International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-7, Issue-5S4, February 2019

Investigation of Tyre Pressure Drop Phenomenon Using Specially Designed Real-Time Data Mining and Storage System

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Abstract: ***Tyre pressure plays an important role in ensuring safe operation and performance of a motor vehicle. Improper monitoring of tyre pressure always results in reduction of gas mileage, tyre life, vehicle safety and performance. Studies reflects that, properly inflated tyres can increase tyre life span up to 20% which is equivalent to nine months of its life span, save fuel from 4% to 10%, increase braking efficiency up to 20%, lightens steering system and ease self-steer. Monitoring proper tyre pressure using manual gauges are less effective as they tend to provide slight gap at the valve for air leakage during pressure checking. Therefore, a device called tyre pressure monitoring system (TPMS) is used in the current research to efficiently monitor air pressure and temperature in the tyre of a motor vehicle which then generates a signal indicative of the pressure and temperature in each of the tyre thus increasing the monitoring system of a vehicle and its safety. This paper presents a "cost-effective" real-time data plotting application based on LabVIEW graphical user interface using a TPMS device. Notably, the entire system is tailored to the situation whereby with the existence of this interface; tyre researches and scientist would able to effectively monitor and simultaneously plot the tyre pressure and temperature data even at dynamic condition.***

Index Terms: ***Data mining, TPMS, tyre presure, tyre pressure drop, tyre safety, tyre temperature.***

I. INTRODUCTION

Improperly inflated tyres are noticed to be fairly common problems on passenger vehicles and would equally causes critical impacts on safety and motoring cost. In fact, 80% of passenger vehicles on the road are observed to have at least one under-inflated tyre and 36% of passenger cars have at least one tyre that is 20% or more under-inflated [1]. Research finding also shows that every tyre pressure drop of 10 to 20 kilopascal a month is equivalent of adding a 70 kilogram person into a car [2] and causes overloading due to the 'virtual' passenger condition. The facts are that, tires with proper inflated pressure can safe its life up to 20% which is nine months more of its life span, save fuel from 4% to 10%, increase braking efficiency up to 20%, lightens vehicle steering system and ease self-steer. Often pressure losses in a tyre are associated with natural permeation of the gas through the elastic rubber of the tubeless tyre material [3] with the presence of high operating temperature [4]-[8]. Improper monitoring of the tyre pressure is one of the main reasons resulting in tyre failure and regular usages of common air pressure kiosk usually doesn't provide accurate readings of the tyre pressure.

Drivers usually do not check tyre pressure unless they notice unusual vehicle performance and furthermore visual checks are often insufficient to determine tyre condition. Therefore, tyre pressure maintenance system (TPMS) was introduced and due to its importance which plays a vital role in vehicle safety system, it is a mandatory system to be installed in most of the foreign production vehicles nowadays [9]. A modern TPMS system can notify the driver on current tyre pressure and temperature level and warn the driver on when a tyre needs to be inflated [10]. By using the application of a TPMS, a graphical user interface are being organized and designed on LabVIEW which consist of real-time data monitoring, plotting and data storing of the tyre pressure and temperature continuously and simultaneously even during dynamic condition when the vehicle begins to travel. Furthermore, the characteristic and behaviour of a vehicle tyre can be studied and analysed effectively by scientist and more importantly tyre researchers using this developed graphical user interface. Besides that, it possesses many advantages such as easy to be maintained, a "plug and play" portable system, alerts users automatically and instant graph plotting.

Revised Manuscript Received on February 11, 2019.

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II. TYRE PRESSURE MONITORING SYSTEM

Basically, a tyre pressure monitoring system (TPMS) monitors the air pressure in the tyres of a vehicle, which eventually generates a signal indicative of the tyre pressure in each of the tyre which indirectly increase motoring safety and performance [11]. It is also described as driver-assist system that warns the driver when the tyre pressure is below or above the prescribed limits according to the vehicle manufacturer's guide [12]. Each tyre inflation pressure is identified and measured by a pressure sensor fitted internally in the rim. As the pressure is measured, it is transmitted through its transmitter and sensor. Next, the transmitted signals are received, decoded and processed by the receiver to trigger a warning indicator through an alarm lamp, audible lamp and pressure display unit mounted on the dashboard in the driving compartment which functions as a receiver for the driver to take immediate action to curb the problem. Fig. 1 shows the basic TPMS setup in a vehicle.

