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Uncertainty Factor Analysis of Tyre Wet Grip Index for EU and Korea Tyre Labelling System

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Abstract

EU and Korea governments are running the tyre labelling system from last year. European tyre label displays the grade of three performance parameters (Rolling resistance, wet grip and outside rolling noise).and All tyres sold in Korea will have to carry a label displaying information about two performance criteria (Rolling resistance, Wet Grip). Wet Grip is an important measure of tyre safety. There is growing interest in the wet grip test which is regarded as the most important test item in the tyre label. The wet grip index calculated by wet grip test determines the wet grip rating categories. In this study, uncertainty factors of wet grip index (such as SRTT, test surface friction, static load and water depth) and their effects on the wet grip index are analyzed using the design of experiments. When the uncertainty factors were varied within the test regulation conditions, the variations of wet grip index are analyzed.

Keywords: WGI(Wet Grip Index), BFC(Braking Force Coefficient), SRTT16"(Standard Reference Test Tyre 16inch), SRTT14"(Standard Reference Test Tyre 14inch)

1 Introduction

As an effort to reduce exhaust gas emission of the transportation, the improvement of tyre energy efficiency is required. Therefore, tyre manufacturers are trying to develop eco-friendly tyres and to supply this. [1] The tyre labelling system has been enforced by European Parliament and EU Council since November, 2012 [2] as well as by Korea government since December, 2012 [3]. European tyre label indicates the grade of three performance parameters (Rolling resistance, wet grip and outside rolling noise). European tyre label is shown in Fig. 1. All tyres sold in Korea will have to carry a label with information about two performance criteria (Rolling resistance, Wet Grip). Korean tyre label is shown in Fig. 1. Fuel consumption is related to the rolling resistance. Wet grip is one of the most important safety characteristics of a tyre. Tyres with excellent wet grip will have shorter braking distance on wet road. The EU tyre label indicates wet grip on a scale from 'A' to 'F'. And Korea tyre label also indicates wet grip on a scale from 1 to 5. The grade 'A' and '1' mean tyres with shortest braking distances and the grade 'F' and '5' mean tyres with longest braking distance.

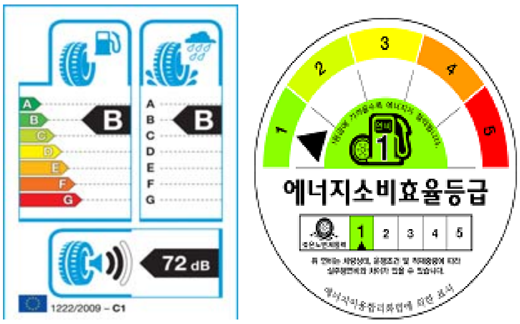

Figure1: Tyre Energy Efficiency Rating Label (EU, KOREA)

In this study, uncertainty factors of wet grip index (such as SRTT, test surface friction, static load and water depth) and their effects on the wet grip index are analyzed using design of experiments. When the uncertainty factors are varied within the test regulation conditions, the variations of wet grip index are analyzed.

2 Wet Grip Test Method

2.1 Wet Grip Test Procedure and Condition

There are two methods (vehicle and trailer methods) for measuring the wet grip index of passenger car tyres. In this study, the trailer method with high accuracy and good repeatability was used. Peak braking force coefficient occurred prior to wheel lockup at a test speed 65 km/h is measured using the trailer method. Test procedure and general test conditions are tabulated in Table 1 and Table 2.

Table1: Test Procedure

1. The SRTT is tested
2. After at least six valid measurements are performed, the SRTT is replaced by the candidate tyre
3. After six valid measurements of the candidate tyre are performed, two more candidate tyres (test tyres) may be measured
4. The test cycle is closed by six more valid measurements of the same SRTT as at the beginning of test cycle

Table2: Test Conditions

Test Speed	(65 ± 2) km/h
Test Load	(75 ± 5) % of Load Index
Test Inflation Pressure	Standard-load tyre : 180 kPa Extra-load tyre : 220 kPa
Water Depth	(1.0 ± 0.5) mm
Ambient Temperature	5 ~ 35 ℃
Wet Surface Temperature	5 ~ 35 ℃
Wetted Frictional Properties of Test Surface	0.7 ± 0.1 $\mu_{peak.corrected\ by\ temp.}$ of SRTT 14”

