JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
TOME VI (year 2008), FASCICULE 2, (ISSN 1584 – 2665)

AN ATTEMPT TO IDENTIFY THE DUST FORMED BY THE FRICTIONAL ELEMENTS OF VEHICLES IN ROAD CONDITIONS

Robert WIESZAŁA[1], Andrzej WYCIŚLIK[2]

[(1)]THE SILESIAN UNIVERSITY OF TECHNOLOGY, FACULTY OF TRANSPORT, DEPARTMENT OF AUTOMOTIVE VEHICLE SERVICE, GLIWICE, POLAND
[(2)]THE SILESIAN UNIVERSITY OF TECHNOLOGY, FACULTY OF MATERIALS SCIENCE AND METALLURGY, DEPARTMENT OF TECHNOLOGICAL PROCESSES ADMINISTRATION, SECTION OF TECHNOLOGY AND ENVIRONMENT MANAGEMENT, GLIWICE, POLAND

Abstract:
One of the crucial dangers caused by car exploitation, connected with air pollution, is the dust emission. The chemical composition of the dust formed during car exploitation, due to the variety of aspects, is differentiated and hard to define both in terms of quality and quantity. The dust formed and kindled by the movement of the cars, consists, apart from neutral elements, also of harmful substances, coming from the burning of fuels as well as from grinded road surface, tyres, frictional brake lining and other car elements. From the conducted granulometric analysis of the exploitation dust, coming from the frictional elements of the car one can conclude that over 88% of the elements is included in a fraction of up to 56 μm. The most harmful to human fraction that is under 20 μm forms 17 % of the whole in the exploitation dust. One can cautiously conclude that elements of roadside dust with a diameter up to 56 μm are formed mainly because of car exploitation. Therefore there is no need to conduct detailed and expensive research of the dust chemical composition in order to define the amount of emission from the cars in road conditions.

Key words:
Heavy metal particles, road dust, brake dust,

INTRODUCTION

One of the crucial dangers caused by car exploitation, connected with air pollution, is the dust emission. The problem showed up in recent years with the rise in number of the cars used on the roads. The chemical composition of the dust formed during car exploitation, due to the variety of aspects, is differentiated and hard to define both in terms of quality and quantity [1, 2]. The main source of dust formation in the process of car exploitation are certain parts of the car: braking system, tyres and clutch plates [3]. Although one can find in literature some general data on the topic, there are no detailed analysis of the size of dust elements, getting out of the car depending on the changing exploitation conditions such as speed, braking power and driving dynamics. There are also no law regulations concerning the amount of dust emission from cars. The existing limitations concern only the smokiness of the car fumes for engines ZS [4].

The dust formed during car use can be divided into two types: fine-grained dust and coarse-grained dust [4, 5]. Fine-grained dust is defined as small elements of solid with a diameter of less than 50μm [4]. Coarse-grained dust is defined as small elements of solid with a diameter of more than 50μm. Moreover, here the boundary size does not unambiguously decide if the dust floats or settles. It happens sometimes that dust with bigger diameter floats in the air while the smaller diameter dust elements fall on the ground surface. Lots of aspects have influence on the given case, such as precipitation, chemical composition and physical properties of the dust, etc. During car exploitation both coarse-grained dust and fine-grained dust is formed. Mostly, however, the dust is of a fine-grained type.

Although in the topic range of fumes emission and noise there are law regulations limiting the amount of the emission, methods of decreasing the negative influence consequences, for example by the introduction of new technologies; there are no codified dispositions and appropriate law regulations so far, which would refer to dust emission.

In published papers, usually the problems of outside dust emission coming from the car use are discussed. Most commonly in such publications the material use and exploitation use of the car elements are described and the problem of dust emission is marginalised. The problems connected with dust analysis are more complex than in case of exploitation analysis due to the variety of materials used in different types of cars. It is especially connected with braking systems. In order to define the exploitation use of the braking system that is the brake discs, break blocks, brake drums, special tests are conducted in laboratory conditions. It is necessary then to equip the machines used in tests with sample producing devices.