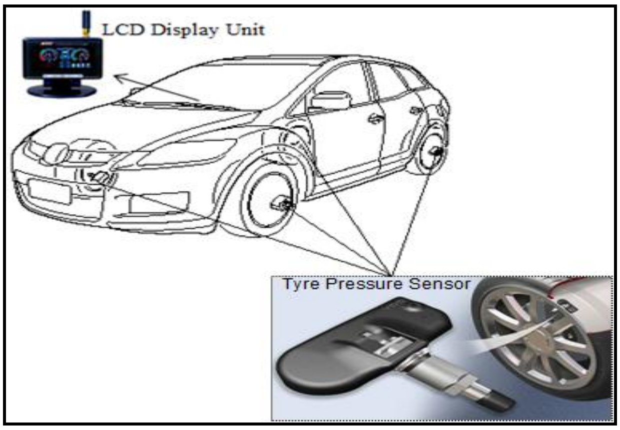

Fig. 1: Basic TPMS setup in a vehicle

TPMS used in this research comes with a LCD Display Unit (receiver), four tyre pressure sensor (transmitter) and valve set for each tyres respectively, a power cord cigarette adapter act as a power supplier to the LCD Display Unit and a RS232 connector to convey the storage of the recorded data of tyre pressure and temperature with time-stamp in a personal computer which the data are stored in an ASCII format. The data are shown starting from tyre 1 (Front Left), tyre 2 (Front Right), tyre 3 (Rear Right) and finally tyre 4 (Rear Left) in a 30 second period clockwise manner. After proper installation and pre-setting, this particular TPMS informs the driver not only the accurate and up-to-date tyre pressure but its temperature too; and upon detection of any irregularities in the tyre pressure or temperature, it will immediately notify the driver by sounding an alarm and flash on the LCD display. Normally, this situation happens if there is any problem of either slow or fast tyre air leakage. Fig. 2 reveals the detailed specifications [13] of the TPMS sensor/transmitter and receiver unit.

Sensors/Transmitter Specifications

Battery life	Estimated 5 to 7 years (under normal operating condition)
Battery voltage	3 V
Storage Temperature	-55°C to 125°C
Operating Temperature	-40°C to 125°C
Temperature Resolution	±3°C
Pressure range	700kPa (Car), 1400kPa (Truck)
Pressure Resolution	2.66kPa (Car), 5.5kPa (Truck)
Operating Humidity	100%
Operating Frequency	434 MHz

Receiver Specifications

Operating Voltage	9V to 18V
Operating Temperature	-20°C to 85°C
Monitored Temperature	-40°C to100°C

Fig. 2: TPMS sensor and receiver specifications

III. LABVIEW SYSTEM

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) is a graphicalprogramming environment well suited for high-level and system-level design which is developed by National Instrument (NI). This programming approach is based on building block diagrams called Virtual Instruments (VI).

To date, this software package is one of the first and advanced graphical programming product and predominantly used in industries and academic sectors for data analysis, data acquisition, simulation and remote control [14], [15]. The LabVIEW programming software used in this research are installed with Report Generation Toolkit compatible for Microsoft Office. It is an 'add-on tools' library of flexible, easy to use VI's for programmatically creating and editing Microsoft Word or Excel reports from the LabVIEW system. It also enables to generate, summarize, compile and store test results/data or reports of the entire system for various professional usage [16]-[18]. A proper VI consists of the following main components [19]:

a) Front Panel = serves as the user interface
b) Block Diagram = contains the graphical source code that describes the functionality of the Virtual Instruments (VI)
c) Icon and Connector Panel

The LabVIEW system used for this research is mainly for retrieving the data which is the internal tyre pressure and temperature from the TPMS sensor of all the tyre and instantly plot and store the obtained data according to the "Date and Time" frame. Fig. 3 discloses the complete flow-chart of the LabVIEW system used in this research.

