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NON-ASBESTOS FRICTION MATERIALS

by

Michael G. Jacko, Ph.D.
Bendix Advanced Technology Center
Southfield, Michigan

and

Mr. Charles M. Brunhofer and Mr. F. William Aldrich*
Bendix Friction Materials Division
Troy, New York

ABSTRACT

Friction materials for automotive brakes are complex composites containing three general types of ingredient materials: reinforcing fibers; modifiers that adjust or maintain friction level, wear rate, and noise properties; and organic resin binders. Historically, the foundation or major constitutent of automotive friction materials has been asbestos fiber, so chosen because of thermal stability, friction level, reinforcing properties, availability, and relatively low cost.

Numerous substitutes for asbestos in conventional organic materials have been evaluated, including both naturally occurring and synthetic materials. Direct substitution of these alternative materials in conventional formulations has resulted in poor friction levels, friction instability, roughness, structural failure, increased noise, mating surface deterioration and/or front-to-rear vehicle brake imbalance. Complete reformulation, not simple substitution, is necessary to meet the numerous, complex performance requirements of consumers, manufacturers, and government standards, such as FMVSS 105-75 and FMVSS 121.

In the 1960's, a new class of friction materials, called semimetallics, was developed to meet severe braking requirements, primarily in heavy-duty disc brake and extreme duty truck block applications. Semimetallics operate satisfactorily against the ventilated cast-iron rotors in the smaller brakes of downsized cars, as well as against the solid rotors found in the lighter brakes of new front wheel drive vehicles. Semimetallics rely on steel fiber and powder metallurgy techniques for reinforcement, and do not require asbestos. The improved performance of semimetallics compensates for their higher costs due to more expensive ingredients, higher specific gravity, and more costly processing requirements. Overall development took more than 10 years from introduction to significant customer acceptance.

*Presented by Mr. Charles M. Brunhofer

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metallics make them extremely difficult and costly
g segment. Consequently, an additional new class of
er development, specifically for drum lining applica-
pment effort is necessary, not only to confirm the
ce of these new substitute fiber formulations, but
ssing techniques. These new-type friction materials
ever, due to the ingredients and new processing

an be viewed, quite simply, as energy transformers.
ion, the friction material (stator) makes contact with
sc (rotor), creating a friction force resisting the
the two bodies. The energy of motion is transformed
is dissipated, primarily through the rotating member.

t, the friction material must operate in a rather hostile
eak temperatures in excess of 400°C (750°F) are not
res at the contact interface can exceed 850°C (1560°F).
he-road operating environment (dust, mud, salt, water,
problem. The friction material must possess an optimized
stics, and maintain those characteristics throughout
a of vehicle operation.

characteristics of friction materials are listed in
evel must be adequate and stable over a wide range of
plication pressures, and temperatures, regardless of the
of the material. *Of particular interest are the fade/*
tics; i.e., the ability to resist friction level deterio-
d to extreme elevated temperatures (the fade) and then to
de friction level on cooling (the recovery). The friction
good wear properties for long life, but it must also not
r or grooving on the mating disc or drum. Excessive com-
and roughness (chatter, vibration, pulsation) must be
ivity to moisture must be minimized. Finally, the friction
apable of being manufactured with consistency at a reasonable

nitions of these characteristics, and their interaction and
ave been discussed at length by Aldrich and Jacko.[1] In gen-
to improve upon one characteristic often results in the deterio-
haracteristics. The development of friction materials is
ex, interactive process seeking an optimized combination of
aracteristics.

ce of numerous brake designs provides another level of com-
ning friction materials. Linings for drum brakes require a
operties. The duo-servo drum brake (the most popular U.S.
s two different types of linings, designated primary and

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TABLE 1. CHARACTERISTICS OF FRICTION MATERIALS

Friction
• Level (coefficient)
• Stability - speed
- pressure
- temperature
- conditioning
- age
• Fade/recovery
Wear
• Friction material
• Drum or disc
Noise
Roughness
Moisture sensitivity
Manufacturability
• Processibility
• Uniformity

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secondary, each of which needs different properties of strength, wear resistance, friction level and friction stability. The non-servo drum brake (used on many sub-compact vehicles) requires a friction material which encompasses the best characteristics of the primary and secondary in a single formulation, with emphasis on low-temperature properties and static friction capability. The large hydraulic and air-operated drum brakes utilized on medium and heavy trucks require, in general, the maximum properties of the smaller vehicle linings but at significantly higher operating temperatures. The arcuate form of drum brake linings places additional restrictions on the formulation, because of processing requirements.