A lot of companies dealing with the production of the braking elements are currently on the market. That is why the differences connected with the chemical and phase composition occur in the manufactured materials and, moreover, the systematically conducted experiments and research result in introducing new material, for example various composites [6]. It makes though the identification of braking dust among the general amount of road dust difficult, and at the same time complicates defining the influence of exploitation factors on the level of pollution. The difficulties in identification are even bigger because of material differences in each type of vehicle for example for private cars and transport vehicles [7].

The dust created and kindled by moving cars, contain, apart from the neutral elements, also elements coming from burning of fuels as well as from grinded road surface, tyres, frictional brake lining and other car elements [8]. Such dust also contains a lot of substances harmful to the environment and health of living organisms. These are chemical elements of heavy metals included in the frictional elements, complex organic chemical compounds (among other, the multi-cyclic aromatic hydrocarbons and their derivatives), and asbestos, which may be found in many older vehicles [9,10].

In order to determine the influence of the exploitation factors on the level of dust pollution, it is necessary to educe from the whole of the road dust the elements which come from car use. In order to achieve this research was conducted to enable to educe the exploitation dust from the previously collected road dust.

THE EXPERIMENTAL PART

1. WAYS OF EXPLOITATION DUST COLLECTION

The elements of dust were collected with the used of specially adjusted car vacuum cleaner. In the place of traditional filters a filter paper was placed, which enabled to stop the dust part of the size of the grain up to 4 μm. The elements of the exploitation dust were collected during a test with the use of T-01M tester of a mandrel-disc type as well as in a car garage during the exchange repair works of the frictional elements of a car. During the research with the use of this tester 3 braking sets and 2 sets of friction clutches were examined.

1.1 RESEARCH WITH THE USE OF A MANDREL-DISC TYPE TESTER

The test elements in T-01M device type mandrel-disc were the samples in the form of mandrel and anti-sample in the form of disc placed in special holders. The samples(mandrels) were made of a material, which came from examined frictional elements of the vehicles such as brake blocks, brake shoes, and discs from disc-type friction clutches. The samples were made out of materials in the form of a mandrel with a diameter of 8mm and were marked with numbers 1,2 (brake blocks), 3 (brake shoes), 4,5 (discs from disc-type friction clutches). The rings made of the following materials: samples 1,2 brake discs, 3 frictional brake linings, 4,5 pressing clutch plate were used as anti-samples. After grinding with the use of magnetic grinder the appropriate shape and size was achieved.

1.2 THE STRUCTURE OF THE RESEARCH STAND

The testing machine T-01 M(fig.1) consists of two main sets:
- testing machine,
- measuring system.

The testing machine consists of frame, base, power unit, set of levers, set of sample mount. The most important element is the set of sample fastening. During the research a video camera from the LUMIX FZ7 digital camera was also used.

Set of sample fastening is situated in the front part of the lever and consists of a collet, which is placed inside a sleeve (4), with the use of a nut (50) and washer (56). The sleeve is attached to the lever with the use of nut (5) and washer (54) (figure below)