As the system starts, it will initialize all the input data from the connected PC communication port (COM-port). Next, it will begin to read the data from the converted (RS232 to USB port) which used as "COM-port 4" in the front panel and block diagram of the complete interface as exposed in Fig. 4 and Fig. 5. While, the basic communication settings on the front panel of the system are listed as below:

i. COM port name = COM 4
ii. Data bits = 8
iii. Byte count = 20
iv. Parity bit = 0 (none)
v. Timeout (10sec) = 10000
vi. Boundary rate = 115200

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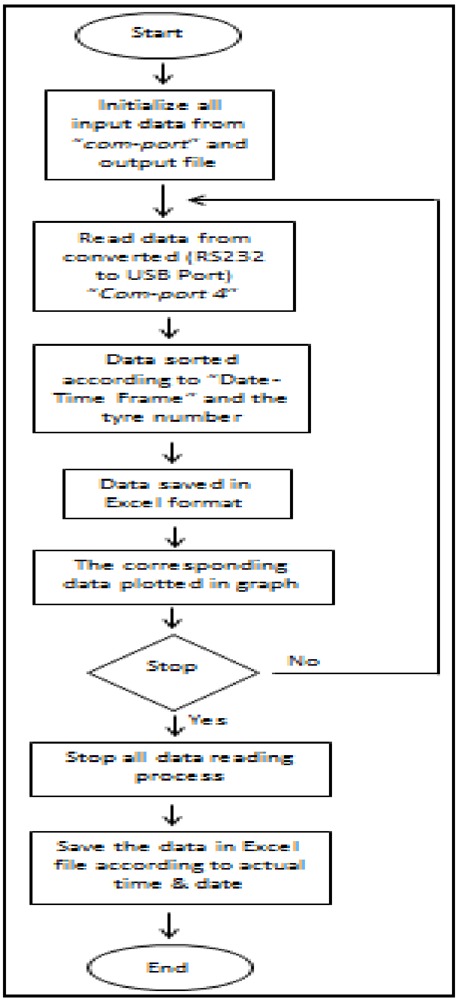


Fig. 3: Flow chart of the overall LabVIEW system

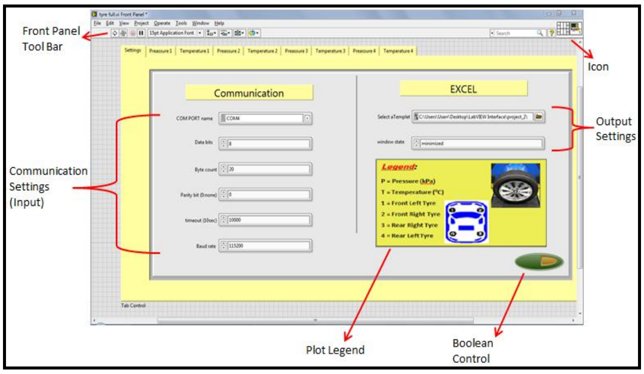


Fig. 4: Front panel of the interface

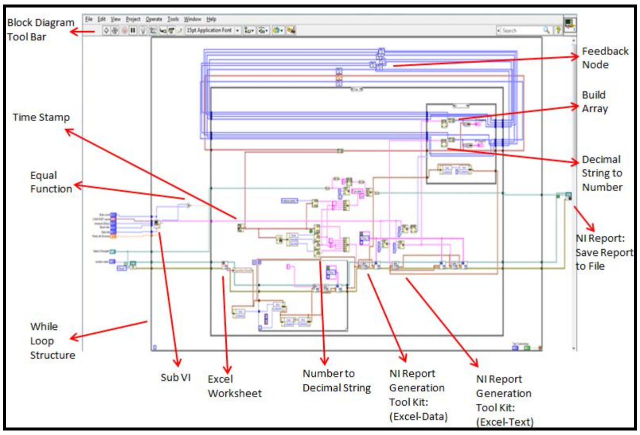
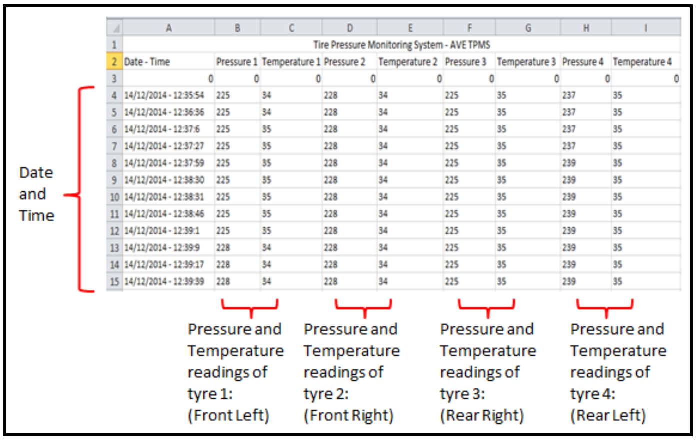