2.2 Wet Grip Index

Wet Grip Index is measured complying with the standard procedure, comparing the candidate tyre (test tyre) to the reference tyre (SRTT16”, Standard Reference Test Tyre 16”) defined in the regulation. The tyre’s wet grip class on the label is classified by the ratio of the two peak braking force coefficients (candidate tyre/reference tyre)

The wet grip index of the candidate tyre is calculated with the equation (1)

$$G = \left[\frac{\mu_{peak,ave}(T)}{\mu_{peak,ave}(R)} \times 125 + a \times (t - t_0) + b \times \left(\frac{\mu_{peak,ave}(R)}{\mu_{peak,ave}(R_0)} - 1.0 \right) \right] \times 10^{-2} \quad (1)$$

where,

t : wet surface temperature (℃)

t_0 : wet surface reference temperature condition, 20 ℃ for normal tyres, 10 ℃ for snow tyres

$\mu_{peak,ave}(R0)$: 0.85, peak braking force coefficient for the reference tyre

a : -0.4232, b : -8.297

3 Uncertainty Factor Analysis of Wet Grip Index

3.1 SRTT Factor Analysis

There are two kinds of SRTTs (Standard Reference Test Tyres) defined in the standard. One of SRTTs is SRTT16” that has the characteristics regulated in ASTM F 2493-08. SRTT16” is used as a benchmark in an evaluation program. And the other is SRTT14" that has the characteristics regulated in ASTM E 1136-93. SRTT14" is used to measure the wetted frictional properties of the surface.

3.1.1 Effect of Temperature on SRTT Property

Average braking force coefficients of SRTT14" and 16" are shown in Fig. 2. When the wet surface temperature rise by between 5 and 35 degrees Celsius, both average braking force coefficients of SRTT14"s and SRTT16"s are declined shown in Fig. 2.

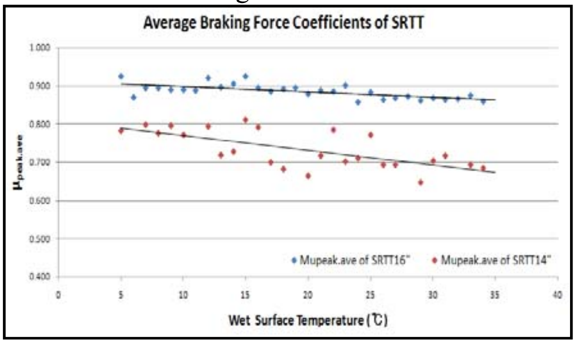

Figure2: Average PBFC of SRTT with Temperature

3.1.2 Effect of Tread Wear of SRTT16"

SRTT16" is very important because wet grip index is calculated by using the braking force coefficients of candidate tyre and SRTT16". But there is not any comment about the tread wear condition of SRTT16"s in the regulation. In this paper, wet grip test is performed to review effects of tread wear of SRTT16"s. Four SRTT16"s with different tread depth are such as Table 3. And other four SRTT16"s with similar tread depth but other braking times are such as Table 4. All SRTT16"s involved in the test programme have the same DOT. The tread depth of new SRTT16" is approximately 8.3mm and the tread depth of SRTT16" reached a wear limit line is approximately 2.3mm.

Table3: Tread depth of Test Cases

ID	Tread depth (mm)
Wear 1	8
Wear 2	7.1
Wear 3	5.9
Wear 4	2.8

Table4: Braking Times of Test Cases

ID (Braking Times)	Tread depth (mm)
100	8
300	7.9
500	7.1
800	7.1

Wet grip test of all eight tyres is performed at same test position. Average peak braking force coefficient of SRTT16"s with different tread depth is shown in Fig. 3. Wet grip index calculated by these SRTT16"s is shown in fig. 4. The braking force coefficients of wear 1, 2 and 3 except wear 4 are almost similar. Standard deviation of results is 0.009, coefficient of variation is 1.0. But standard deviation of the results included Wear 4 is 0.803, coefficient of variation is very high by 4.7%. Since water drainage capacity of SRTT16" with tread depth of 2.8mm is not enough, average braking force coefficient of Wear 4 is very low shown in Fig. 3. And Maximum difference of Wet grip index of test results is about 12% shown in Fig. 4. This is a very large value because difference of wet grip grade is about 10%. When the braking times rise (from 100 to 800 braking times), average peak braking force coefficient of SRTTs is increases by 2.4% shown in Fig. 5 and wet grip index is reduced about 2.3% shown in Fig. 6. Despite the similar tread depth, average braking force coefficient of SRTT16"s with similar tread depth is changed according to braking times