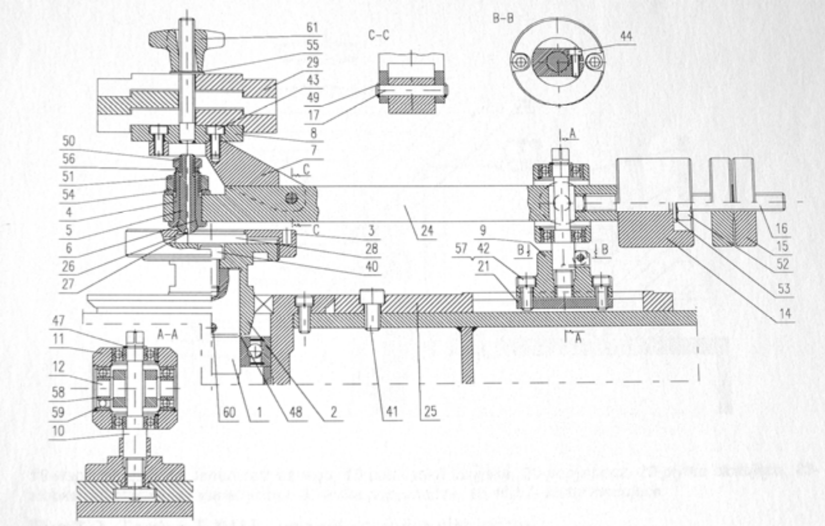

FIGURE 1. Tester T – 01M – set of levers and set of sample fastening 1 – spindle, 2 – resistance disc 3 – nut, 4 – sleeve, 5 – collet, 6 – mandrel collet 7 – cantilever 8 – dish, 9 – reduction sleeve, 10 – shaft, 11 – yoke, 12 – axis of the lever, 14 – counterweight, 15 – regulating weight, 16 – double-nutted bolt, 17 – pin, 18 – cantilever of the sensor, 19 – washer, 20 – pusher, 21,22 – blocking plates, 23 – footer, 24 – lever, 25 – base, 27 – mandrel, 28 – disc, 29 – weight, 30 – extensometer sensor.

1.3 SAMPLING OF THE EXPLOITATION DUST FROM FRICTIONAL ELEMENTS OF CARS

The intake of a pipe from a vacuum cleaner has been attached to the base(25). It was illustrated on fig.2. At the beginning of the test the vacuum cleaner was switched on and switched off only after the whole cycle of testing for one sample was over. Each time, the collected dust was placed in a polyethylene container, a new filter paper was attached and the elements of the vacuum cleaner were being rinsed in an ultrasonic rinser.

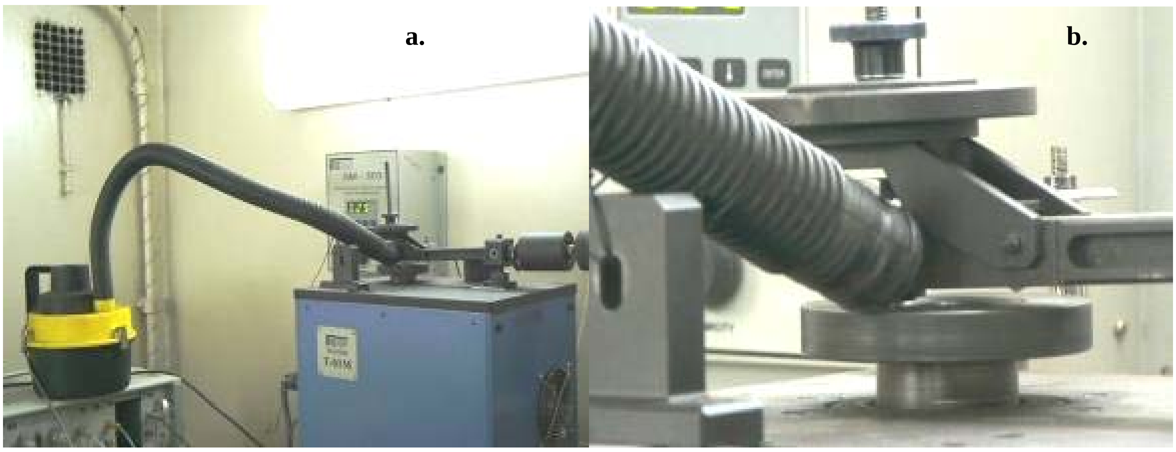

FIGURE 2. Fitting of the sampling device dust on the research station a. general view of the research station b. the place where the dust is formed and the way it is collected

1.4 THE METHODOLOGY OF THE RESEARCH CONDUCTION

The mandrel-disc type tester T – 01M enables the conduction of research with different loads and rotating speeds of anti-sample (different speeds of lost motion). The research methods with the use of tester T – 01M are not normalised and in case of the application of a programmed test cycle, the computer realises the test offered by the producer. In case of test conduction with other methods, prior to the test, one should define the work parameters for friction knot, such as the load on the contact, the speed of lost motion, time or way of friction, and the diameter of the sample as well as radius of friction. On the basis of the preliminary tests, in a proper test cycle the following parameters for the friction knot were established and they were:

For tests of category I for all samples:

1. friction path equalled 5000 [m],
2. speed of lost motion V_p = 2 [m/s],
3. the load on the contact P = 1 [N],
4. radius of friction r = 0,015 [m].

