lock to the spindle which is also stationary. Figure 4.7 shows the drawing of the connection between the rotary joint with the wheel hub and the spindle.

Figure 4.7: Assembly drawing of the system

Flexible tube of ¼" diameter will be use as the air transfer method along with a 1/8" NPT tap. This fitting had the best transition for ¼" hose from the base to tip. Also, the 1/8" NPT was significantly smaller in diameter that allows a smaller hole at the rotary joint for the tube connection.

Figure 4.7 shows the assembly drawing and design of the system. The tube from the compressor will transport air into the rotary joint through the 1/8inch NPT tap. The air chamber will act as the medium between the stationary joint to the rotating joint and went straight to the tyre tube.

An additional locking plate will be used to lock both part of the rotary joint together and to endure the air pressure during the transfer so that the rotary joint would not fall apart. The locking plate is to be screwed to the rotary side and will not affect the stationary joint. Another air seal is to be installed at the locking plate to prevent air from getting out.

The rotary joint will form a spacer between the wheel hub and the spindle and fit nicely. The rotary side will be bolted to the wheel hub using the locking angle attached to the hub and bolted through the rotary side.

4.4 MATERIAL PURCHASING

In order to start fabricating the system, a lot of material and few car parts are required. The lists of the part are shown in table 4.1.The cost to complete the system are approximately RM 244.00.

Table 4.1: Bill of material

No	Description	Purpose	Quantity	Price(RM)
1	Drive shaft with wheel hub	For the test rig	1	50
2	Ball bearing	To able rotation of drive shaft	2	30
3	175/70/R13 size tyre	For the test rig	1	10
4	A steel handle	To rotate the driveshaft	1	5
5	Steel Angle	For the base of the test rig	8	19
6	Air Tube	Air transportation method	2	5
7	1/8 inch Npt tap	To connect the tube to the joint	2	10
8	Steel Block	To fabricate the joint	1	50
9	Seal ball bearing	For the joint rotation	1	30
10	Seal	To seal the air in the joint	3	30
11	M2 x 10 screw	To screw the joint	4	5
			Total	RM 244.00

Below are the pictures of some material and car parts that have been acquired for the test rig fabrication. The driveshaft however still need to be modified a bit since the actual spindle is attached to the suspension component and hence, a hollow pipe are used to replace the spindle in the test rig.

Figure 4.8: 175/70/R13 sized tyre

Figure 4.9: Seals to be use in the rotary joint

Figure 4.10: Driveshaft with wheel hub

Figure 4.11: Ball bearing for the driveshaft

A collar needs to be machined so that the pipe can be attached nicely onto the ball bearing for the spindle to stay static. The steel angles have also been bought to be developed as the based for the test rig as shown in the AutoCAD drawing.

4.5 Fabrication process

The fabrication process has begun for about 2 months and the final prototype have been completed. Various machining process are required in order to develop the rotary joint itself. For the rotary joint, the first part of the works including turning, boring and grooving.

All the works are conducted on Heavy Duty Lathe machine manually since the CNC machine does not have the tool for grooving. For parting process, Linear Hack Saw machine was used to cut the steel block as shown in figure 4.12. A lot of times were spent at machining the rotary joint so that the dimension is accurate for both rotating joint and stationary joint to clamp together.

Figure 4.12: Parting process of the stationary joint using Linear Hack Saw machine

4.6 TESTING AND RESULT

4.6.1 Relationship between tyre widths with air pressure inside the tyre

The first experiment done was to find the relationship between the tyre width and the air pressure inside the tyre. The pressure range tested is between 26 until 32 psi. The tyre are inflate according to the air pressure needed and a fixed weight of 100kg were put onto the tyre to measure the tyre width and result were recorded as shown in table 4.2.

Table 4.2: Relationship between tyre width and air pressure

	Pressure			
	26psi	**28psi**	**30psi**	**32psi**
Width(cm)	**11.5**	**11.2**	**10.7**	**10**
Height(cm)	**16**	**15**	**14**	**13.5**
Section area(cm^2)	**184**	**168**	**149.8**	**135**

From the table, it is obvious that a low tyre pressure will cause an increased to the tyre width. The increased tyre width will contribute to a lot of factor such as road friction which ultimately lead to higher fuel consumption. Nevertheless, sometimes it is better to have more tyre width so that the vehicle will have more traction and increase vehicle mobility.