Fig. 5: Block diagram of the complete system

Then, the data is sorted according to the "Date-Time Frame" and the tyre number starting from tyre 1 (Front Left), tyre 2 (Front Right), tyre 3 (Rear Right) and finally tyre 4 (Rear Left) in a 30 second period. As the readings of the tyre pressure in kilopascal (kPa) and temperature in degree Celsius (°C) saved as excel template in PC, it will auto-plot the data in a graph simultaneously as displayed in Fig. 6 and 7. Two graphs for each tyre are developed which is the graph for pressure versus time and temperature versus time for all the tyres. This enables us to instantly detect any slight changes either on any particular tyre pressure and temperature. If the system is stopped, it will immediately pause all the reading process and save the final received data in Excel template according to the PC date and time; otherwise it will continuously repeat all the functions from retrieving the data to auto-plotting in a graph until the system is finally stopped.



Tire Pressure Monitoring System - AVE TPMS

Date - Time	Pressure 1	Temperature 1	Pressure 2	Temperature 2	Pressure 3	Temperature 3	Pressure 4	Temperature 4
0	0	0	0	0	0	0	0	0
14/12/2014 - 12:35:54	225	34	228	34	225	35	237	35
14/12/2014 - 12:36:36	225	34	228	34	225	35	237	35
14/12/2014 - 12:37:6	225	35	228	34	225	35	237	35
14/12/2014 - 12:37:27	225	35	228	34	225	35	237	35
14/12/2014 - 12:37:59	225	35	228	34	225	35	239	35
14/12/2014 - 12:38:30	225	35	228	34	225	35	239	35
14/12/2014 - 12:38:31	225	35	228	34	225	35	239	35
14/12/2014 - 12:38:46	225	35	228	34	225	35	239	35
14/12/2014 - 12:39:1	225	35	228	34	225	35	239	35
14/12/2014 - 12:39:9	228	34	228	34	225	35	239	35
14/12/2014 - 12:39:17	228	34	228	34	225	35	239	35
14/12/2014 - 12:39:39	228	34	228	34	225	35	239	35

Fig. 6: Data saved in Excel template

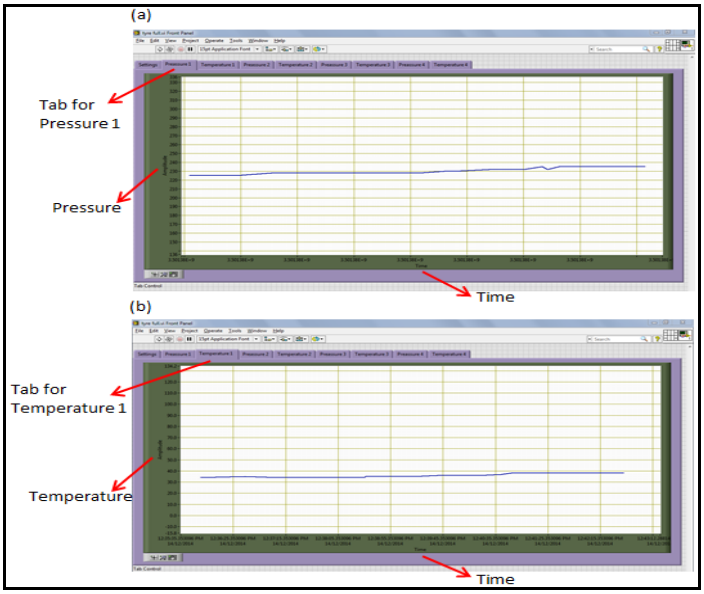


Fig. 7: Auto-plotted graph for tyre 1 (a) pressure vs. time and (b) temperature vs. time

