ANALYSIS OF BRAKING MARKS LEFT BY VEHICLES EQUIPPED WITH ABS WITH IR SPECTROSCOPY – DIFFERENT TYPES OF ASPHALT

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Abstract

Detailed analysis of literature showed that there is no method that can be used in order to investigate skid marks left by vehicles equipped with ABS. Authors decided to identify braking trace by using IR spectroscopy. Preliminary studies have been performed and results were promising. Due to that fact authors decided to conduct detailed research where the influence of various factors on the possibility of revealing breaking traces would be taken into account. This article is the first in a series of articles taking into account the influence of various factors on the possibility of revealing breaking marks using IR spectroscopy. In this article the influence of the type of asphalt was studied. Authors conducted tests with the most popular types of asphalts used for the wearing course. 100 samples from 5 different types of asphalt were prepared. Each sample was measured 3 times to create its spectrum. The results were analyzed thoroughly using the dedicated SpectraGryph software. The analysis showed that for 4 out of 5 types of tested asphalt, the braking traces were visible at a wavelength of approximately 11 500 nm. Only for the rubberized asphalt there weren't possibility to reveal skid mark.

Keywords: IR spectroscopy, accident investigation, skid marks

1. Introduction

The problem with the visibility of brake marks has been known from the very beginning of the ABS system and it is unsolved to this day [15, 17]. We decided to try to use IR spectroscopy to solve this problem. IR spectroscopy is a technology used to identify substances [3, 14,16] and, according to our opinion, it will be possible to use it to identify

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the braking trace at the scene of a road accident. Preliminary studies have been performed. The results was presented in The Archives of Automotive Engineering - Archives of Automotive Engineering Vol. 84, No. 2, 2019 Analysis of braking traces on the road accident site using IR spectrophotometry [4]. Due to the promising results in preliminary studies we decided to check in detail the influence of various factors on the possibility of revealing breaking traces using IR spectroscopy. For this purpose it is planned a series of tests taking into account the influence of various factors on the possibility of revealing breaking traces. We decided to examine the influence of each element on the visibility of the skid marks separately. In the beginning we decided to verify the influence of the type of asphalt. Results are presented in this article.

2. Literature review

Braking system equipped with the ABS system improves the road safety [8, 9]. At the same time, ABS caused difficulties in the reconstruction of road accidents [13, 19].There has been a problem with the visibility of skid marks since vehicles with ABS were mass produced [1, 2, 12]. So far, two different ways to reveal skid marks have been proposed. These are:

- Image Refinement Methods [20];
- Thermovision method [6];

All above methods were precisely described in first article, where we proposed completely new method that based on IR spectroscopy [4]. No new research results have been published since then. As mentioned in the introduction we decided to examine the influence of each element on the visibility of the skid marks separately. During this series of tests, the influence of the type of asphalt on the possibility of revealing a skid mark was analysed. In road construction asphalt is a mineral mix that contains a set of stone components (chippings, dust, filler), binder and addings that improve final characteristic [18]. Mineral-asphalt mixtures are divided into:

- compact;
    - asphalt concretes;
    - stone mastic asphalt;
    - hot rolled asphalt;
    - mixtures with discontinuous grain size;
- not compact;
    - mastic asphalt.

The bituminous pavement in cross-section is not homogeneous. It contains 2 or 3 layers made of different kind of asphalt that provides different functions [10, 11]. The main layers of the asphalt pavement are:

- wearing course - task of the wearing course is to provide the road surface with appropriate surface features, such as roughness, which are responsible for the driving comfort and safety, and to protect the lower layers of the road against weather conditions;
- binder course - task of the binder course is to transfer the stresses generated during the pavement loading by vehicle traffic to the layers below. There are often maximum stress in this layer;

- base course - it is the foundation of the entire structure. In terms of the type of mixture, it is similar to the binder course, however its composition includes chippings with a larger grain size.

