Research onto use of New Textile Friction Composites in the Reduction of Non-exhaust Emissions

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Problems

Nowadays, one of the most important topics in context of environmental and health hazard research became airborne particles. Exposure to traffic-related PM plays an important role in the development of adverse health effects. Traffic-generated particles are associated with cardiovascular and pulmonary effects, as shown by both epidemiological and toxicological studies [1-8]. Some of these studies suggest that brake wear particles might contribute to these adverse effects [5,6]. Specific health concerns are related to the allergenity of tyre components such as Polycyclic Aromatic Hydrocarbons (PAH’s) and latex, and the heavy metals used in brake linings. All of these compounds have toxic, mutagen attributes [9], but above all are respiratory sensitizers, inducing irreversible allergic reactions in the respiratory system.

Whilst exhaust gases in the road transport are already a concern for the European directives, there are currently no legal requirements for the control of non-exhaust particle emissions. Consequently, some of the approaches relating to non-exhaust particulate matter were highlighted [10]. Researches reveal that the traffic-related emissions are major sources of suspended PM in the urban areas [11-13]. Nevertheless, it can be claimed undoubtedly, that data relating to the physical and chemical properties, emission rates, and health consequences of non-exhaust particles derived from specific wear brake are uncertain/far from comprehensive.

Consequently a consistent knowledge concerning the effectiveness of the emission strategies is mandatory, in order to develop practical strategies for reducing the pollutant concentrations.

Three different technical approaches related both to vehicles and the infrastructure have been studied to reduce the emissions of PM:

- Preventive controls have been engineered to avoid material from being deposited onto the surface.
- Mitigative controls focused onto the removing any material that has been already deposited.
- "Adaptation" to reduce exposure to the existing level of pollution.

Testing known amount of well-characterized brake wear particles, it was shown that:

- Cleaning techniques including high-pressure water washing in combination with vacuuming the road surface might be also efficient when it comes to collecting PM from the road surface [14-16].
- Application of dust suppressants can also be effective, but there are various disadvantages about the potential health and environmental impacts of the compounds used.

The abrasion elements, such as: brake wear, tyre wear and road surface wear have been evaluated as having dominancy, representing more than three quarters of the source strength of non-exhaust particles.

Starting from the idea the applicant has two major sustainable research expertise’s, one being knowledge of the cellulosic polymeric supports treatment against ageing process, gained during the doctoral studies, and the other being a higher comprehension of synthesis and characterization of nanoporous materials used in photo catalysis of organic pollutants derived from textile industry wastewaters, during her post-doctoral activity, to reduce the emission of brake wear particles, the research proposes two novel directions tightly bound to her double expertise. These are (I) development of new ecological friction materials; (ii) collecting the brake particles as they are produced.

Characteristics of Coarse Fine and UFP Particles

According to their modes of aggregation, PM can be divided into:

- Aucelation mode generating ultra-fine particles (in the PM0.1 fraction), which can penetrate into the alveolar region.
- Accumulation mode giving “birth” to fine particles ranging between 0.05 μm and 2 μm in diameter).
- Coarse particle mode comprises particles with diameters in the size range between 2.5 μm and 10 μm contributing substantially to total aerosol mass [17,18].

The main constituents of these above primary particles are crustal elements (e.g. Si, Al, Ca, Fe), elemental carbon, and different organic compounds. Secondary particles are consisted of inorganic compounds (sulphates and nitrates) [19].

Physical and Chemical Phenomena Underlying the Brake Wear Process

Despite the fact that brake wear is recognized as a major source of traffic-related PM emissions, a deeper knowledge of the physical attributes and chemical composition of brake lining materials and particulate matter generated as a result of brake wear is uncertain [18].

Factors Affecting Brake Wear

A mechanically-induced wear meaning large frictional heat generation associated with wear is the results achieved when vehicle brake linings are subject to large friction during forced deceleration. Subsequently brake lining particles are released to the environment [20].

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A huge variety of brake pad compositions is available. For instance Filip P and his co-workers analysed the composition of 82 brake pads on the American market [21]. Also Garg found that at each stop the increasing of brake temperature induces a proportional increment of the mass of lost friction material: PM 10 and PM 2.5 emission [22,23].