This factor hence leads to the design of in-motion tyre inflator so that the driver can change the air pressure inside the tyre to balance between the need of speed and vehicle mobility. Figure 4.13 (a) and (b) shows the footprint or section area of the tyre during the experiment.

Figure 4.13(a): Tyre footprint at 32psi

Figure 4.13(b): Tyre footprint at 26psi

4.6.2 Conducting the simulation of air flow on the test rig

The prototype of the test rig have been completed and assembled together with the rotary joint to conduct the simulation. The simulation will be tested at pressure of 28 psi to ensure the rotary joint can withstand the amount of air pressure flow into the tyre while maintaining the air pressure inside it. The joint are rotated at 25 rpm for 3 minutes to determine the difference of air pressure for air leakage detection.

However, the tyre was replaced with a motorcycle tube so that the physical changes can be seen after the airs have been transferred. Table 4.3 below shows then time taken for the motorcycle tube to be inflated. At approximately 2 minutes, the pressure drop slightly due to the air leakage.

Table 4.3: Time taken to inflate motorcycle tube at 28psi

	Time					
	5seconds	**15seconds**	**30seconds**	**1 minute**	**2minute**	**3minutes**
Pressure, psi	15	28	28	28	27	27

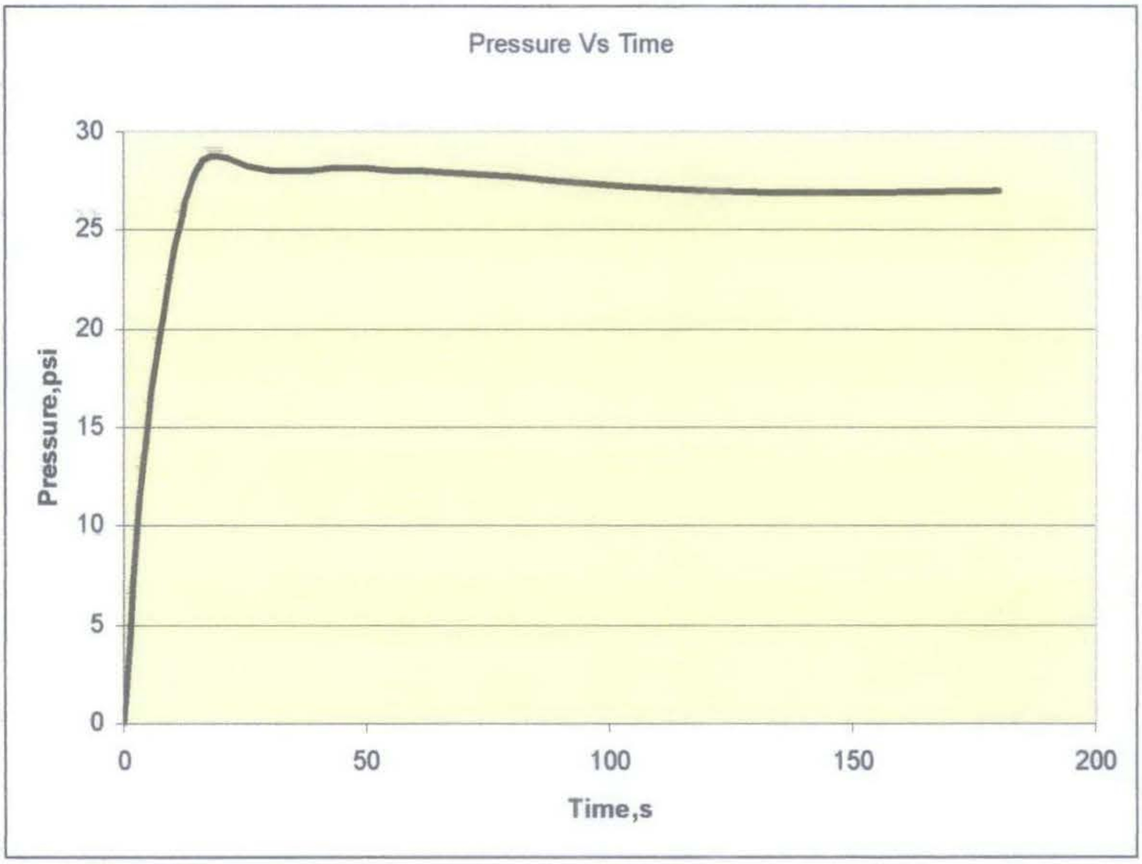


Figure 4.14: Graph for Pressure Vs Time taken

From the graph, it shows that the rotary joint are capable of withstanding the air transfer at 28psi and able to act as the medium for the air transfer while rotating. It takes 15 seconds to inflate the tube to 28 psi and after that the graph also shows that there is a slight air leakage to the rotary joint due to the pressure drop from the graph.

