QUANTIFICATION OF THE ROAD ADHESION PROPERTIES BY OPTICAL METHOD

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The paper is the result of continuation to measure the total projection dealing with the determination of adhesion of the tires with the road. There is proposed and tested a method that could be useful for online determination of adhesion properties and the resulting increase safety and smooth operation. The chosen method consists in indirect optical measurements. This method is carried out to measure on dry, wet and snow and ice-covered roads. The result is a statistical evaluation along with a graphical representation of the frequency histograms for all individual shades and design surfaces for use in practice.

tire; road; adhesion coefficient; shade and design surface

INTRODUCTION

The road safety issues are gradualy, gaining more attention all around the world. As the consequences of the traffic accidents, more than 1.2 million people is dying annually. From 20 to 50 million are injured. In the most of the countries the mortality is growing more rapidly than percentage of injuries. Without rapid action, by 2030 we should expect roughly 2.4 million deaths each year and the death in road accidents will represent more than 20% of all deaths – worldwide. It is clear that we have to act immediately. In many countries, achieving the material damage caused by accidents roughly 1.5 percent of GDP (B a c h m a n n , 1999). This problem must begin to be solved.

To determine the adhesion properties of the tire and the road surface is very challenging aspect both in terms of instrumentation testing and in terms of test spaces. Measurement of adhesion characteristics of the tire is carried out in the longitudinal direction, particularly when evaluated breaking capability of the vehicle. Furthermore, in the lateral direction, which indicates the possibility of vehicles driving through a curve or other maneuvering movements, respectively (Z a d á k , 2011). Neither in the literature nor in practice is mentioned any method or apparatus, which could diagnose the coefficient of adhesion in normal operation and on-line processing results.

We select the indirect method of measurement – optical one. The aim will be to identify and verify the correlation between the hue of the road surface and its adhesion properties. To establish criteria for the quantification of various hues of road surfaces is a main task of this article.

MATERIAL AND METHODS

For basic authentication method chosen, we chose an asphalt surface, which occurs as rounded statistics ŘSD (T h e C z e c h D i r e c t o r a t e o f R o a d s a n d H i g h w a y s) (Table 1) nearly 99% on our roads.

To measure by a camera with which panned the road surface. Each frame is analyzed by Adobe Photoshop and processed statistically. He used the additive RGB color model. The whole image is converted into black-blue spectrum (0–255, black-blue). The image is divided into individual pixels and each pixel is assigned a number, with which it was also counted. The result is a count histogram of colors hue. Individual data were statistically processed and important for us are the characteristics of random variables: mean, standard deviation and median. A detailed description of the methods of image analysis is presented in Z a d á k , P e t e r k a (2011).

Measurements conducted on the selected surfaces of a road. Images are continuously carried out within a few days under selected suitable climatic conditions. Measurements were done in the afternoon. The vehicle speed was always constant and was chosen to 50 km/h (31 mph). Images are made using flash.

Measurements on dry roads

In total, approximately 300 pictures were recorded and processed. In the first phase of exploration we randomly selected 100 images that were further investigated and statistically evaluated. The remaining images are significantly different from average.

To show a selected slide dry surface (Fig. 1) was selected. The resulting frequency distribution analysis of the image color hue (Fig. 5).

Table 1. Overview lengths of roads under cover of the roadway (year 2010)

No.	Type of road	Highway	Class I off highway	Class II	Class III	Total
		(length km)				
1	paved	0	5	105	268	378
2	concrete	37	12	35	22	107
3	asphalt heavy	327	4 953	5 932	4 744	15 956
4	asphalt medium	0	784	7 660	21 203	29 647
5	asphalt light	0	32	784	7 633	8 449
8	no designation	49	31	97	115	291
	total	413	5 817	14 613	33 985	54 828