For tests of category II for all samples:

1. friction path equalled 5000 [m],
2. speed of lost motion V_p = 2 [m/s],
3. the load on the contact P = 5 [N],
4. radius of friction r = 0,015 [m].

The test cycle was conducted with the absence of lubricant. For each of the tested materials 5 measurements were conducted, so as to collect the adequate number of the dust elements.

2. THE GRANULOMETRIC ANALYSIS

In order to define the granulometric content of the exploitation dust a sieve analysis was conducted according to the procedure presented in fig.3. The dust was dried in the initial phase for 45 minutes in temperature of 50°C ± 1°C. During that period the dust was in polyethylene containers. Next the whole of the dust was weighed with measuring accuracy of two decimal places. In the next stage the dust was poured through a set of sieves with the following inside diameter of mesh 250 μm, 90 μm, 56 μm, 20 μm, using the analyser produced by Fritsch company.

Before each use, the sieves were placed in ultrasonic rinser filled with redistilled water. The shaking process of the dust lasted 45 minutes each time. After that time each fraction was poured to a separate polyethylene container and was weighed with accuracy of two decimal places. The difference between the weight of the whole dust and the weight of it after the sieve analysis was also calculated. It was assumed that the possibility of difference cannot be bigger than 1%. Bigger mistake would mean untight pile of sieves and the achieved result would be falsified. During the test the biggest mistake equalled 0.63% so it can be assumed that the analysis was conducted correctly. The achieved results for each type of fraction were written in a diagram forming in this way a granulometric curve.

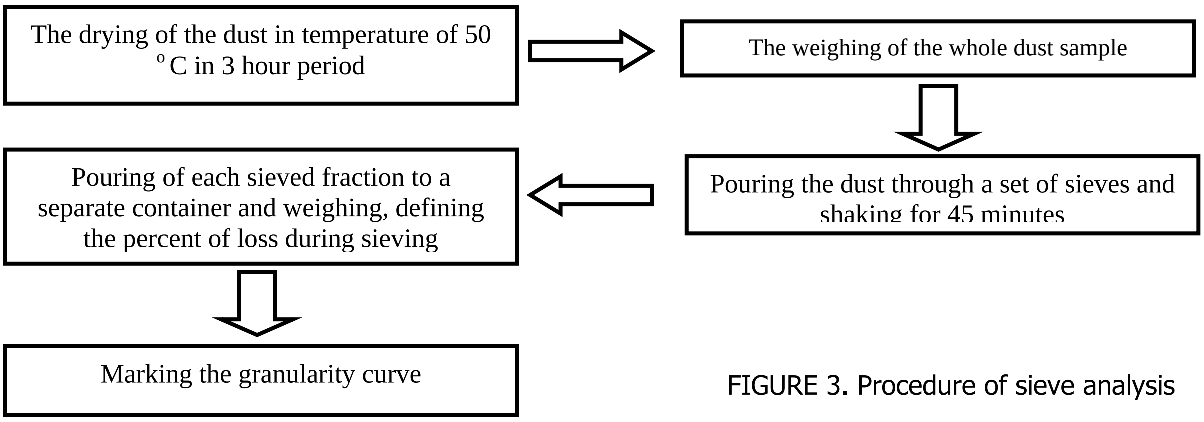

FIGURE 3. Procedure of sieve analysis

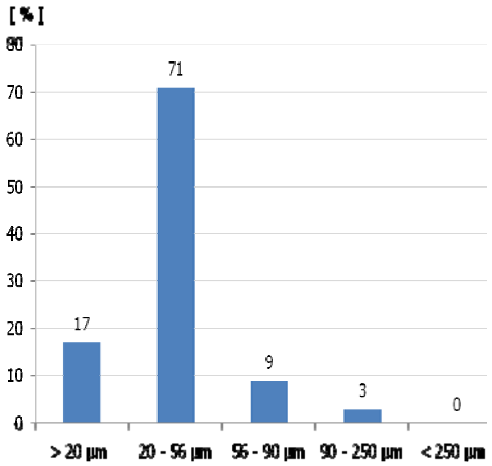

FIGURE 4. The results of granulometric analysis for elements of exploitation dust