Brake Composition

Generally speaking, the chemical composition of brake linings consists of four main components: binders (phenol-formaldehyde resins), fibres (metallic, mineral, ceramic, or aramide, including steel, copper, brass, potassium titanate, glass, asbestos, organic material, and Kevlar), fillers (barium and antimony sulphate, kaolinite clays, metal powders.) and friction modifiers with inorganic, organic, or metallic nature. Graphite is a major modifier used to influence friction, but other modifiers include cashew dust, ground rubber, and carbon black [24,25].

Brake Wear Particles

Physical Properties

Particle size and number: From all of no exhaust emissions, TNO Institute of Environmental Sciences, Energy Research and Process Innovation, Apeldoorn, The Netherlands revealed a dominancy of around 90% (by mass) belonging to PM 10, whilst around 40-60% can be classified as PM 2.5, and up to 33% as PM 0.1. A significant fraction of airborne brake wear particles can be associated to PM 0.1 [26]. They also claimed that on average; around 35% of brake wear mass is released as airborne PM.

Particle composition: Investigating the chemical composition of both brake lining materials and emitted brake dusts from a range of commercial, heavy-goods vehicles, and trailers, using a combination of analytical techniques, such as: X-ray Fluorescence (XRF) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), a lot of reports have been emitted.

Thus, Kennedy and co-workers are discussing about concentrations of metals varying in terms of manufacturer and lining type, in some cases by several orders of magnitude [26]: iron (between 1% and 60%), copper (Cu 25% by mass) stressing the idea of the large variation in elemental composition of brake linings between manufacturers [27-30]. Dominant are also lead (Pb), cadmium (Cd), chromium (Cr), Cu, nickel (Ni), and zinc (Zn) being repeatedly reported to reveal their high concentrations in brake linings. Although a prohibitive fuel additive, Pb content of brake linings is high enough (12%), consequently brake wear emissions seem to picture a significant source of airborne Pb [30-32].

In Japan studies brought into attention levels of a few weight percent of: potassium (K), titanium (Ti), Cu, Sb, and barium (Ba). The occurrence of Sb in brake dust samples arises from the use of Sb as an alternative to asbestos in brake lining manufacture [31-34].

Using scanning electron microscopy and energy dispersive spectrometry to examine the morphological structure and elemental composition of brake lining material the studies revealed a noteworthy aspect: the brake wear process behaves only to reduce the size of the inorganic lining constituents relative to the original lining, whilst the chemical composition remains unchanged [35].

In terms of organic components, the identifiable portion of the brake particle organics consisted mainly of n-alkanoic acids (34.3%) and polyalkylene glycol ethers (56.9%), the findings suggest that only a small proportion of the organic content of brake linings and emitted as brake dust is extractable [36,37].

Sampling Methods

Laboratory-based brake system testing has the advantage that the collection efficiencies of wear debris tend to be high-90% or more, without significant particle losses to the surroundings, as opposed during on road operation.

Laser scattering method characterized brake wear particles concluding that wear debris tends to show a bimodal particle number size distribution.

Brushing brake dust samples from the inside of the rear drum brakes, consisting of suspension and filtration [38].

Brake dynamometer laboratory, in order to simulate “real-world” driving conditions [39,40].

Cascade impactor collected size-fractionated brake dust samples [32].

Subsequently the project proposes two main directions:

- development of new improved ecological friction materials;
- collecting/entrapping the brake wear particles as they are produced by photo catalytic methods (filters)

Rationale

Development of new friction materials as an alternative to asbestos fibres made brake pads arouse from the context of environmental and health hazard within global climate change. During braking asbestos could generate wear particles of different chemistries, released into the environment, with different potential of toxicity and mutagenity.

Moreover, there are various problems associated with asbestos due to its adverse effect on problem of life cycle assessment and waste management at the end of its service life. Since asbestos was banned, the number of its substitutes has been tested in formulations of the friction composites. The typical example is aramide fibers for the non-asbestos organic low-metallic (or nonmetallic) friction composites [41]. Nevertheless, aramide fibers are still of synthetic origin, being prepared by means of chemical synthesis [42], which could be hardly regarded as an environmentally friendly process.

