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STEPHEN L. BERGER, P.E.
PATENT AGENT
4418 Pleasant Valley Court
Oakland, CA 94611
(510) 622-2345 Work
(510) 658-2256 Home

July 31, 1998

Walter Weathers
333 Clay Street, #4440
Houston, Texas 77002

BENDIX REFERENCES AND RELATED MATERIAL

Dear Walter:

I have enclosed literature and patent references on Bendix (both Aldrich and Kwolek), some patents assigned to General Motors, a 1950 article by a Chrysler employee, and a 1979 general reference comparing different brake linings.

Most of the references should be self-explanatory after reading the enclosed three page report I wrote for NRDC in 1983. The report also details a telephone conversation I had with Aldrich in 1983. If you have any questions, I will gladly discuss them with you.

Sincerely,

Stephen L. Berger, P.E.

Stephen L. Berger
6631 Saroni Drive
Oakland, CA 94611

June 22, 1983

Dear Barry,

Here is the report on asbestos-free brakes for NRDC.

I looked through the Engineering Index from 1970 to April 1983 and the Index for SAE Transactions from 1974 to 1981.

The only reference that might be of interest and which I could not locate here is a book entitled Friction Materials; Recent Advances by Louis B. Newan (it might be Newman) published in 1978. It is based on patents and mentions commercial applications.

Sincerely,

Steve

ASBESTOS FREE BRAKES

Stephen L. Berger
June 22, 1983

Possible replacements for asbestos brake linings (pads) can be divided into two groups: (1) the semi-metallic friction materials, and (2) linings in which the asbestos fibers are replaced by other fibers, specifically Kevlar (du Pont trademark) aramid fibers.

The following references describe the semi-metallic brake linings.

SAE Transactions Paper No. 710591, by F. William Aldrich from the Bendix Corp. This 1971 paper describes the advantages of semi-metallics: improved wear resistance; improved fade resistance; improved high speed effectiveness; improved frictional stability; minimal noise; and excellent mating surface compatibility. The paper seems to imply that semi-metallics are useful as both disc and drum brakes.

SAE Transactions Paper No. 750874 by John P. Kwolek, at the time from the Bendix Corp. This 1975 paper is directed to semi-metallic solid rotor disc brakes in small cars. Reviewing the history of semi-metallics, the paper states that they were first developed in the 1960's and first used on foreign vehicles. Police cars and taxicabs were also equipped with them. In 1970 in this country, semi-metallics were used for the front disc brakes of police cars. Additional costs were apparently the only reason widespread usage did not occur.

> "Semi-metallics are currently being produced for one domestic vehicle equipped with solid rotors. Combinations of organic and semi-metallic pads are being used on a domestic station wagon, luxury car and several light truck applications. The use of semi-metallics has also been expanded to the larger disc brakes currently released for heavy trucks."

The above paper mentions a 1974 U.S. patent 3,835,118 (enclosed) to Rhee and Kwolek and assigned to the Bendix Corp. This patent is the only place I found which actually describes

typical semi-metallic brake pad formulations. The patent discloses coarse sponge iron particles as a friction modifier. The patent also mentions that "one of the major obstacles to the acceptance of semi-metallics as a friction material has been the poorer wear resistance of the semi-metallics (compared to organics) when operating at temperatures below 325°F." (col. 3, line 66 to col. 4, line 2). The brake pad of the patent apparently overcomes this objection.

SAE Paper No. 790717 (abstract only is enclosed) by Harry M. Schiefer and George V. Kubczak of Dow Corning Corp. This 1979 paper describes a Dow Corning friction modifier for semi-metallic brakes and clutches to reduce squeal and wear.

An article, based on the above 790717 paper, in Automotive Engineering entitled "Friction Modifiers Tailor Brake and Clutch Characteristics." This article gives more detail than the abstract and compares the properties of the different classes of brake linings. Semi-metallic brake linings (because of their hardness) without friction modifiers creat much noise (the squeal one hears from many European cars).