Disc brakes demand a totally different set of operating conditions for the friction materials. Disc brakes generally operate at significantly higher temperatures than equivalent drum brakes, and the front disc brakes run hotter than the rear drum brakes on the same vehicle (Table 2). The friction material for disc brakes must be specifically designed for these higher temperatures, and must possess a higher coefficient of friction and better wear characteristics across the temperature range. Friction-material formulations must also be tailored to the specific needs of the particular vehicle application. Numerous parameters such as vehicle weight, front-to-rear brake balance, actuating system design, and duty cycle affect the capability of a particular lining formulation to perform satisfactorily.

The existence of numerous complex performance standards emanating from consumers, associations, manufacturers, and government agencies provides an additional set of parameters that friction materials must meet. Significant differences can exist between friction materials used as original equipment in new vehicles and friction materials available as replacement parts in the aftermarket. Each vehicle manufacturer has a unique, extensive set of test and acceptance standards to ensure the safety, durability, and performance of its products and the components used therein. Government-instituted requirements exist at the federal, state, and local levels. Federal requirements include those promulgated by the Department of Transportation (vehicle performance), the Occupational Safety and Health Administration (manufacturing work practices), and the Environmental Protection Agency (manufacturing practices and raw materials).

In order to meet the many characteristics outlined thus far, friction materials for automotive brakes have developed as complex composites containing three general types of ingredient materials: reinforcing fibers; modifiers that adjust or maintain friction level; wear rate and noise properties; and organic resin binders. Historically, the type of friction materials used in most automotive applications has been conventional organic friction material. The foundation or major constituent of conventional organic friction material has been asbestos fiber, so chosen because of its unique combination of characteristics. Asbestos fibers provide reinforcement, possess a high coefficient of friction, and more importantly, have excellent thermal stability. The openness of the fiber, its adsorptiveness, and its compactability enhance the processing and uniformity requirements. Finally, asbestos fibers have been available in a variety of grades at a relatively low cost.

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TABLE 2. BRAKE FADE TEMPERATURES[a] (°F) (SUBCOMPACT FRONT WHEEL DRIVE VEHICLE)

	1st SAE fade[b] (10 stops)		2nd SAE fade[b] (15 stops)	
	Disc front	Drum rear	Disc front	Drum rear
Combination 1	780	300	870	360
Combination 2	985	235	1030	240
Combination 3	760	200	855	235

[a]Temperatures measured before the last stop. Actual temperatures for disc brakes are 80 to 180°F higher, as measured below the rubbing surface. Surface temperatures are in excess of 1600°F (870°C).

[b]SAE J843c

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Once the friction material has been cured, the asbestos fibers are locked into the matrix. During brake operation, the high temperatures generated at the interface convert more than 99.7 percent of the asbestos to non-fibrous residues (primarily olivine) in the wear debris,[2] and less than 0.02 percent asbestos becomes airborne.[3,4]

The conventional organic formulations and the processes by which they are made have been dependent upon and tailored to the physical and chemical properties of asbestos. Two courses of action are open for elimination of asbestos from automotive friction materials:

1. Develop a new generation of friction materials, designed from the start without asbestos in mind.

2. Attempt to substitute an alternative fiber system for the asbestos in conventional formulations, with subsequent modification of composition and process techniques.

Bendix is aggressively pursuing both courses of action. As Mr. William Agee, our Chairman and Chief Executive Officer, has stated, Bendix is committed to being asbestos-free at the earliest possible date within this decade.