2.1 ANALYSIS OF THE RESULTS

The achieved tests results of exploitation dust elements from frictional car elements were shown in figure 4. The example characteristics of dust coming from a car brake was shown in table 1, whereas the characteristics of road dust coming from a motorway section was shown in figure 5. The research was conducted with the use of scanning microscope SEM): S4200 (HITACHI) in the following experimental conditions: the energy of primary electron beam 15 keV, cold cathode with field emission, the intensity of absorption current 1 * 10^{-10} A. In order to take a micro-photo of the dust a signal of secondary electrons (SEM) was used. A magnification from 50x to 8000x was used. To the analysis of chemical composition of the dust a X-ray spectrometer with energy dispersion cooperating with a microscope was used (EDS): VOYAGER (NORAN, detector Si – Li, thin polymer window. During the tests a presence of such chemical elements was proved: antimony Sb, titanium Ti, strontium Sr, zinc Zn, barium Ba, chromium Cr, potassium K, and magnesium Mg.

Table 1. Characteristics of dust coming from a car brake

	Characteristic chemical elements	Granulometric layout	Characteristics
	Antimony – Sb Titanium – Ti; Strontium – Sr Zinc – Zn; Barium – Ba Chromium – Cr; Potassium – K Magnesium – Mg Aluminium - Al	less 20 µm – 17 % 20 – 56 µm – 71 % 56 – 90 µm – 9 % 90 – 250 µm – 3 % 250 µm more. – 0 %	Emission occurs temporarily in the moment of braking. The biggest consumption occurs in the moment of total car stoppage.