A telephone call to Aldrich at Bendix in Troy, N.Y. (518 273-6550) revealed the following information about semi-metallics:

(1) some European manufacturers have used semi-metallics for about a decade
(2) companies are very secretive about their proprietary brake formulations and, therefore, few articles giving details are published
(3) semi-metallics work better than asbestos linings, but cost more
(4) more than half of GM and Chrysler disc brakes are now semi-metallics
(5) brake manufacturers will soon have to stop using asbestos because it will be too expensive for them to meet the proposed OSHA standards.

A telephone call to Schiefer at Dow Corning in Midland, Mich. (517 496-4000) did not reveal any new information, but he did confirm that brake formulations are hard to find in the published literature.

I do not have information on changes in manufacturing equipment or processes for the semi-metallics.

Brakes in which asbestos is replaced (the basic formulation remaining about the same) are best exemplified by SAE Transactions Paper No. 800667 by Halvar Y. Ioken from du Pont. This 1980 paper suggests replacement of asbestos by a combination of "a low cost inorganic filler with higher cost reinforcing fibers added for strength and crack resistance. This approach would in principle make it possible to continue to use the production methods that have been developed for asbestos-based friction materials."

The paper presents a table which lists the advantages and potential problems of various reinforcing fibers for friction materials. The problem with Kevlar: "Cut forms...require special attention in mixing because the fibers are tough and do not break up but tend to clump together on prolonged mixing." The paper does mention that Kevlar reinforced friction materials can outperform asbestos friction materials. However, Aldrich told me that Kevlar is very expensive (about $6.00 per pound compared to about $0.25 per pound for asbestos) and that this fact might limit the commercial applications of Kevlar. On the other hand, the formulations in the paper use only 5% Kevlar, but premium quality asbestos linings use 50-60% asbestos. Semi-metallics cost less than Kevlar-based friction materials.

Also enclosed is U.S. patent 4,119,591 to Aldrich and assigned to Bendix. This discloses a friction material reinforced with steel and cellulose fibers. Aldrich said that this patent is "worthless."

There is also enclosed an abstract of SAE Paper No. 800979 entitled "Performance Characteristics of a Non-Asbestos Cellulose Fiber Composite Friction Material." No evaluation of this paper can be made by me.

Lastly, there are two U.S. patents, 3,870,581 assigned to Johns-Manville and 4,118,528 assigned to Raybestos Manhattan, both disclosing glass fiber clutch facings.

In conclusion, asbestos free brake linings can be made using either semi-metallic friction materials or by replacing the asbestos with a combination of Kevlar aramid fibers and filler. Since semi-metallics have already proven themselves in commercial applications in Europe, and recently in the U.S., and cost less than Kevlar-based friction materials, they will probably be the first choice of U.S. manufacturers when asbestos is eliminated.

United States Patent Office 3,434,998 Patented Mar. 25, 1969

3,434,998

MODIFIED ORGANIC BASE FRICTION MATERIAL

F. William Aldrich and Theodore E. Deane, Troy, N.Y., assignors to The Bendix Corporation, a corporation of Delaware

No Drawing. Filed Sept. 13, 1965, Ser. No. 487,052
Int. Cl. C08g 51/08, C09k 3/14. Filed 69/02
U.S. Cl. 260—38 5 Claims

ABSTRACT OF THE DISCLOSURE

An organic base friction material having dispersed therein chunks of a semi-metallic friction modifying material to serve as the friction controlling means. The semi-metallic modifier being essentially high concentrations of metal and metal oxide powders in a base organic resin matrix

In order to obtain the ultimate in friction characteristics particularly high friction level for an organic type brake lining or friction material, it is necessary to add friction modifiers. The most common of these friction modifiers are the cured resinous particles such as that derived from cashew nut shell liquid. The use of such cashew resin particles results in increased frictional effectiveness of the base lining or frictional material, particularly at ambient or relatively-low temperatures. However such use has the disadvantage of decreased fade resistance or decreased effectiveness at elevated temperatures, poor recovery, and also the disadvantage of decreased effectiveness over long term normal use, observed as an increase in required pedal pressure over life of the brake lining.

