Generating a Representative Sample of Brake Pad Wear Debris

Brake Manufacturers Council
Product Environmental Committee
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I. Introduction

This document summarizes the Brake Manufacturer's Council (BMC) methodology for generating a representative sample of brake pad wear debris for use by the Brake Pad Partnership (BPP) physical and chemical characterization of brake pad wear debris. The methodology was developed with technical input and analysis from the Brake Manufacturers Council-Product Environmental Committee (BMC-PEC) in close consultation with the BPP Steering Committee.

II. Background

As a part of the brake manufacturing industry's participation in the Brake Pad Partnership (BPP), the BMC-PEC voluntarily reports on the amount of copper used in original equipment[1] automotive friction materials[2] on an annual basis.[3] Information is compiled as part of the Copper Use Monitoring Program. "Friction materials" include disc brake pads (on front and rear brakes) and drum brake linings (on rear brakes only). The data are based on manufacturers' reporting of the actual copper content of their products. These data are collected and made available by the BMC-PEC in a manner that protects manufacturers' confidential business information, including the copper content of friction materials on specific new vehicles and the name of the manufacturer that supplies the friction materials. The BMC-PEC collects data for the top 20 to 25 best-selling vehicles, which comprise approximately 40% of the new cars and light trucks sold in the United States.

III. Purpose

A sample of brake wear debris that is representative of the brake wear being generated from automobile use in the San Francisco Bay Area is needed to determine the physical and chemical parameters affecting the transport and fate of the material. The information generated on wear debris characteristics will be used in subsequent environmental modeling studies aimed at understanding the role of copper in brake wear debris in stormwater and surface water quality in the San Francisco Bay. The representative sample of wear debris represents the nationwide average brake pad wear debris of Original Equipment Manufacturers (OEM) pads only and does not include aftermarket pads. The copper types represented in the sample of wear debris are found in Table 1.

IV. Analysis of the Prevalence of Copper Forms

A variety of forms of copper are used in brake pad formulations, including copper fiber, copper powder, brass fiber, brass powder, copper with organic complexes, copper sulfide as well as other forms of copper compounds. The Copper Use Monitoring Program reports on total copper used, and does not differentiate between different forms of copper.

Since the goal of the effort was to develop a sample of brake wear debris that is representative with respect to copper, it was important to understand the relative prevalence of the various forms of copper in use. Thus, the BMC-PEC conducted a follow-up survey of the manufacturers who reported on copper use in brake pads for model year 2002 (the most recent model year for which data were available), to determine the extent to which different forms of copper are being used.

The BMC again used confidential reporting methods to protect the manufacturers' proprietary business information. The BMC-PEC member companies submitted information on the forms of copper used in

[1] "Original equipment" refers to equipment that comes on new vehicles, and does not include "aftermarket" or replacement parts.
[2] "Automotive friction materials" refers to friction materials used in cars and light trucks, and does not include friction materials used on heavy-duty trucks, off-road vehicles, or motorcycles.
[3] Brake Pad Partnership 2004. Copper Use Monitoring Program Results for Model Years 1998 – 2002. Available at: http://www.suscon.org/brakepad/pdfs/CuUMPFinalReport.pdf

each application to the BMC. The BMC then presented the PEC members with the data showing: (1) the materials letter code, (2) the percent of copper, (3) the form of copper, and (4) the percent of the top 20 sales volume that the material represented.

Table 1 presents the aggregate results of the BMC-PEC survey of copper forms used. This table illustrates that the predominant forms of copper in brake pads are copper fiber and copper powder.

Table 1. BMC-PEC Copper Forms Survey for Model Year 2002 (99.09% Reported)

Forms of Copper	Fiber	Powder
Copper Fiber	●	
Copper Powder		●
Brass Fiber		
Bronze Powder		
Copper Fiber & Copper Powder	●	●
Copper Fiber & Organic Complexes	●	
Copper Powder & Bronze Fiber		●
Copper Powder & Copper Sulfide		●
Bronze Powder & Copper Sulfide		
Copper Fiber, Copper Powder & Organic Complexes	●	●

The BMC-PEC conducted a Pareto Analysis on the survey data to mathematically determine the prevalence of the different copper forms in use. Table 2 contains the results of the Pareto analysis, which show that copper fiber use amounts to between 76.04 and 86.68% of the copper use, and copper powder amounts to between 2.38 and 13.85% of the copper use. Other forms of copper amount to between 0.00 and 5.30% of the copper use.

Table 2. Pareto Analysis Survey Results

Survey Results	Pareto Analysis
Copper Fiber	> 76.04 – < 86.68 %
Copper Powder	> 2.38 – < 13.85 %
Copper Alloys/Compounds	> 0.00 – < 5.30 %

V. Material Selection Process

The results of the Pareto Analysis indicate that the large percentage of copper used in brake pads is in the form of copper fiber and copper powder. Based on this finding, the BMC-PEC determined that a relatively small set of brake pads containing copper fiber and copper powder could be used as the basis for generating a representative sample. Wear debris generated from pads containing only copper fiber and only copper powder could be combined in the proportions obtained from the analysis to comprise the representative sample.

