Enhancement of the tyre rolling resistance testing machine

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Abstract. Rubber tree is an outstanding product in commercial area of Thailand. Tyre is one of the prominent and downstream products as components in the automotive industry with a high production capacity. While tyres are used widely, a regulation for the rolling resistance of tyres has been set up by the European Commission. Therefore, the operators must test their products. By the high costs for the testing before certification, the researchers realize the limitation of the test equipment suffering with the small and medium enterprises that do not have access to check their tyres. This is the weakness of the tyre industry in Thailand. Therefore, the low-cost of tyre rolling resistance testing machine has been built in accordance with the UNECE Regulation No. 117 which is accepted worldwide. As a result, the in-house tyre rolling resistance testing machine is compared with the imported one in terms of production cost. The budget can be reduced up to 50% since the test equipment can be produced with currently technology in the country. Moreover, this is the self-reliance of technological machinery industry. For the working result, it was found that the vibration level of tyre rolling resistance testing machine consented to the standard ISO 10816. Besides, the experimental results of tyre rolling resistance coefficient is compliance with the requirements UNECE Regulation No. 117 Annex 6 and also verified by the international authority (TUV Rheinland Thailand Ltd). It can reduce the limitation in terms of the testing and also support the economic expansion of the production of quality tyres in the country to be accepted in international level.

1. Introduction
Rubber tree is an outstanding product in commercial area of Thailand. Vehicle tyres are the products in the tyre industry that use natural rubber as the number one among all rubber products. The value of exports in the past year is approximately 120 million Baht. The direction of the tyre industry, studied by the International Rubber Study Group or IRSG [1], has predicted that the demand for natural rubber in the world is steadily increasing. By the 2020, the world's demand for rubber will reach 31.7 million tons or approximately value 13 trillion US dollars. The Ministry of Industry has discovered the growth direction of the car industry in China that has become to the No. 1 car of market since 2009. As a results, the potential of Thai tyre production must be complied to the standards relating to tyres as the UN/ECE standards and other international standards. Moreover, adaption of Thailand to be the center of tyre production in ASEAN Economic Community is also a main reason. The development of machinery to support the testing of rubber tyre products has led to such research.
This research aims to establish the tyre friction coefficient testing machine which is compliance to the requirement of UN ECE Regulation No.117 [2] by in-house technology in terms of both controller and mechanic systems.

2. Literature survey

The motion resistance ratio of a high-lug agricultural tyre was investigated by Elwaled A K. [3] The analysis of covariance (ANCOVA) revealed that both inflation pressure and wheel numeric have significant effects on tyre motion resistance ratio. Regression analysis was also conducted to determine the closeness of fit for Wismer–Luth’s and Brixius’ equations in predicting the motion resistance ratio of the tested tyre. Finally, three new logarithmic models for tyre motion resistance were formulated. The advantage of reducing tyre inflation pressure from 221 (nominal pressure) to 193 kPa on the motion resistance ratio of the high-lug agricultural tyre was pronounced. However, the tyre’s motion resistance ratio deteriorated with further reduction in tyre inflation pressure from 221 (nominal pressure) to 166 kPa. Furthermore, the supervision of vehicle's tyre pressures is a major aspect of improved active car safety. A method for monitoring the tyre pressures is presented [4], using body acceleration signals. Analyzing the frequency spectrum of the virtual transfer function between the body acceleration at the front and rear wheel on one side of the vehicle, characteristic features are generated. Thereby, external interferences on the spectrum and their influences on the symptoms are discussed.

In USA, energy conservation from systematic tire pressure regulation was setup by The 2000 TREAD Act [5]. It requires automakers to gradually provide tire pressure monitoring systems for vehicles sold in the US will correct this problem for new vehicles. This law does not impact the problem in previously deployed vehicles, which have a turnover time of ~20 years. A solution is provided here to address under-inflated tires on the current 220 million vehicles and the concomitant wasted energy due to increased rolling resistance in the US automobile fleet. This communication reports on a preliminary study of tire pressures in randomly chosen vehicles, which were undergoing oil changes at a combined retail/auto-care facility. The study indicates that substantial benefits would accrue if car care facilities systematically offered complimentary tire pressure checks with oil changes.