An alternate to the use of such cured resinous particles is the use of inorganic materials of abrasive characteristics. Such materials for example alumina will offer increased effectiveness and will also offer improved fade resistance, improved recovery properties, and less hardening (pedal pressure increase) with extended use. Such inorganic materials, however, also have definite disadvantages in increased noise characteristics and excessive wearing, grooving or general destruction of the mating surface (brake drum or disc).

It is an object of the present invention to provide a semi-metallic friction modifier for organic base lining to provide increased friction effectiveness at both low and elevated temperatures without displaying poor fade resistance, recovery, long term hardening, excessive wear, or scoring.

It is another object of the present invention to provide an improved friction modifier for organic base lining comprised of a semi-metallic particle or chunk consisting of a metal powder or metallic oxide powder matrix, a ceramic constituent and powdered graphite all bound together under heat and pressure by a thermosetting phenolic resin binder.

The friction modifier of the present invention is for use with an organic base lining of the conventional type consisting of a resin base with additive organic friction modifiers, asbestos and the like.

The semi-metallic friction modifier or friction controlling means added to the basic organic lining preferably comprises 12½ to 20% by volume of the total lining material. Below 12½%, effectiveness is not obtained, above 20%, processing limitations cause the addition to become uneconomical. A functional upper limit is 25% wherein the abrasive content can be expected to have deleterious effects with respect to drum or disc wear.

The semi-metallic is to be added as a particle or chunk size greater than 20 mesh since the effect is masked at

smaller particle sizes. There is effectively no upper limit on particle size and the entire 25% of semi-metallic may be comprised of a single large particle or insert in the base organic. However, to facilitate processing, a preferred particle size range is from plus 20 to minus 4 mesh.

The preferred composition of the semi-metallic friction modifying particle is as follows:

Constituent	Vol., percent
Organic resin binder	20 and over
Graphite	15–25
Ceramic powder	10–25
Metal or metal oxide powder	30–50

The processing sequence is to manufacture a semi-metallic friction modifying particle by combining the metal or metal oxide powder, ceramic powder and powdered graphite in an organic resin binder of the thermosetting phenolic resin type which is then cured under heat and pressure to form a blended rigid mass of semi-metallic material. This material is then broken into particles of a size greater than 20 mesh and added to a conventional organic brake lining mix, comprising preferably 12½ to 20% of the volume of the finished lining material. The organic lining material with semi-metallic particle added is then processed, cured and shaped into a finished organic brake lining segment or block. The appearance of the lining can best be described as mottled compared to conventional linings when the semi-metallic particle size is within the preferred size range of plus 20 minus 4 mesh.

Suitable ceramic constituents are sillamanite, mullite, intermediate oxide, and zirconium oxide. Best results are obtained with ceramics of the aluminum silicate type, i.e. sillamanite and mullite although others have been used.

Preferred metals and metal oxides are copper, iron and iron oxide. Many other metals may be used, depending to a significant extent on cost. Soft iron oxide, Fe_2O_3, is a substitute for metals rather than ceramics. It will be noted that the organic resin is the primary binder and the metal is not required for this purpose. Generally speaking, the line of distinction between ceramics and metal oxides which can be substituted for the metal content depends on the abrasive or hardness characteristic.

Brake linings, manufactured in accordance with the above teachings, represents a significant advance over conventional organic linings known in the prior art. Generally speaking the advance is in terms of increased lining friction effectiveness under various conditions of operation. Comparison tests reveal that increased effectiveness is most pronounced under severe conditions of operation, where conventional organic linings are the weakest. For example, brake fade induced by high temperature, caused by frequent brake application in short time intervals is lessened from 50% to 10%. Recovery of effectiveness after fade is increased in excess of 25%. High speed and burnish wear and effectiveness is improved by a similar degree. While to some extent these are predictable results of high friction characteristics of metal and ceramic particles resistant to deterioration at high temperature, the main significance of the present invention resides in the fact that this improvement is achieved without sacrificing lining wear or scoring the mating brake surface such as encountered with metal base or inorganic linings. In fact, test results have demonstrated an increase in lining life of greater than 20% comparing an organic with 10% semi-metallic particles with a full organic of the same type.