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IV. METHODOLOGY

In order to conduct a test on the developed LabVIEW system using TPMS application, a methodology was organized [20] to study the tyre pressure deflation rate on a car. The entire system were fitted in a road traveling car (Malaysian made Proton Perdana 2.0 litre, V6) as shown in Fig. 8 where it weighs about a metric tonne. The tyres used for this were of the same widely commercialised brand with the aspect ratio 205/55R16 in similar conditions and initially inflated at 230kPa with compressed air.

Fig. 8: Tyre pressure deflation test setup on a vehicle

For this test, all four tyres (Tyre 1: Front Left), (Tyre 2: Front Right), (Tyre 3:Rear Right) and (Tyre 4: Rear Left) are tested and monitored. The vehicle was being driven at 300km straight-stretch without passengers and additional load, three times in a month (seven days interval each time) and finally obtained the pressure drop rate in all four tyres. The speed of the vehicle while driving was limited, ranging from 70km/h to 90km/h. All the readings are measured and stored from the date the test was started, while driving and exactly 30 days from the date as the vehicle complete its driving requirements within.

The objective of this experiment is to differentiate and evaluate the pressure drop of the tyre condition and ultimately the performance, reliability, usability, efficiency and ability of the developed LabVIEW system in monitoring, recording and auto-plotting the retrieved data of tyre pressure and temperature in each tyres respectively during dynamic condition.

V. RESULTS AND DISCUSSION

After 30 days of experiment, the complete readings of pressure and temperature for all the tyres during dynamic condition are obtained and plotted in a graph as shown in Fig. 9 for the first 300km straight-stretch attempt. During this trial, the pressure for the entire tyre increases gradually with temperature and time and become static after travelling 40 minutes.

During interval (seven days from the first 300km attempt), the car was parked in a closed compartment to reduce any external environment temperature variance which could affect the entire testing. Before the second 300km attempt, the pressure for tyre 1 and 3 is noticed to be deflated to 218kPa where else tyre 2 and 4 deflated to 221kPa. The pressure for all the tyre increases gradually with temperature and time and become static at 40th minute and continue to rise moderately until at 180th minute. All the data are tabulated as in Fig. 10.

After another seven days interval from the second 300km attempt, the pressure for tyre 1, 2 and 3 is observed at 223kPa and 197kPa for tyre 4. The pressure and temperature for both the tyre increases simultaneously and arrives to a steady-state form at 110th minute which displayed in Fig. 11.