Due to the main purpose of the research, i.e. revealing the braking traces at the road accident site, only the wearing course, i.e. the layer where the traces are left at the time of the accident, were taken into account in the tests. The following types of asphalt are used for wearing courses:
- thin asphalt overlay;
- stone mastic asphalt;
- porous asphalt;
- rubberized asphalt;
- foamed asphalt.

3. Preparing samples

We prepared 20 samples of each type of asphalt used in the construction of the wearing course. 100 samples were analysed in total. Due to the high sensitivity of the IR spectroscopy method it was not possible to use samples collected in field conditions due to their contamination with many types of substances such as oils, fuels, plant debris. There was also the possibility that the samples had invisible braking traces left by previously passing vehicles. A proprietary multi-step method of sample preparation was developed for this reason. The first step of preparing samples was designing and manufacturing a punch that enables plastic forming. Then, the asphalt samples were heated to 80°C and formed using the above-mentioned punch and a press with a pressure of 20 tons to compact the sample, similar to the technology of making the asphalt layer on the road. As a result dimensionally normalized cylindrical samples were obtained. The diameter of the samples was 25 mm. The height of the samples was in the range of (25-35) mm depending on the amount of asphalt. Then the measuring surfaces of the sample (base of the cylinder) were washed with a ethoxylated alcohol in order to remove any contamination from the sample production process. Next, the skid marks was laid down on every 10 samples of each asphalt type. The condition of that process was controlled. In order to apply skid marks under controlled conditions, a test stand was built. Its schematic drawing is shown in Figure 1. It consists of 7 main components. The motor and the belt transmission drive the car wheel mounted on the frame. The car wheel drives the asphalt wheel by friction. The pressure necessary to generate the friction force with a value corresponding to the pressure of the wheel on the road is generated by the hydraulic cylinder. Slip between the car wheel and the asphalt wheel is generated by a disc brake braking the asphalt wheel. The asphalt wheel consists of a steel rim covered with an asphalt. Inside there is a mechanism that allows mounting an asphalt sample. The mechanism automatically extends and retracts the sample so that only one layer of the skid mark is applied to the sample For this series of tests the braking marks were laid down with a 30% wheel slip corresponding to braking with an active ABS system. The velocity of car wheel was 40 km/h. The pressure force was 4000 N. An example of the sample is shown in Figure 2.

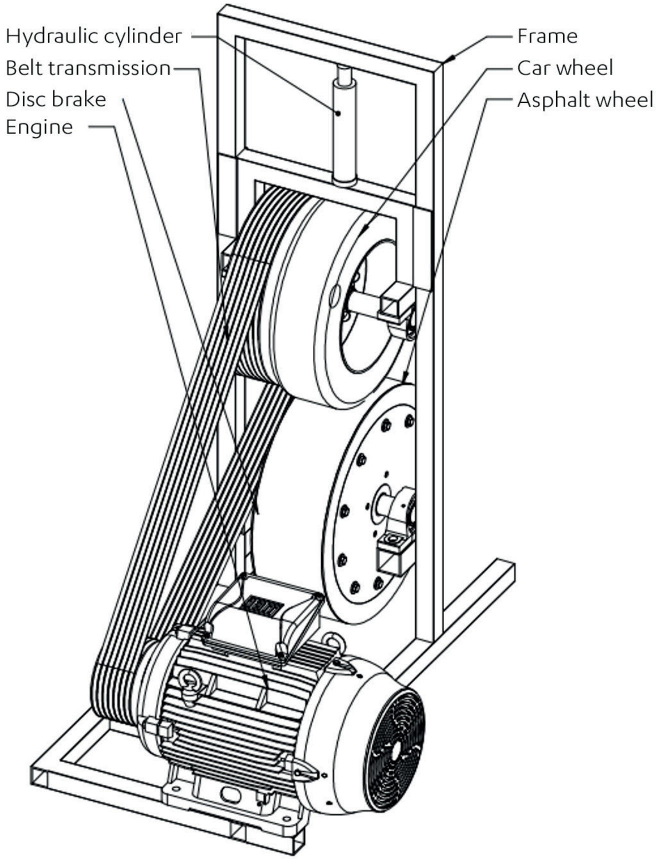
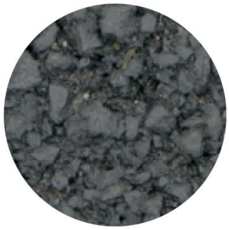
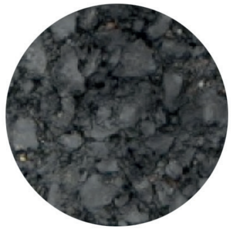
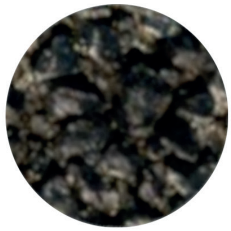
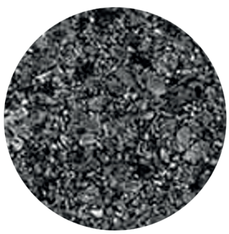
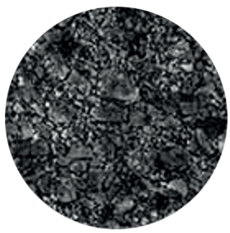
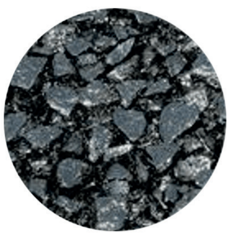