We claim:

1. A modified organic base friction material consisting of an organic base friction lining material containing

from 1½ to 25% by volume of a semimetallic particle of a size greater than 20 mesh; said semi-metallic particle having as constituents by volume percent graphite from 15–25%, ceramic powder from 10–25%, and metal or metal oxide from 30–50% being bound together by an organic resin binder from greater than about 20%.

2. A modified organic base friction material as claimed in claim 1 wherein said organic resin binder is a thermosetting phenolic resin

3. A modified organic base friction material as claimed in claim 1 wherein said ceramic powder is a ceramic selected from the group consisting of sillamanite, mullite, magnesium oxide, zirconium oxide or mixtures tiereof.

4. A modified organic base friction lining material as claimed in claim 1 wherein said metal or metal oxide is selected from the group consisting of iron copper, iron oxide, or mixtures thereof

5. A modified organic base friction material consisting of an organic base friction lining material containing

from 1½ to 20% by volume of a semi-metallic particle within the size range of plus 20 minus 4 mesh, said semi-metallic particle having as constituents by volume percent graphite from 15–25%, ceramic powder from 10–25% and metal or metal oxide from 30–50% being bound together by an organic resin binder from greater than about 20%

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UNITED STATES PATENTS

3,007,549	11/1961	Klein	
3,210,303	10/1965	Biggs	

MORRIS LIEBMAN *Primary Examiner*

R. BARON, *Assistant Examiner*

U.S. Cl. X.R.

106—36

SAE TRANSACTIONS

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710591

Semi-Metallics: A New Type of Friction Material

F. William Aldrich
Automotive Control Systems Group, The Bendix Corp.

THE PAST TWO decades have seen rather dramatic changes in the requirements for frictional elements used in the braking systems of motor vehicles. Essentially, this shift in requirements has been in the direction of greater heat resistance, greater frictional stability at a higher friction level, reduced noise, and extended durability. In general, the state-of-the-art development of friction materials has kept reasonable pace with these required changes through improved resin binder systems, improved friction modifiers and fillers, and the increased application of scientific aids for greater uniformity

Although friction material development has not been restricted to the use of organic constituents 100%, a substantial portion of their composition has been organic type materials and they have been, thereby, subject to whatever shortcomings these materials may have. It is unfortunate that the prime shortcoming of organic type materials, namely their inherent nature to change both their form and properties with temperature, is at complete odds with the requirement of frictional materials to maintain maximum uniformity and stability of effectiveness over a wide range of temperatures.

In the past, considerable effort has gone into a potential solution to this problem of organic thermal instability in the form of development based on 100% inorganic materials, namely sintered metallics. However, even these supposed ultimate materials had their shortcomings, perhaps the greatest of which was that they also had too much sensitivity to temperature. At low temperatures they were ineffective and at high temperatures they were too effective. Their major advantage was low wear in the extreme temperature ranges of 1000-2000 F, which made them quite successful as aircraft linings. Sintered metallics did have, however, a potential of frictional stability, superior to the organics, if it could be controlled.

It became obvious that if the technological advantages of both the organic and sintered metallic friction types could be combined, then a new generation of substantially improved friction materials could be obtained. The result of this marriage is todays state-of-the-art semimetallic friction materials.

This paper will, as a rule, not differentiate between drum brake and disc brake applications for friction materials, since the basic characteristics remain essentially the same regardless of application. Any difference in the requirements of friction material for these two types is ordinarily only a matter of degree, with disc brakes, for example, generally operating at higher temperature ranges than drum brakes

CLASSES OF FRICTION MATERIALS

Any discussion of friction materials can be clarified to an extent, by first classifying them along general lines. For purposes of this paper, let us assume three classes for current materials, Class A, Class B, and Class C, with the latter being semimetallic.