SEMIMETALLIC DISC PADS

Properties

In the 1960s, a new generation of friction materials, called semimetallic, was developed to meet severe braking requirements which organics could not meet. Class A organics (typical U.S. materials), which perform well in low and moderate temperature duty, are prone to fade and exhibit compressibility and poor wear resistance at high temperatures. Class B organics (typical European and Japanese materials) provide good high-temperature wear and friction levels, but have poor low-temperature wear resistance, produce rotor scoring and/or wear, and are prone to being noisy. Semimetallics were initially develed for these extreme, high-temperature applications.[5]

Semimetallics rely on steel fiber and powder metallurgy techniques for reinforcement. Various property modifiers are added to enhance performance to desired levels, with a resin binder holding the materials in a uniform solid mass. Semimetallics may contain metallic powder, sponge iron particles, ceramic powder, steel fiber, rubber particles, graphite powder, and phenolic resin.[6,7] Some manufacturers utilize a backing layer of a different composition which can contain asbestos.

Problems Overcome

Inherent in the uniqueness of the semimetallic formulations and their performance properties were a number of significant problems which required resolution. Concentrated development effort was required to resolve both processing and performance related issues. Processing issues included: the uniformity of the raw materials mixtures, the ability to form and handle the in-process material, and the ability to manufacture high-quality parts consistently.

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Performance issues included: materials strength, cold friction properties, initial wear resistance, and attachment to the backing plate. The development effort on semimetallic friction material has been continuous, not only to further improve its characteristics and properties, but also to overcome the problems inherent in accommodating new vehicle applications.

Semimetallics gained acceptance because they were able to solve some of the problems that could not be overcome using Class A or Class B organics. The improvements/advantages are listed in Table 3. The key element is the attainment of overall excellent properties at both low and high temperatures. Semimetallics cost more because of more expensive ingredients and a costlier process, but the improved performance capabilities offset these factors. An increased usage of semimetallics has occurred over the past few years. The downsizing of vehicles, with resulting smaller front brakes and higher operating temperatures has given impetus to increased use of semimetallics.[8] It is expected that the trend toward asbestos-free semimetallic disc pads will continue.

SEMIMETALLIC DRUM LININGS

An obvious alternative to conventional organic drum brake linings is the use of semimetallic material for drum linings. In fact, one of the first applications for semimetallics was for air brakes on heavy-duty trucks used in the logging industry--an extremely severe application.

Significant development effort has been expended on semimetallic drum brake linings. However, the basic nature of semimetallics does not lend itself to the arcuate segment configuration required for small drum brakes. The semimetallic mix does not possess the necessary green strength, is difficult to bend into the arcuate shape, and is more brittle in its cured form and therefore subject to cracking. Modifications to the formulation to facilitate processibility generally result in a product that cannot achieve commercially acceptable performance characteristics.

These difficulties present a clear challenge, and development work on semimetallic drum brake linings continues.

ALTERNATE FIBERS/REINFORCERS

<u>Properties</u>

Alternative fiber systems in conventional organic formulations represent the second course of action open to friction-material manufacturers. Table 4 is a summary of the properties of some of the various materials which could be considered as alternate reinforcements. Since conventional organics and semimetallics have traditionally been reinforced with asbestos and steel fiber, respectively, these fibers are also included in the table for comparative purposes. The data in Table 4 were obtained from the material manufacturer's literature and extensive characterization data developed at Bendix. Characterization included scanning electron microscopy and x-ray energy spectroscopy (SEM/XES). The selection of suitable alternate materials must also consider

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TABLE 3. IMPROVEMENTS OFFERED BY SEMIMETALLIC DISC PADS

- Improved energy absorption
- Fade resistance
  - Temperature insensitivity
  - In-stop fade
  - Speed spread
- Friction stability (FMVSS 105-75)
- Higher temperature capabilities (life)
- Rotor compatibility
  - Scoring
  - Heat checking
- Reduced noise
- Smaller brake sizing