Fig. 1. Test stand allowing the application of skid marks in controlled conditions

Fig. 2. The sample prepared for the application of the braking trace

The front surfaces of the exemplary samples are presented in the Table 1.

Tab. 1. Exemplary samples

Asphalt type	Surface without skid mark	Surface with skid mark
Thin asphalt overlay		
Stone mastic asphalt		
Porous asphalt		
Rubberized asphalt		
Foamed asphalt		

Due to the relatively high value of the wheel slip at which the braking marks were applied, there were poorly visible traces of skid marks on most of the samples surface. Traces are the most visible when the sample surface was observed at a low angle. It should be emphasized that under real conditions, during braking, the wheel slip value changes within range (5-30)%. The lower slip value, the more difficult organoleptic evaluation of the braking trace is.

A series of measurements were made at 3 randomly selected points of the sample. The sample was mounted to the measuring table by using the standard spectrophotometer equipment, i.e. a pressure arm with a screw. The downforce was limited by a clutch in the screw handle. Measurements were made with a resolution of 128 and a measuring gap width of 2 mm. Such parameters lengthened the time of the measurement, but allowed to obtain high accuracy. The relation between the absorption and the electromagnetic wavelength was obtained from each measurement. In order to prepare the measurement results for further analysis, all functions obtained for a given type of asphalt were averaged. This means that 10 samples with a trace and 10 without a trace were prepared for each type of asphalt and three measurements were made for each of them, each averaging was carried out for 30 functions at once. All operations were performed by using the specialized software SpctraGryph [7], which is used to process spectra data. Before the averaging operation, the results were normalized, i.e. the scale was adjusted to be able to compare the obtained values. It was a necessary procedure due to the fact that the strength of the measurement signal was different for each sample and largely dependent on the quality of the adherence of the sample to the measuring table. The next step was to subtract the obtained results for a given type of asphalt. The averaged results of the samples without braking traces were subtracted from the averaged results of the samples with the braking traces. In this way it was received the differential spectrum. The resulting spectrum shows the separated braking trace.

4. Results

The diagrams below show the results obtained for each type of asphalt.