Equipping the tube with an external valve will solved the air leakage of the tyre tube. Figure flow chart below shown the step by step taken to show the success of the simulation.

FLOW OF THE SIMULATION FOR AIR TRANSFER

1. The initial motorcycle tube

2. Rotate the handle to begin rotation

3. The air is being transferred

4. The inflated motorcycle tube

4.6.3 Cost Estimation

The design and development of in-motion tyre inflator are targeted to the local car maker in Malaysia which is Proton and Perodua, hence the cost of the product should not be to the extend of burdening the buyer of the car. Table 4.4 and 4.5 shown the estimated cost for the development of the system.

Table 4.4: Cost estimation of the rotary joint assembly

	Material	Quantity	Cost per item	Process Cost	Total Cost
Rotating joint	Mild Steel	1	RM 40.00	RM 15.00	RM 55.00
Stationary joint	Mild Steel	1	RM40.00	RM 10.00	RM 50.00
Total assembly cost					Rm105.00

Table 4.5: Cost estimation of system assembly

	Quantity	Cost per item	Process Cost	Total Cost
Ball bearing	1	RM 36.00	-	RM 36.00
Compressor	1	RM 80.00	-	RM 80.00
Air Tube	2	RM 2.00	-	RM 4.00
Pressure sensor	1	RM 12.00	-	RM 12.00
Seal	3	RM 8.00	-	RM 24.00
Total assembly cost				RM 156.00

Hence, the total cost for the system is estimated to be RM 261.00. The cost is reasonable considering the capabilities of the system and its function to assist the driver.

4.6.4 Prototype reflection

From the initial test of the prototype, I have found few parts that can be improved in order to make the system much better in term of the design. The reflections from the prototype are as follows:

- ✓ Sealed ball bearing should be used in the rotary joint instead of standard ball bearing to improve its lifetime.
- ✓ Shield or housing must be used to protect the joint from dirt
- ✓ The thickness of the outer wall seems very thin and looks like it can be made thicker without compromising the performance
- ✓ The machining process should be done by professional to ensure good surface finish and allows air to flow smoothly
- ✓ An external valve should be used at the tube to avoid pressure drop due to the air leakage from the tyre.
- ✓ Another one way valve are optional to be put before the rotary joint so that there will be no air pressure drop after the transfer.

4.7 Discussion

The rotary joint which have been design is suppose to be air tight by using the stepped feature implemented onto the design but air loss are to be expected . The problem in sealing the air is to determine the best method to seal the air since there will be friction between the rotary joint.

Flouropolymer based material is used as best method in sealing the air in this rotating joint. 2 type of seal will be used which is the O-ring seal and Rotating seal. After asking few opinions from the seal vendor, it is safe to assume that O-ring seal should be able to withstand low speed friction.

The size of the rotary joint is based on assumption according to the real vehicle compartment of the wheel hub. This is for making the prototype and to see whether the system will function as it suppose to.

Mild steel is used to fabricate as the rotary joint since it is considerably cheaper and can serve its purpose in this design. However, during the fabrication process, a lot of problems were encountered especially during grooving. The CNC machine can't be used for grooving due to lack of tool. Hence, the tool were custom made for this design and can be used only on manual lathe machine.

This is the first time our lab technician encountered grooving at this size and has cause problem to determine the speed and size of the tool resulting in broke tool at the first attempt.

The second attempt after the tool have been custom made once again, managed to barely do the grooving tasks. Grooving process is the one that will take longer time to be completed and to make sure that it is accurate, frequent dimension reading is necessary.