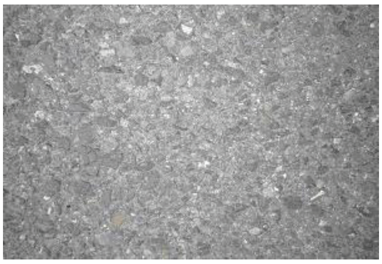

Fig. 1. Image of dry surface

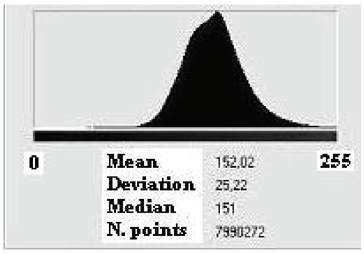

Fig. 5. The histogram of the counts for dry surface

Fig. 2. Image of wet surface

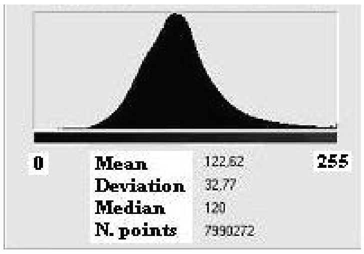

Fig. 6. The histogram of the counts for wet surface

Fig. 3. Image of snow covered surface

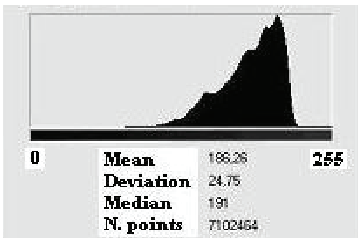

Fig. 7. The histogram of the counts for snow covered surface

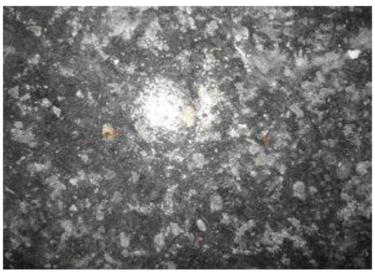

Fig. 4. Image of ice covered surface

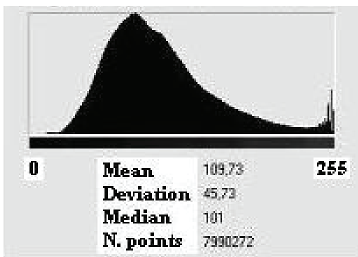

Fig. 8. The histogram of the counts for ice covered surface

Measurements on wet roads

In total we recorded and processed approximately 250 images. We randomly selected 100 images that were further investigated and statistically evaluated.

To show a selected slide we have chosen wet surface (Fig. 2). The resulting frequency distribution analysis of the image color hue (Fig. 6).

Measurement of snow-covered roads

In total we recorded and processed approximately 120 images. We randomly selected 100 images that were further investigated and statistically evaluated.

To show a selected slide we have chosen snow covered surface (Fig. 3). The resulting frequency distribution analysis of the image color hue (Fig. 7).

Measurement of ice-covered roads

Before measuring the roadway while driving was covered with a layer of water. At night it had frozen. We made 36 images. To show a selected slide we have chosen ice covered surface (Fig. 4). The resulting frequency distribution analysis of the image color hue (Fig. 8).

RESULTS AND DISCUSSION

Measurements on dry roads

The histogram of the counts (Fig. 5) illustrates that the hue distribution and their width is roughly the same. There are no extreme values outside the mean. Mean hue is 152.02. The standard deviation has a value of 25.22. The median is the 151. In the interval < 126.8, 177.24 > 68.3% of the total of all hues.

Results of the statistical evaluation of selected photos are for convenience listed in the Table 2. Median hues in photos varies in the interval < 146.18, 160.18 >. The standard deviation varies < 22.72, 27.80 >. The resulting mean average value of all measurements is 152.93. The variance of mean values is 10.09. Standard deviation of mean values is 3.18.

The median is in the range of < 145, 159 >. The resulting average median is 152.15. Scattering of medians is 10.73. Median standard deviation is 3.28. The difference between the average mean values and medians of 0.5%.