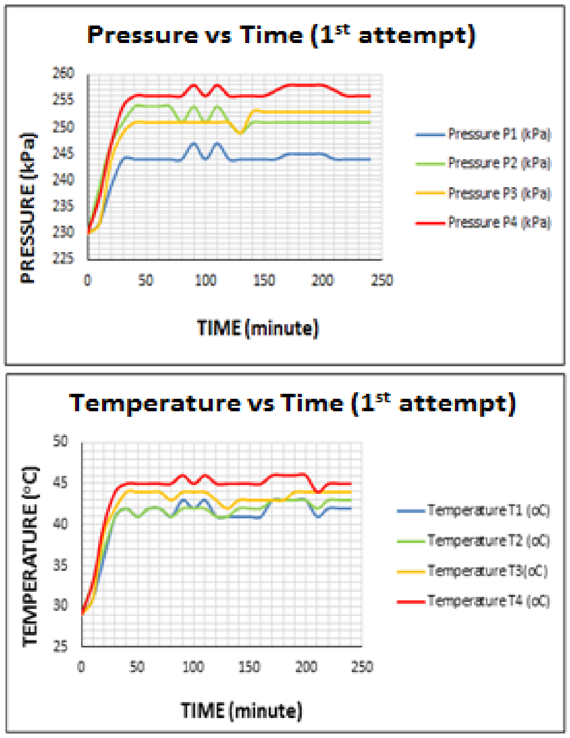

Fig. 9: Pressure and temperature variation over time during first 300km attempt

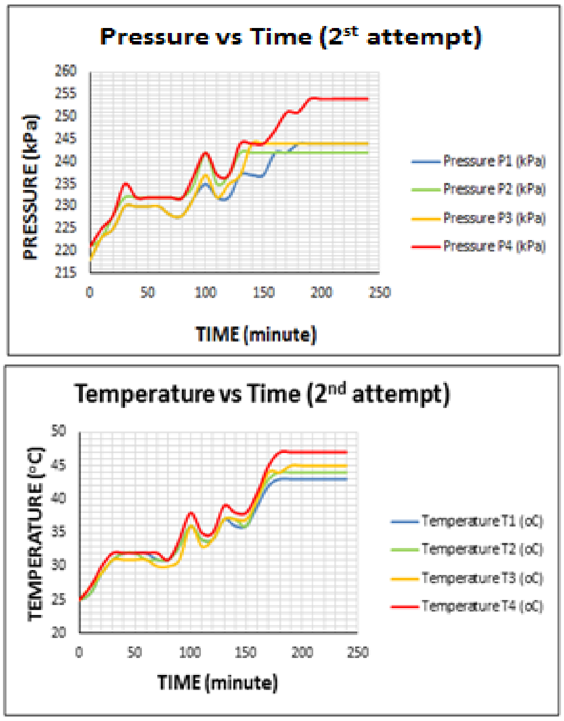

Fig. 10: Pressure and temperature variation over time during second 300km attempt

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From this retrieved data from the LabVIEW system, it reflects that after 30 days the pressure for tyre 1 is measured to be 222kPa reduces only 8kPa per month, tyre 2 with 207kPa reduces 23kPa, tyre 3 with 221kPa reduces 9kPa while tyre 4 which experiences high temperature rise for all the "300km straight-stretch" attempt; greatly drops to 190kPa with deflation over 40kPa per month. Therefore, tyre with high heat concentration experiences more air permeation which eventually leads to pressure loss [21]-[23].

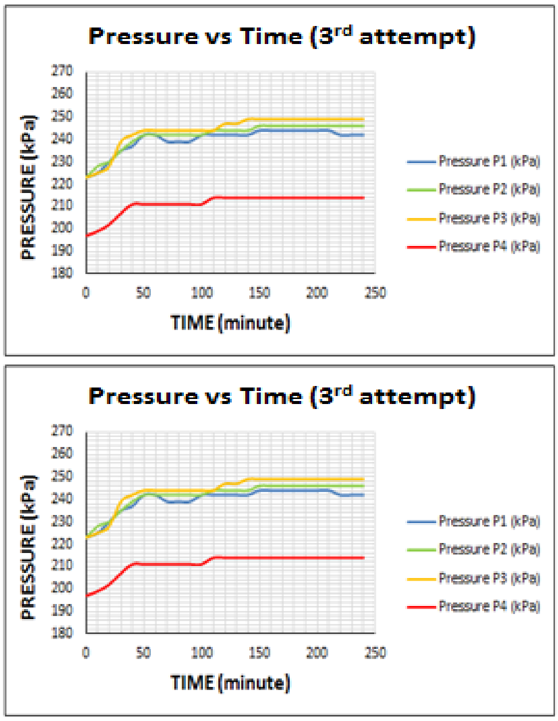

Fig. 11: Pressure and temperature variation over time during second 300km attempt

VI. CONCLUSION

In conclusion, the developed LabVIEW interface acts as a system to monitor the characterization and behaviour of both pressure and temperature of an automotive tyre. Moreover, it is field tested and functions very well in retrieving, recording and auto-plotting the obtained data of all four tyre pressure and temperature even at dynamic condition from the TPMS. From this system, it reflects that the tyre with highest heat concentration experiences more air permeation which ultimately leads to excessive pressure loss. Nevertheless, the developed system is considered user-friendly and easy to maintain by any individual and would be beneficial especially for tyre researchers.

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknikal Malaysia Melaka, Universiti Pertahanan Nasional Malaysia and Ministry of Higher Education Malaysia for supporting this research under grant PJP/2017/FKP/HI15/S01547.

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