Figure 4.15: Grooving area in the stationary joint

CHAPTER 5
CONCLUSION

For the conclusion, the in-motion tyre inflator system can be realized using the rotary joint air transfer method. A lot of research and modification can be done before the system goes into perfection. The in-motion tyre inflator system would be capable of succeeding as a new product in the automotive supplier industry. It specifically addresses the needs of the consumers by maintaining appropriate tyre pressure conditions for:

- Reduced tyre wear
- Increased fuel economy
- Increased overall vehicle safety

REFERENCES

1) 'Mario Andretti's real information on tyre safety' – Mario Andretti, 2008

2) 'In-motion tyre pressure control system for vehicles' - M.L.Groenewald and J. G-ouws, 2006

3) 'Tyre catalog' - 2008 Bridgestone Firestone North American Tire, LLC

4) SABS 1550 & *ARP* 007 "Motor vehicle tyres and rims - Dimensions and loads", South African Bureau of Standards, Pretoria

5) 'Vehicle Tyre Pressure Monitoring' article - Kais Mnif of MOTOROLA SEMICONDUCTOR PRODUCTS

6) Harrington, Ron; Hock, Kathy (1991). *Flexible Polyurethane Foams*. Midland: The Dow Chemical Company

7) Dynamically-Self-Inflating Tire System (2006) - Michael Alexander, Anthony Brieschke, Jonathan Quijano, and Lau Yip

8) http://auto.howstuffworks.com/self-inflating-tire.htm

9) http://www.carbibles.com/tyre_bible_pg1.html - author by Christopher J Longhurst

10) Http://www.freepatentsonline.com/EP1514704.html

11) Http://www.mbzponton.org.

12) Http://www.denysschen.com/rotating/critspeed.asp

13) Http://www.efunda.com/materials

14) Http://www.wansern.com/application.html#01

15) Http://en.wikipedia.org/wiki

16) Http://www.fluoropolymer-facts.com/

17) Http://www.amazon.com/Campbell-Hausfeld-RP3200-Cordless Worklight/dp/B000642GAM

APPENDIX A: Aluminum Alloy 3 series properties

AA 3105

Category	Aluminum Alloy
Class	Wrought

Composition

Element	Weight %
Al	99.0
Mn	0.55
Mg	0.50

Mechanical Properties

Properties		Conditions	
		T (°C)	Treatment
Density (×1000 kg/m^3)	2.6-2.8	25	
Poisson's Ratio	0.33	25	
Elastic Modulus (GPa)	70-80	25	
Tensile Strength (Mpa)	150	25	H12 more
Yield Strength (Mpa)	130		
Elongation (%)	7		
Reduction in Area (%)			
Shear Strength (MPa)	97	25	H12 more

Thermal Properties

Properties		Conditions	
		T (°C)	Treatment
Thermal Conductivity (W/m-K)	173	25	O (all)

Electric Properties

Properties		Conditions	
		T (°C)	Treatment
Electric Resistivity (10^{-9}W-m)	38	25	O(all)

APPENDIX B: Steel general properties

General Properties of Steels

The following table lists the typical properties of steels at room temperature (25°C). The wide ranges of ultimate tensile strength, yield strength, and hardness are largely due to different heat treatment conditions.

Properties	Carbon Steels	Alloy Steels	Stainless Steels	Tool Steels
Density (1000 kg/m^3)	7.85	7.85	7.75-8.1	7.72-8.0
Elastic Modulus (GPa)	190-210	190-210	190-210	190-210
Poisson's Ratio	0.27-0.3	0.27-0.3	0.27-0.3	0.27-0.3
Thermal Expansion (10^{-6}/K)	11-16.6	9.0-15	9.0-20.7	9.4-15.1
Melting Point (°C)			1371-1454	
Thermal Conductivity (W/m-K)	24.3-65.2	26-48.6	11.2-36.7	19.9-48.3
Specific Heat (J/kg-K)	450-2081	452-1499	420-500	
Electrical Resistivity (10^{-9} Ω-m)	130-1250	210-1251	75.7-1020	
Tensile Strength (MPa)	276-1882	758-1882	515-827	640-2000
Yield Strength (MPa)	186-758	366-1793	207-552	380-440
Percent Elongation (%)	10-32	4-31	12-40	5-25
Hardness (Brinell 3000kg)	86-388	149-627	137-595	210-620

APPENDIX C: Gantt chart for semester 2

Activity	Week												
	1	2	3	4	5	6	7	8	9	10	12	13	14
Drawing the final design	■	■											
Develop the interface			■	■	■	■							
Assembly of the system							■	■	■				
Testing the system										■	■		
Analysis and final report											■	■	■