Measurements on wet roads

The histogram of the counts (Fig. 6) illustrates that the hue distribution and their width is roughly the same. There are no extreme values outside the mean. Mean hue is 122.62. The standard deviation has a value of 32.77. The median is the 120. In the interval < 89.85, 155.39 > 68.3% of the total of all hues.

Results of the statistical evaluation of selected photos are for convenience listed in the Table 2. Median hues in photos varies in the interval < 103.06, 138.10 >. The standard deviation varies between 29.70 and 38.85 >. The resulting mean average value of all measurements is 124.42. The variance of mean values is 26.14. Standard deviation of mean values is 5.11.

The median is in the range of < 97, 134 >. The resulting average median is 120.18. Scattering of medians is 24.33. Median standard deviation is 4.93. The difference between the average mean values and medians is 3.5%.

Measurement of snow-covered roads

The histogram of the counts (Fig. 7) illustrates that the hue distribution and their width is roughly the same. There are no extreme values outside the mean. Mean hue is 186.26. The standard deviation has a value of 24.75. The median is the 191. In the interval < 161.51, 211.01 > 68.3% of the total of all hues.

Results of the statistical evaluation of selected photos are for convenience listed in the Table 2. Median hues in photos varies in the interval < 169.40, 207.57 >. The standard deviation varies < 19.59, 31.75 >. The resulting mean average value of all measurements is 181.38. The variance of mean values is 94.8. Standard deviation of mean values is 9.74.

The median is in the range of < 173, 210 >. The resulting average median is 184.99. Scattering of medians is 106.03. Median standard deviation is 10.3. The difference between the average mean values and medians of 2%.

From the results it is clear that the individual images differs significantly mean and medians. This is due to heterogeneous snow cover. On some sections of the road after car passing surface began to appear.

Measurement of ice-covered roads

The histogram of the counts (Fig. 8) illustrates that the hue distribution and their width varies considerably. There are extreme values outside the mean. This is essentially a very bright area of the camera flash. Mean hue is 109.73. The standard deviation has a value of 45.73. The median is the 101. In the interval < 64, 155.46 > 68.3% of the total of all hues.

Results of the statistical evaluation of selected photos are for convenience listed in the Table 2. Median hues in photos varies in the interval < 97.91, 118.5 >. The standard deviation varies < 41.64, 48.4 >. The resulting mean average value of all measurements is 109.11. The variance of mean values is 20.74. Standard deviation of mean values is 4.55.

Table 2. Statistical results of measured surface

Surface	Interval of values		
	mean	standard deviation	median
Dry	< 146.18; 160.18 >	< 22.72; 27.80 >	< 145; 159 >
Wet	< 115.54; 138.10 >	< 29.70; 38.85 >	< 111; 134 >
Snow	< 169.40; 207.57 >	< 19.59; 31.75 >	< 173; 210 >
Ice	< 97.91; 118.50 >	< 41.64; 48.40 >	< 90; 112 >

The median is in the range of < 90, 112 >. The resulting average median is 101.39. Scattering of medians is 3.4. Median standard deviation is 1.84. The difference between the average mean values and medians of 7.5%. This large difference is due to reflective properties of ice on road surfaces.

The results obtained from measurements are grouped for clarity in Fig. 9, which contains the intervals of tone frequency histograms for each surface.

Each main groups histograms differ significantly do not overlap. Partially overlapping graphs are for the wet and ice covered roads only. To identify each individual road surface the median values from the pictures are sufficient. For the critical area between the wet and ice-covered surfaces it is necessary to use another statistical factor, standard deviation. We decided to choose the value of standard deviation equal to 40.2. This is calculated as to the arithmetic mean of minimum deviations observed in the icy roadway and the maximum value of deviation for the wet surface.

It is now necessary for all sorts of areas assigned the true coefficient of adhesion and finaly to perform a verification. These measurements are performed on a specially modified trailer. Results will vary mainly with different types of tires, and even individual producers.