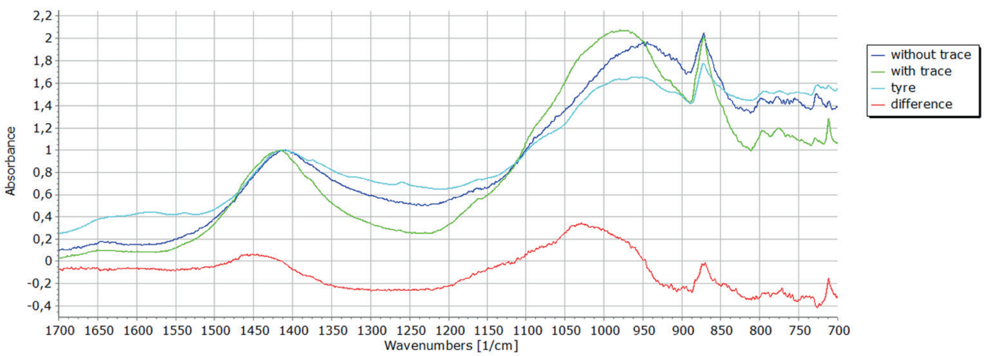


Fig. 3. Result for the thin asphalt overlay

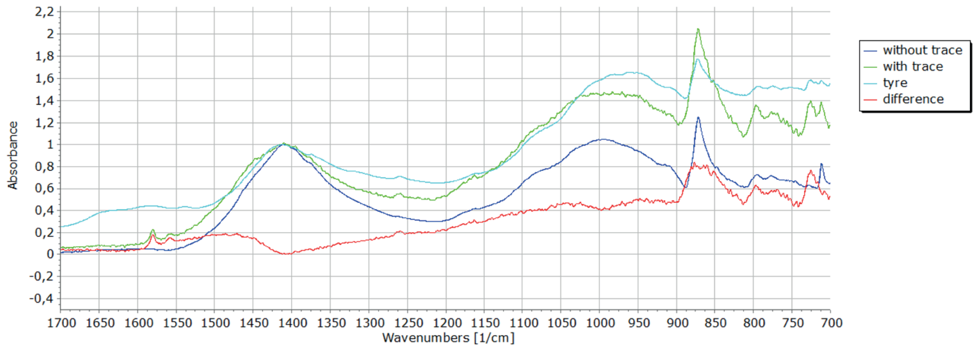


Fig. 4. Result for the stone mastic asphalt

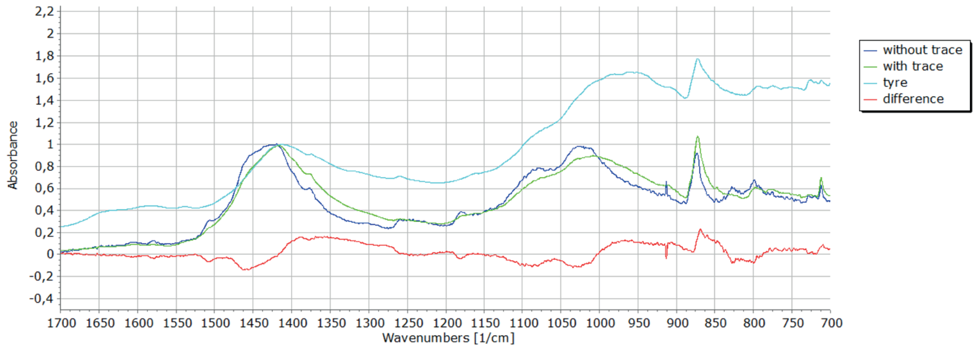


Fig. 5. Result for the porous asphalt

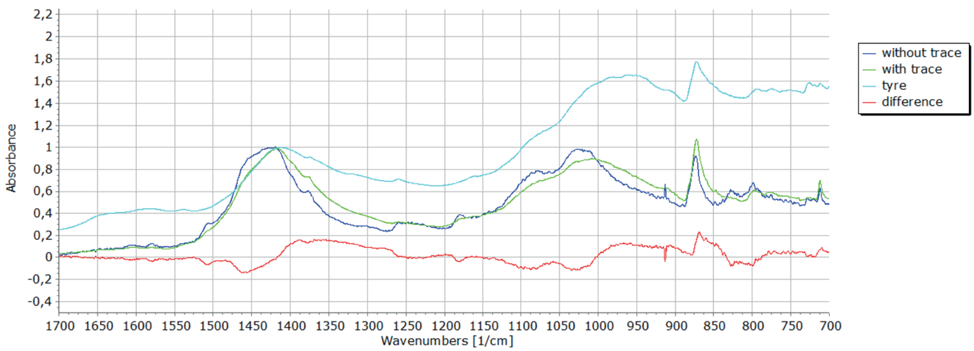


Fig. 6. Result for the rubberized asphalt

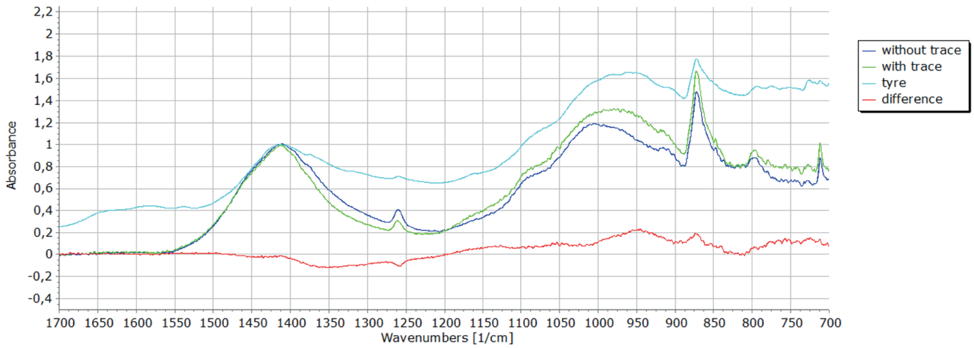


Fig. 7. Result for the foamed asphalt

5. Results discussion

Figures 3 to 7 show the obtained absorption results. All charts for different types of asphalt are very similar to each other. There are the same peaks for similar wavelengths. The absorption differences are slight and result from different chemical compositions of the tested asphalts. Function sequence in microscopic terms depends on the frequency of resonance vibrations of the molecules included in the sample. Therefore, knowing the values of these frequencies, it is possible to identify some characteristic functional groups. For our purposes, it is not necessary to define the substance exactly. It is sufficient to indicate the wavelength at which the difference is clearly visible. The most characteristic point where that difference is clearly visible is located at the wavelength of 872 cm-1, i.e. around 11 500 nm. This is the mid-infrared range. At this value, the tire spectrum shows a characteristic increase in the absorption value. Local extremes were found on most of the differential spectra at this wavelength. It means that on differential spectra skid marks were found. However, these differences do not differ significantly from each other, which is confirmed by the similar waveforms of braking traces. Results were the least promising for rubberized asphalt. For the expected wavelength, the differential spectrum had not visible local extreme. The reason for this is the composition of the asphalt. It is an asphalt where rubber waste from tires is used. That caused that the rubber waste [5] coincides with lied down braking trace, and thus there is the same absorption at the wavelength of 872 cm-1.

6. Conclusion

Based on the research, it can be concluded that for 4 out of 5 types of tested asphalt, the braking traces are visible at a wavelength of approximately 11 500 nm. Only for the rubberized asphalt there isn't possibility to reveal skid mark. Conducted research confirmed that it would be possible to investigate skid marks left on the scene by vehicles equipped with ABS systems on most of the types of asphalt. In future research, the influence of other elements on the possibility of revealing skid marks using IR spectroscopy, such as the type of tire or the pressure force, will be analyzed. If positive results are obtained, it should be possible to construct a device enabling investigation of skid marks by forensic technicians. Due to the great potential of the method, as well as market demand itself, the authors of the article intend to continue their research.

7. References

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