The following were the steps taken to select the actual brake pads used in a manner that masked the identity of the actual brake pad product and its manufacturer.

1. The form of copper was determined using only the vehicle/pad manufacturer's data from the copper monitoring study. From this information, the BMC made a random selection of each pad manufacturer's products. Each manufacturer then prepared brake pads using the formula/compound used on that particular vehicle application but in the appropriate size and shape (FMSI # 7620-D752) required to generate wear debris by the BMC, and submitted the parts to the BMC.
2. The random selection of materials submitted resulted in three friction material samples. The three brake pad samples were labeled Material A, Material B, and Material C. The BMC retained a record of the copper content and form for each individual sample pad. This information may be disclosed only at the discretion of the BMC.
3. The permanently labeled materials were sent to Link Test Laboratories for the generation of brake pad wear debris on a brake dynamometer according to the Wear Debris Generation and Collection Protocol[4] (The Protocol) previously developed by the BMC.

VI. Generation of representative samples

At Link, the three material samples were run in succession on a brake dynamometer to generate wear debris per The Protocol. Each material was run for a period of time proportionate to the volume of the material sold on vehicles in 2002. Run time was determined by using vehicle data to determine copper type percentage (vehicles using a given form of copper divided by total number of vehicles). Run times were 38, 20.3 and 85.7 hours for Material A, B and C, respectively.

Upon completion of the successive wear debris generation runs for the three pads per The Protocol, all the wear debris was recovered from the dynamometer enclosure according to the procedures specified in The Protocol. Airborne wear debris was captured in 3 separate filters (one for each material A, B, C). Fallout wear debris was collected only at the end of all runs, generating a combined sample of non-airborne wear debris. Pad and rotor weight loss was analyzed on each material after the test to determine the total mass balance.

VII. Results

Data collected from the generation of brake pad wear debris is limited to the mass balance as reported in Link Test Reports 4AA205, 4AA206 and 4AA207 (Table 1; additional information found in Appendix B). The generation of a representative sample was intended to give the BPP wear debris for use in physical and chemical characterization.

[4] J. Trainor, T. Duncan, and R. Mangan, *Disc Brake Wear Debris Generation and Collection*, 2002-01-2595, SAE Technical Paper Series, SAE International, Warrendale, PA, 2002.

Table 1

	Initial Weight (g)	Final Weight (g)	Change in Mass (g)
Sample A			
Inboard Pad	384.9	380.3	4.6
Outboard Pad	340.7	336.1	4.6
Rotor	6330.7	6329	1.7
Tray	80.2	80.6	-0.4
Sample B			
Inboard Pad	325.1	317.8	7.3
Outboard Pad	358.4	351.3	7.1
Rotor	6329	6325.7	3.3
Tray	26.3	27	-0.7
Sample C			
Inboard Pad	389.7	387.2	2.5
Outboard Pad	338.3	335.3	3
Rotor	6376.9	6376	0.9
Tray	26	26.1	-0.1
High Flow Filter	180.1	202.6	-22.5
Wash Down	1162.0	1165	-3.0
Combo Tray	26.2	29.8	-3.6

Total Loss from Rotors and Pads	**35**	grams
Total collected	30.3	grams

Summary

All test samples were run to specifications provided in emails pertaining to the testing. Attached is a single cycle of stop data to ensure all cycles were consistent from test to test. The fall out directly to the ground was very minimal, most was either swept away as airborne particles or was attached to the rim, caliper, and knuckle. All collected material, 4 tin foil trays, 1 bag containing 6 high volume filters, and a jar with wash down extract, has been sent to Clemson University care of Mark Schlautman.

VIII. References

Link Testing Laboratories, Inc.

13840 Elmira Avenue

Detroit Mi, 48227-3017

Phone 313.933.4900

www.linkeng.com

Brake Manufacturers Council

10 Laboratory Dr.

Research Triangle, NC 27709

www.brakecouncil.org

Society of Automotive Engineers (SAE)

400 Commonwealth Drive
Warrendale, PA 15096-0001 USA

www.sae.org

Professor Mark Schlautman, PhD

Environmental Chemistry; Soil & Water Quality

Department of Environmental Toxicology

Clemson Institute of Environmental Toxicology

509 Westinghouse Rd.

PO Box 709

Pendleton, SC 29670

IX. Appendices

The Disc Brake Wear Debris Generation and Collection (SAE Document 2002-01-2595) abstract is as follows:

> *This paper describes a reproducible and practical dynamometer-based procedure for generating and collecting disc brake wear debris. The procedure is intended to provide friction material producers, brake system suppliers and other interested researchers a standardized protocol for generating and collecting brake wear debris. A standardized procedure for generating and collecting wear debris is the starting point for characterizing a disc brake material and assessing its impact on the environment.*

The paper can be purchased at www.sae.org using the following link:

http://www.sae.org/servlets/productDetail?PROD_TYP=PAPER&PROD_CD=2002-01-2595