At this juncture, the idea of asbestos replacement with friction materials having at least the same friction performance, given by its main attributes thermal, electrical, and sound insulation, inflammability has appeared. There have been trials to combine asbestos fibres with cement or woven into fabric or mats/ sheets [43,44].

Since worldwide, remarkable research is being done for the development of biodegradable polymers for various engineering applications [45,46], the research proposes plant fibres, such as sisal, jute, hemp, flax, to be used as reinforcement for different polymers in place of synthetic fibres (glass, Kevlar, carbon, etc.). Being renewable and biodegradable materials, cellulosic fibres are one of the highest valued alternative to be used as components in different kind of composites applications (e.g. kenaf fibers and betel nut fibers) [47-49]. Shalwan and Yousuf summarized the literature data and worked out a comprehensive review of the utilization of natural fibers as components in polymer matrix composites, also with a special focus on their tribological behavior [50].
The main demands these new friction composites for brake linings should fulfill are:

- Acceptable values of the friction coefficient.
- Stability at higher temperatures.

The most extremely serious aspect is the one regarding the thermal stability of the plant fibres. It is well known that hemicellulose decomposes from 220 to 315°C, and the most thermally stable is cellulose, which starts to decompose above 300°C and its decomposition terminates at 400°C [51]. In comparison with the most valued aramide fibers in terms of thermal stability, whose decomposition interval ranging from 400 to 450°C, these temperatures are lower [52].

Since, during intense braking, the temperature at the friction contact surface can locally exceed several hundred °C, the question is if the natural plant fibers can be used for application at such higher temperatures.

The proposal stresses the idea of increasing in the thermal stability of the plant fibres which will be used, by two main approaches:

- Increasing the content of cellulose, through removing the hemicellulose and lignin content by an alkaline procedure.
- The improvement of thermal stability of the newly obtained friction polymeric composites using Montmorillonite (MMT) emulsion, which is a type of inorganic natural clay containing SiO4 tetrahedral sheets arranged into a two-dimensional network structure, and might provide thermal resistance [53].
- The other research approach is the direct growth of pure and doped nanostructured ZnO coating onto the above mentioned fibrous polymeric support as active photo catalyst material in air purification reactors.

Impact

The expected results will be a valuable addition to the knowledge in the field of novel materials with friction performance, because ecological friction materials are in its infancy. This research might open a broad field of technological applications, due to their cost and low environmental impact of the eco-pad, with potential commercialization in future.

The newly developed eco-pad will be non-asbestos, non-metal, and non-aramid friction materials, which meets all the developing trends of the modern friction industry.

In terms of the second research direction, the expected impact is to make accessible new scientific information regarding photo catalytic materials on polymeric support, in order to capture/block/entrap the emissions of brake wear particulate matter, where this kind of knowledge is uncertain.