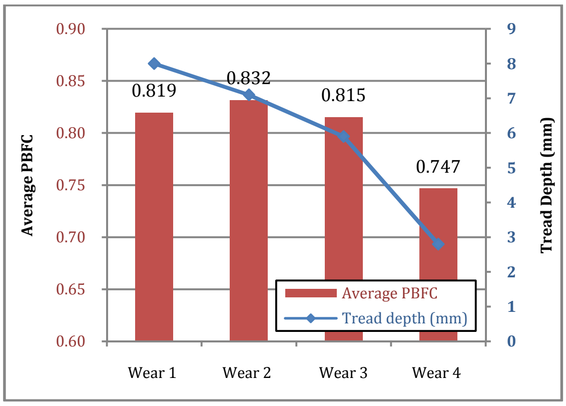

Figure3: Average PBFC of SRTT16"s with Different Tread depth

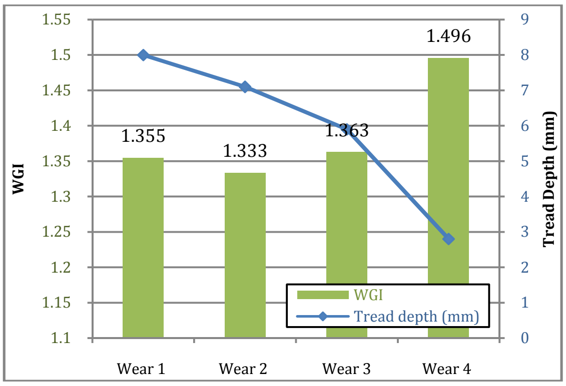

Figure4: Wet Grip Index with Different Tread Depth of SRTT16"s

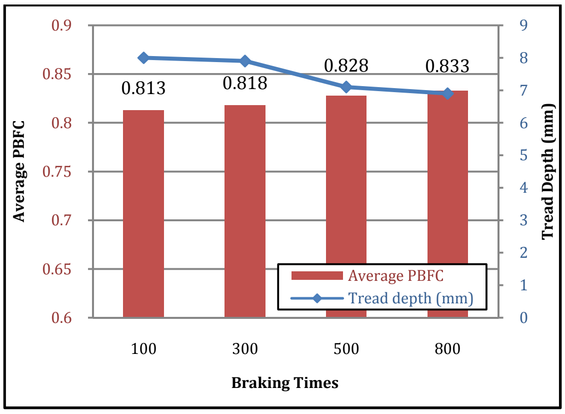

Figure5: Average PBFC of SRTTs with Different Braking Times

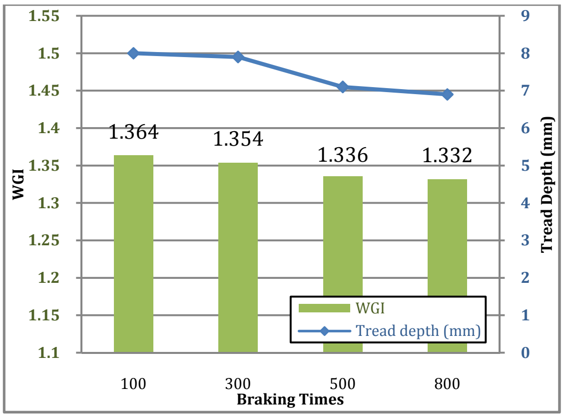

Figure6: Wet Grip Index with Different Braking Times of SRTT16"s

3.2 Surface Friction Factor Analysis

There is some variation in friction on surface, so each test run should be made at the same spot on the testing according to the regulation. In order to review the effect of surface friction factor on wet grip index, the wet grip test is performed at several test positions with different wetted frictional properties of the surface using four test tyres. Wetted frictional properties are measured by using the two methods (British Pendulum Number Method and ASTM E 1136 Standard Reference Test Tyre Method). Test Tyres involved in the test program are such as Table 5.

Table5: Specification of Test Tyres

ID	Usage	Size
Test Tyre A	Summer Tyre	225/40ZR18
Test Tyre B	All Season Tyre	P205/65R16
Test Tyre C	All Season Tyre	205/65R15
Test Tyre D	Summer Tyre	245/45ZR18

Average peak braking force coefficients of five test Tyres are shown in Fig. 7. Wet grip index of five test tyres is shown in Fig. 8. As friction of test surface increases, both average peak braking force coefficients of SRTT and test tyre increase in proportion. The wet grip index change very little. In the case of Test tyre B, wet gip index is increases by 2.5% as maximum.