CONCLUSIONS

This paper deals with the selected optical method for evaluating the coefficient of adhesion. For the measurements we selected asphalt surface, which occurs on our roads almost in 99%. The following surfaces were selected which affect the most the coefficient of adhesion. During measuring of day for dry, wet and ice or snow covered roads. Evaluated with color photos that are used to evaluate statistical parameters. The results confirm the assumption that this method can quantify the various surfaces. After capturing an image and analysis, we are able to determine into which group the assigned picture belong. After verification of the results, this method can be used for on-line evaluation of the current stopping distances and the resulting safe spacing between vehicles. It is possible to cooperate with already existing or planned security systems. Interoperability of these systems should ensure that cars will move along the roads safely without a high risk of accidents and traffic smoothness should improve as well. The Future Laboratory studies (Year 2038, 2011) may lead to changes of law in 2038 and the man driving will be illegal. Simply because at the moment over 90% of accidents cause by human errors, and so the transition to a fully automatically controlled cars have significantly lower accident rate and thus the number of injured and death rate on roads. This method may be very helpful in the future.

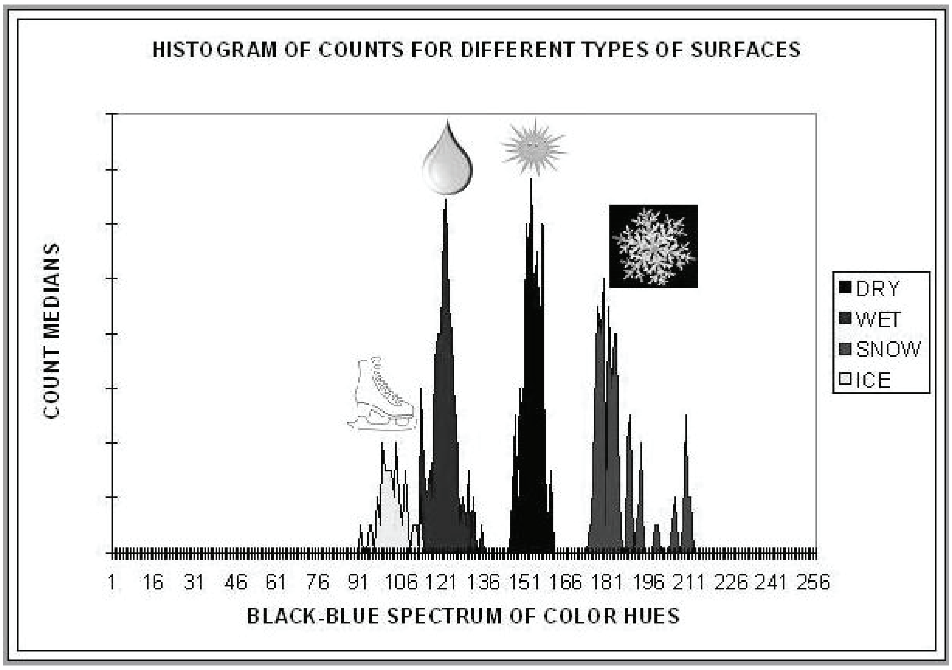

Fig. 9. Histogram of counts for different types of surfaces

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Kvantifikace adhezních vlastností vozovky optickou metodou

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Příspěvek je výsledkem dalšího pokračování měření do celkové mozaiky zabývající se problematikou stanovení adhezních vlastností pneumatik s vozovkou. Je zde navržena a prozkoumána metoda, která by mohla být využitelná při on-line stanovení adhezních vlastností a z toho vyplývající zvýšení bezpečnosti a plynulosti provozu. Zvolenou metodou je optické nepřímé měření. Touto metodou jsou provedena měření na suché, mokré a sněhem a ledem pokryté vozovce. Výsledkem je statistické vyhodnocení spolu s grafickým znázorněním histogramů četností jednotlivých odstínů pro jednotlivé povrchy a návrh k využití v praxi.

pneumatika; vozovka;součinitel adheze;barevný odstín povrchu vozovky

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