References

1. Maynard AD, Ailken RJ (2007) Assessing exposure to airborne nanomaterials: current abilities and future requirements, Nanotoxicol 1: 26-41.
2. Kukuctchova J, Roubic’ek V, Malachova K, Pavlic’kova Z, Holuša R, et al. (2009) Wear mechanism in automotive brake materials, wear debris and its potential environmental impact. Wear 267: 807-17.
3. Schwartz J, Litonjua A, Suh H, Verrier M, Zanobetti A, et al. (2005) Traffic related pollution and heart rate variability in a panel of elderly subjects. Thorax 60: 455-461.
4. Riediker M, Gasser M, Perrenoud A, Gehr P, Rothen-Rutishauser B (2007) A system to test the toxicity of brake wear particle. Am J Respir Crit Care Med 177.
5. Riediker, M, Cascio WE, Griggs TR, Herbst MC, Bromberg PA, et al. (2004) Particulate matter exposure in cars is associated with cardiovascular effects in healthy young men. Am J Respil Crit Care Med 169: 934-940.
6. Riediker M, Koren HS (2004) The importance of environmental exposures to physical, mental and social well-being. Int J Hyg Environ Health 207: 193-201.
7. Gerofos-Nijland ME, Dormans JA, Bloemen HJ, Leseman DL, John A, et al. (2007) Toxicity of coarse and fine particulate matter from sites with contrasting traffic profiles. Inhal Toxicol 19: 1055-1069.
8. Peters A, von Klot S, Heier M, Tantinaglia I, Hörmann A, et al. (2004) Exposure to traffic and the onset of myocardial infarction. N Engl J Med 351: 1721-1730.
9. Kelly FJ, Fussell JC (2011) Air pollution and airway disease. Clin Exp Allergy 41: 1059-1071.
10. Boulter PG (2005) A review of emission factors for road vehicle non-exhaust particulate matter. TRL Report PPR065. TRL Limited, Wokingham, UK.
11. Chow JC, Watson JG, Egami RT, Franzier CA, Lu Z, et al. (1990) Evaluation of regenerative-air Vacuum Street sweeping on geological contributions to PM10. J Air Waste Manag Assoc 40: 1134-1142.
12. Kuhns H, Elyemezian V, Landwehr D, MacDougall C, Pitchford M, et al. (2001) Testing retrained aerosol kinetic emission from roads (TRAKER): a new approach to infer silt loadings on roadways. Atmos Environ 35: 2815-2825.
13. Kuhns H, Elyemezian V, Green M, Hendrickson K, McGown M, et al. (2009) Vehicle-based road dust emission measurement-Part II: Effect of precipitation, wintertime road sanding, and street sweepers on inferred PM10 emission potentials from paved and unpaved roads. Atmos Environ 37: 4573-4582.
14. Gustafsson, Barlow TJ, Boulter PG (2011) Non-Exhaust Particulate Matter Emissions from Road Traffic: Summary Report, TRL Limited, Wokingham, UK.
15. Barlow TJ (2007) A Review of Abatement Measures for Non-Exhaust Particulate Matter from Road Vehicles. Transportation Research Laboratory, UK.
16. Boulter PG, Wayman M, McCrae I, Harrison RM (2007) A review of abatement measures for non-exhaust particulate matter from road vehicles. Transportation Research Laboratory, UK.
17. Thorpe A, Harrison RM (2008) Sources and properties of non-exhaust particulate matter from road traffic: a review. Sci Total Environ 400: 270-292.
18. AQEG (2005) Particulate matter in the United Kingdom. DEFRA, London, UK.
19. Warner LR, Sokhi R, Luhana L. (2000) Non-exhaust particle emissions from road transport: a literature review. University of Herfordshire, UK.
20. Salway AG, Eggleston HS, Goodwin JW, Murrells TP (1997) National Atmospheric Emissions Inventory (NAEI). UK Emissions of Air Pollutants 1970-1995, Oxfordshire, UK.
21. Filip P, Wright MA, Marx DT (1997) On-highway brake characterization and performance evaluation. In: Materially Speaking; Materials Technology Centre and the Centre for Advanced Friction Studies, Southern Illinois University, USA.
22. Garg B, Cadle SH, Mulawa PA, Groblicki PJ (2000) Brake wear particulate matter emissions. Environ Sci Tech 34: 4463-4469.
23. USEPA (1995) Compilation of Air Pollution Emission Factors, USEPA Report AP-42, USA.
24. Brewer P (1997) Vehicles as a Source of Heavy Metal Contamination in the Environment. University of Reading, Berkshire, UK.
25. Legret M, Pegotto C (1999) Personal communication to Dr. Adine Hird at TRL, UK.
26. Kennedy PC, Gadd J, Preliminary examination of inorganic compounds present in tyres, brake pads and road bitumen in New Zealand. Prepared for Ministry of Transport, New Zealand.