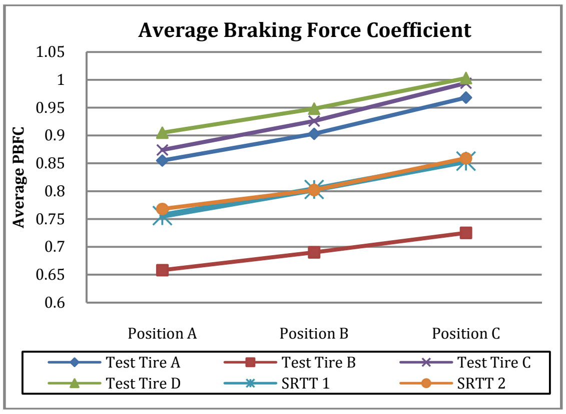

Figure7: The Effect of Surface Friction on PBFC

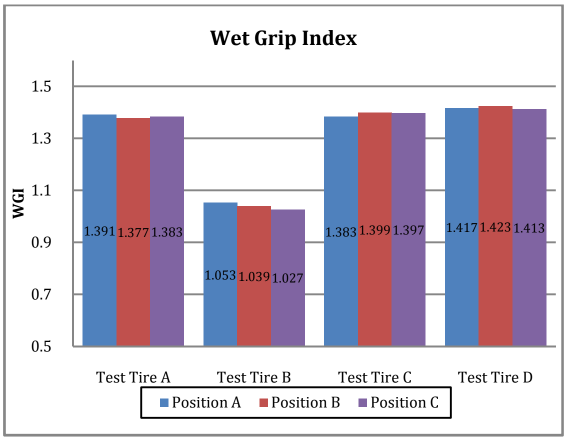

Figure8: The Effect of Surface Friction on Wet Grip Index

3.3 Static Load Factor Analysis

The test static load is defined as 75±5 % of the test tyre load capacity according to the regulation. Wet grip test of three test tyres is performed in 3 conditions of static load (70%, 75% and 80%) to research on the effects of test static load. Wet grip test results are shown in Fig. 9 and Fig. 10. As static load increases by 10% (from 70% to 80%) of tyre load capacity, both average peak braking force coefficient of SRTT and test tyre are decreased. But wet grip index of all test tyres increase little. In the case of Test tyre C, wet grip index increases by 2.3% as a maximum. It is considered the effect of static load on wet grip index is low.