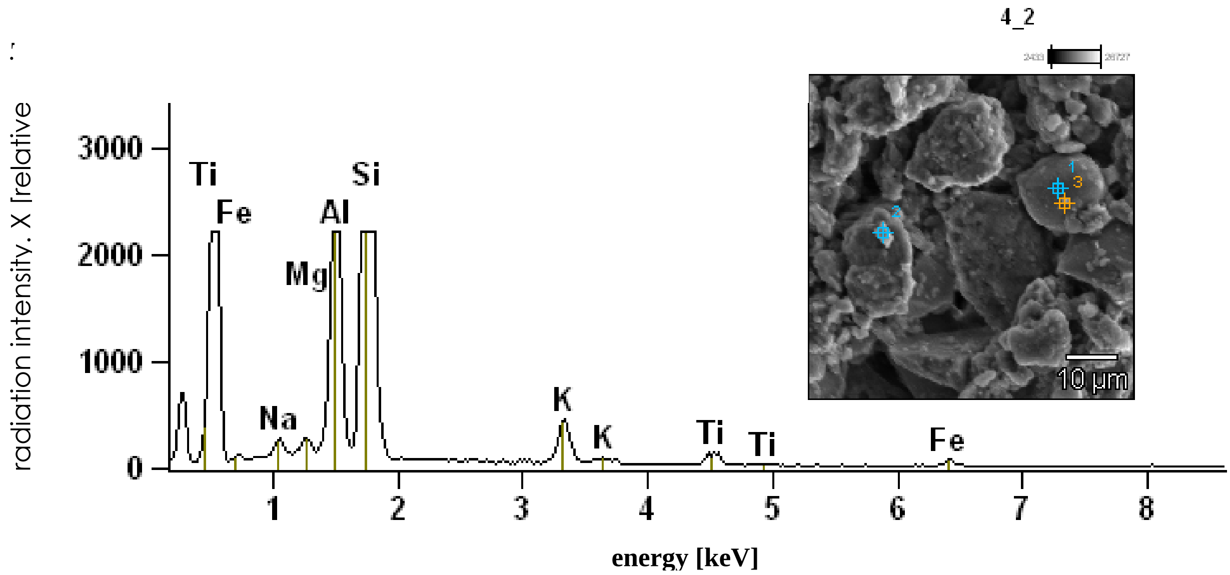

FIGURE 5. Road dust below 20 µm coming from a motorway section. Micro-photo of the surface(SEM) with a magnification 1500x spectrum characteristic of X radiation (EDS). Averaging chemical composition.

From the conducted granulometric analysis of exploitation dust coming from frictional car elements one can state that 88 % of elements is placed in fraction of up to 56 µm. The most dangerous to human fraction that is below 20 µm equals 17 % of the whole of exploitation dust. The elements of a bigger diameter present in the dust that is the ones over 56 µm were observed as bigger abruptions from the frictional surface which are presented in figure 6. Judging the exploitation dust one should also notice that dust elements with a diameter of up to 20 µm are also formed as a result of erosion of the active layer of car catalysts [8 - 10].

FIGURE 6. Fragment of the frictional lining with a visible abruption on the surface

3. CONCLUSION

The conducted tests show that the elements of road dust with a diameter of up to 56 µm are formed mainly as a result of car exploitation.. Therefore, from the collected samples of road dust such fractions were selected for further analysis. It was justified by the analysis of road dust displayed in figure 5. The presence of such chemical elements as titanium, magnesium and potassium shows the exploitation origin, whereas the presence of silicon results from the materials used to build the roads and from the natural environment. The iron existing in tested element comes probably from cars corrosion processes.

There is therefore no need to conduct detailed, expensive analysis of chemical composition of the dust in order to define the approximate amount of emission from the cars. If such a need of precise statement of such emission occurred, one should then chemically analyse the dust, checking the content of characteristic chemical elements for frictional materials and elements of active layer of catalyst in cars.

REFERENCES

1. Adachi K., Tainosho Y.: Characterization of heavy metal particles embedded in tire dust, Environment International 2004, 30: 1009 – 1017
2. Watson J. Chow J.: Source characterization of major emission sources in the Imperial and Mexicali Valleys along the US/Mexico border. The Science of the Total Environment 276 (2001) 33-47
3. Blau P., Meyer H.: „Characteristics of wear particles produced during friction tests of conventional and unconventional disc brake materials", Elsevier Science B.V., 2003.
4. Ntziachristos L. Samaras Z.: COPERT III. Computer programme to calculate emissions from road transport. Methodology and emissions factors. Technical report No 49. November 2000
5. PN-ISO 4225 – Air quality. General aspects. Vocabulary.
6. Kaczmar J., Pietrzak K., Włosiński W.: The production and application of metal matrix composite material. Journal of Materials Processing Technology 106 (2000): 58 -67.
7. Cho J.R., Shin S.W. Yoo W.S.: Crown shape optimization for enhancing tire wear performance by ANN. Computers and Structures 83 (2005): 920 – 933.
8. Wieszała R.: Wpływ czynników eksploatacyjnych na poziom zanieczyszczeń w trakcie eksploatacji pojazdów (The influence of exploitation factors on the pollution lever during car exploitation), Poland, Gliwice 2006, Doctoral thesis
9. Wieszała R. Wyciślik A.: Identyfikacja zanieczyszczeń powstających podczas eksploatacji pojazdów w aspekcie ochrony środowiska (Identification of the pollution resulting from car exploitation in the aspect of environment protection). Środowisko i Rozwój, (Poland), 2008 (In Press)
10. Wieszała R., Hadryś D.: Spaliny na A4. Wpływ remontów drogowych na poziom toksycznych składników spalin (The influence of road repair works on the level of toxic elements in car fumes). Magazyn Autostrady (Poland) nr 1/2, (2008): 48 – 51.