27. Chan D, Stachowiak GW (2004) Review of automotive brake friction materials. J. Automobile Eng 218: 953-966.
28. Schauer JJ, Kleeman MJ, Cass GR, Simonet BR (2002) Measurement of emissions from air pollution sources. 5. C1-C32 organic compounds from gasoline-powered motor vehicles. Environ Sci Technol 36: 1169-1180.
29. Westerlund (2001) Metal emissions from Stockholm traffic, wear of brake linings, Stockholm environmental administration, Stockholm, Sweden.
30. Legret M, Pegotto C (1999) Evaluation of pollutant loadings in the runoff waters from a major rural highway Sci Total Environ 235: 143-150.
31. von UO, Skerfving S, Doyle R, Braungart M (2005) Antimony in brake pads: carcinogenic component? J Clean Prod 13: 19-31.
32. Iijima A, Sato K, Yano K, Kato M, Kimura H, et al. (2007) Particle size and composition distribution analysis of automotive brake abrasion dusts for the evaluation of antimony sources of airborne particulate matter. Atmos Environ 41: 4908-4919.
33. Weckwerth G Verification of traffic emitted aerosol components in the ambient air of Cologne (Germany). Atmos Environ 35: 5525-5536.
34. Kim SJ, Jang H (2000) Friction and wear of friction materials containing two different phenolic resins reinforced with aramid pulp. TribolInt 33: 477-484.
35. Ingo GM, D’Uffizi M, Bultrini G (2004) Thermal and Microchemical investigation of automotive brake pad wear residues. Thermochimica Acta 418: 61-68.
36. Sanders PG, Xu N, Daika TM, Mariaq MM (2003) Airborne brake wear debris: size distributions, composition, and a comparison of dynamometer and vehicle tests. Environ Sci Technol 37: 4060-4069.
37. Mostaleh M, Blaub PJ, Dumitrescu D (2004) Characteristics and morphology of wear particles from laboratory testing of disk brake materials. Wear 256: 1128-1134.
38. Hildemann LM, Markowski GR, Cass GR (1991) Chemical Composition of Emissions from Urban Sources of Fine Organic Aerosol. Environ Sci Tech 25: 744-759.
39. Garg B, Cadle SH, Groblicki PJ, Mulawa PA (2000) Brake wear particulate matter emissions. Proceedings of the 10th CRC On-Road Vehicle Emissions Workshop, Hyatt Islandia, San Diego, California, USA.
40. Blau PJ, Jolly BC, Qu J, Peter WH, Blue CA (2007) Tribological investigation of titanium-based materials for brakes. Wear 263: 1202-1211.
41. Gopal P, Dharani LR, Blum FD (1996) Hybrid phenolic friction composites containing Kevlar_pulp Part 1. Enhancement of friction and wear performance. Wear 193: 199-206.
42. Satapathy BK, Bijwe J (2006) Composite friction materials based on organic fibres: Sensitivity of friction and wear to operating variables. Composites Part A 37: 1557-1567.
43. Yang HH (1988) Fibre reinforcements for composite materials. Composite Materials Series. Elsevier Science Publishers, Amsterdam, Netherlands.
44. Saxena M, Pappu A, Sharma A, Haque R, Wankhede S (2011) Composite Materials from Natural Resources: Recent Trends and Future Potentials, CSIR-Advanced Materials and Processes Research Institute, Council of Scientific & Industrial Research, India.
45. http://www.britannica.com/
46. Lu L, Farris TN, Chandrasekar S (1992) Sliding Microindentation Wear Particles: Spheres in Grinding Swarf. Tribology Series 21: 257-263.
47. Oudshoorn L (1995) Biogas from sisal waste-a new opportunity for the sisal industry in Tanzania. Energy Sustain Dev 2: 46-49.
48. La Mantia FP, Morreale M (2011) Green composites: A brief review. Composites Part A 42: 579-588.
49. Bledzki AK, Gassan J (1999) Composite reinforced with cellulose based fibers. Prog Polym Sci 24: 221-274.
50. Yousuf BF, Nirmal U, Wong KJ (2010) Three-body abrasion on wear and frictional performance of treated betelnut fibre reinforced epoxy (T-BFRE) composite. Mater Des 31: 4514-4521.
51. Shalwan A, Yousif BF (2013) In state of art: Mechanical and tribological behaviour of polymeric composites based on natural fibres. Mater Des 48: 14-24.
52. Perepelkin KE, Andreeva IV, Pakshver EA, Mongoeva IY (2003) Thermal characteristic of para-aramid fibers. Fibre Chem 35: 265-269.
53. Vrinceanu N, Tanasa D, Hristodor CM, Brinza F, Popovic E, et al. (2013) Synthesis and characterization of zinc oxide nanoparticles. J Therm Anal Calorim 111: 1107-1119.