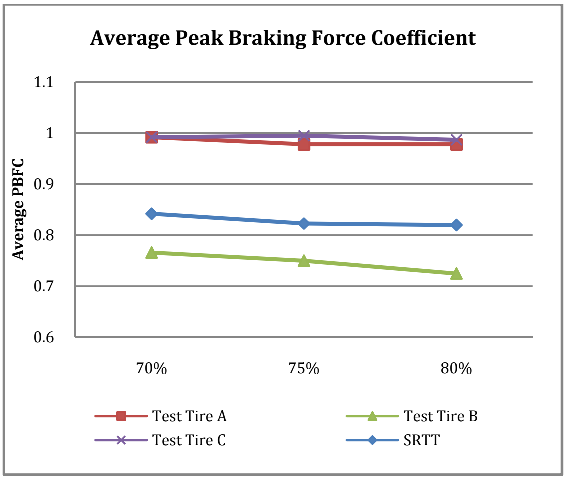

Figure9: The Effect of Static Load on Braking Force Coefficient

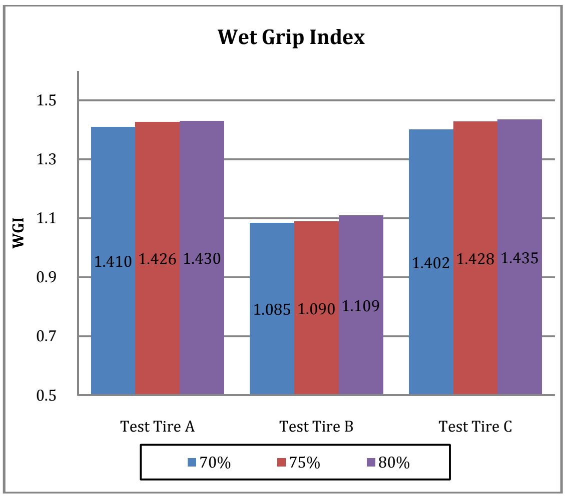

Figure10: The Effect of Static Load on Wet Grip Index

3.4 Water Depth Factor Analysis

Wetting condition is defined as water depth of 1.0±0.5mm according to the regulation. Wet grip test of three test tyres is performed in 2 conditions of water depth (0.5mm and 1.0mm) to review the effect of water depth. Test results are shown in fig. 11 and fig. 12. As the water depth increases 0.5mm (from 0.5mm to 1.0mm), both average peak braking force coefficient of SRTT and test tyre are decreased. But wet grip index of all test tyres is increases little. In the case of Test tyre C, wet grip index is increases by 1.1% as a maximum. It is also considered the effect of water depth on wet grip index is low.

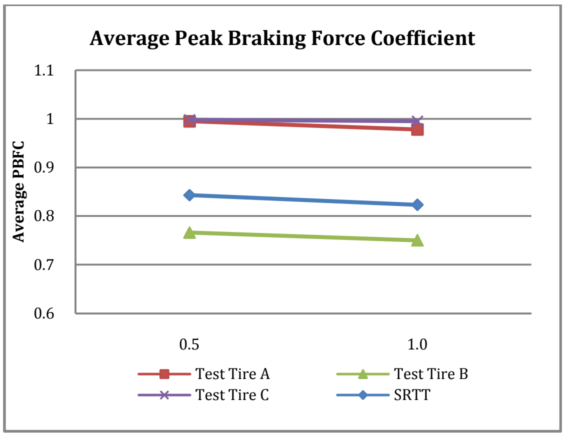

Figure11: The Effect of Water Depth on Braking Force Coefficient

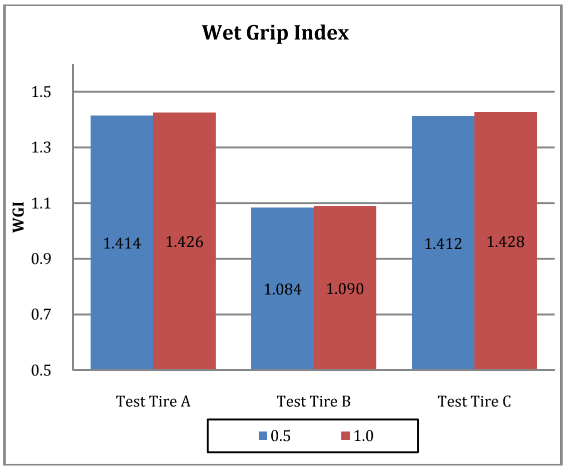

Figure12: The Effect of Water Depth on Wet Grip Index

4 Conclusion

In this paper, Uncertainty factors of wet grip index and their effect on the wet grip index were analyzed using a design of experiments. There are uncertainty factors such as SRTT, surface friction, static load, water depth, etc in test method. When the uncertainty factors are varied within the test regulation conditions, Results of the wet grip index are analyzed. The results are as follows.

- As friction of test surface increases, both average peak braking force coefficients of SRTT and test tyre increase in proportion. Wet gip index is increases by 2.5% as maximum. It is considered the effect of surface friction in the frictional condition required by the regulation on wet grip index is low.
- When the braking times rise (from 100 to 800 braking times), average peak braking force coefficient of SRTT16" with similar tread depth (7.1mm ~ 8mm) increases about 2.4% and wet grip index calculated by this SRTT16" is decreased about 2.3%. It is considered the effect of SRTT16"s with different braking times on wet grip index is low.
- But average braking force coefficient of SRTT16" with tread depth of 2.8mm is very low. Effect of this tread depth on wet grip index is high. SRTT16" s with tread depth of 5mm or lower may influence test results. When wear influences the test results, the use of the tyre shall be discontinued.
- As static load increase 10% (from 75% to , wet grip index is increased by 2.3% as maximum, It is considered the effect of static load on wet grip index is low
- As water depth increases from 0.5 mm to 1.0 mm, wet grip index is increases by 1.1% as maximum. It is also considered the effect of water depth on wet grip index is very low.

Effect of each uncertainty factor is not significant. However as effects of these factors are combined, it is considered that those effects on wet grip index are significant. To reduce the effects of uncertainty factors, wet grip test should be performed by mean values of test conditions in regulation [2], [3]. In the future, to ensure the reliable wet grip index, more studies about the effect of wet grip index is necessary on a variety of test conditions under more precise test conditions.

Acknowledgments

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