3. Methodology

From preliminary study, there are 4 defined methods into the UN ECE Regulation No.117 as 1) torque method 2) force method 3) acceleration method and 4) power method. The force method is generally accepted and also popular because it can support twice specimen as the same time for the testing. However, the torque method is most accepted in terms of the accuracy of measurement because the main data can be directly received by machine. Therefore, the tyre rolling resistance testing machine by torque method was designed as the conceptual research and also established to compare the testing results between the torque method and the force method machine. For the main operation of two type of the machine are illustrated in Figure 1 and also calculated by formula 1 for torque method and 2 for force method:

\[ F_r = \frac{T_t}{R} \]  \hspace{1cm} (1)

\[ F_r = F_t [1 + \frac{T_t}{R}] \]  \hspace{1cm} (2)

where

- \( F_r \) is the rolling resistance force
- \( T_t \) is the input torque
- \( R \) is the test drum radius
- \( F_t \) is the tyre spindle force
- \( r \) is the distance from the tyre axis to the drum outer surface under steady-state conditions
According with the conceptual research, the tyre rolling resistance testing machine base on the torque method was designed in terms of the mechanical production. The main sensors and transducers were defined and installed as shown in Figure 2.

**Figure 1.** The calculation concept of machine following the UN CEC Regulation No.117 [2].

**Figure 2.** The design of the tyre rolling resistance testing machine base on the torque method.

Since the tyre rolling resistance testing machine base on the torque method has been completely established, the setting- up and calibration process were continuously proceeded. There are both the structural and sensor tolerance calibrated by National Institute of Metrology (Thailand). Furthermore, the machine is certificated that is compliance to requirement of UN CEC Regulation No.117 Annex 6 by TUV Rheinland Ltd. Consequently, the 4 tyre specimens were donated by industry company to prove the tyre rolling resistance coefficient by means of the torque and force method following UN ECE Regulation No.117 Annex 6. The experimental work condition is shown in Table 1.

**Table 1.** Test condition [2]

| No. | Tyre type | Test speed (km/h) | Load (N) | Inflation pressure (kPa) | Warm up duration (min) |
|-----|-----------|-------------------|----------|--------------------------|------------------------|
| 1   | C1        | 80                | 80% of maximum | 250                  | 30                      |
| 2   | C1        | 80                | load capacity  | 250                  | 30                      |
| 3   | C2        | 80                | 85% of maximum | 450                  | 50                      |
| 4   | C2        | 80                | load capacity  | 450                  | 50                      |
4. Results and discussion
As a results, the rolling resistance coefficient of the 4 tyre specimens were conducted by means of the torque and force method following UN ECE Regulation No.117 Annex 6. For the force method, the specimens were tested on the standardized testing machine that is used in factory. At the same time, the same tyres were conducted to test on the tyre rolling resistance testing machine by means of torque method. The results of tyre rolling resistance coefficient are presented in the Table 2. The tendency of data show that the torque method machine reports the value slightly higher than the force method machine. There are 6 percentage of maximum difference value of both methods. It should be caused by mechanical loss and sensitivity of measurement system.

Table 2. The results of tyre rolling resistance coefficient

| No. | Tyre type | Torque method machine (N/kN) | Force method machine (N/kN) | Difference (%) |
|-----|-----------|------------------------------|----------------------------|---------------|
| 1   | C1        | 8.84                         | 8.73                       | 1%            |
| 2   | C1        | 9.59                         | 8.99                       | 6%            |
| 3   | C2        | 8.83                         | 8.77                       | 1%            |
| 4   | C2        | 9.13                         | 8.85                       | 3%            |

5. Conclusions
In conclusion, the in-house tyre rolling resistance testing machine (torque method machine) is compared with the imported one (force method machine). The test results between the two machine are slightly difference. Simultaneously, the in-house tyre rolling resistance testing machine is accepted that it is compliance with the requirements UNECE Regulation No. 117 Annex 6 by the international authority (TUV Rheinland Thailand Ltd). In terms of production cost, the budget can be reduced up to 50% since the test equipment can be produced with currently technology in the country. Moreover, this is the self-reliance of technological machinery industry. It can reduce the limitation in terms of the testing and also support the economic expansion of the production of quality tyres in the country to be accepted in international level.

6. References
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