As a general category, Class A friction materials would be represented by production materials on American made cars over the last 5-10 year period. They would be further categorized as being fundamentally organic in nature, excluding, of course, their inorganic asbestos content common to most of them. They are probably highly loaded with organic resin binders, organic resin friction modifiers, and

ABSTRACT

A new semimetallic type of friction material has been developed which offers improved frictional stability and high temperature wear resistance. Having minimal organic content, these materials avoid the thermal sensitivity to chemical and physical change characteristic of typical friction materials.

natural or synthetic rubbers or elastomers. They frequently also contain small amounts of graphite or other carbon type materials, and possibly small amounts of inorganic wear fillers such as ground limestone. As a class, they would be generally low in inorganic content, particularly anything of a substantially abrasive nature. Again, as a class they are reasonably quiet, give respectable durability, and under most conditions perform their frictional purpose without distinction. On the demerit side, sizeable increases in temperature raise havoc with their efficiency, and long term use or abuse frequently lowers their effectiveness. They lose friction rapidly at temperatures over 450-500 F and start considerable thermal decomposition above 600-650 F. Once having been in this "affective" temperature range, they are seldom like they were before.

Class B materials represent a first step major compromise in attempts to improve the Class A types. As a class, they ordinarily have higher inorganic and lower organic contents, a design factor to improve their thermal stability. They are most apt to have some degree of abrasive content to help stabilize their frictional properties.

Generally, as a class, they have better fade resistance, better recovery, and overall improved frictional and thermal stability. They may give good lining life at higher temperatures (+450 deg), but frequently at the expense of the mating surface which suffers from excessive wear, grooving, or scoring. They are quite apt to be noisy, and in terms of frictional stability may become overly effective with use or abuse, thereby increasing their noise and reducing their controllability.

The more recent Class C or semimetallic friction material attempts to extract the desirable properties from each of the Class A and Class B types. To gain maximum frictional and thermal stability it minimizes organic content, but it does not ignore it since organics do add desirable properties. It also maximizes inorganic content to gain thermal and frictional stability, but it does not overdo these since it does not want the potential hazards they offer.

WEAR AND FADE RESISTANCE

It has previously been noted that one of the shortcomings of organic type materials is their tendency to change form and properties at elevated temperatures. It is this characteristic which contributes substantially to highly accelerated wear as the temperature goes up. The property of wear is usually considered to be an economic factor only, but to some extent it can also play a part in performance factors. In the case of a drum braked vehicle with duo-servo brakes,moderate differences in side-to-side lining temperature or side-to-side lining wear rate can lead to unbalanced friction levels and severe pulls or single brake burn-up. Whether the chicken or the egg comes first is problematical, but the fundamental process is the same. In a disc brake, the lack of servo action may prevent pulls for a longer time, but moderate temperatures or wear differences at the higher operating temperature range of the disc brake can result in undesirable and substantial lining life variations, side-to-side and front-to-rear.

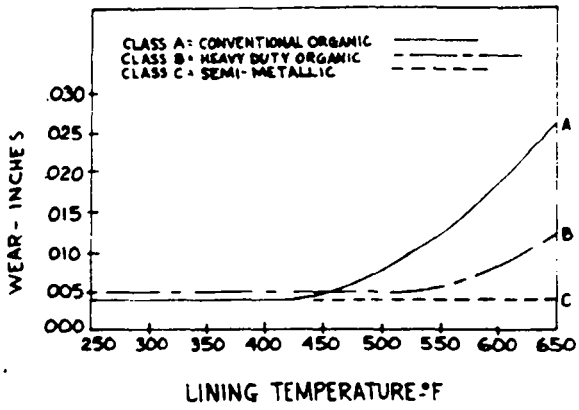


Fig. 1 - Wear versus temperature characteristics

Class A organics do have, as the temperature increases, a temporary degree of self-protection by virtue of their fade properties. By this we mean that increased temperature decreases their effectiveness and their work output, thereby protecting them from further temperature increases and increased wear rate. However, since fade is generally less on each successive fade condition, this protection is somewhat short lived. Some Class A materials also have such a steep wear versus temperature curve that constant surface renewal minimizes fade and also reduces or eliminates this self-protection.

Class B organics generally have improved fade resistance and more gradual wear versus temperature curves. This better fade resistance tends to reduce their self-protection. In spite of the better high temperature wear capability of the Class B types, the organic materials present still cause eventual wear resistance breakdown, even though it may be at a level 100-150 deg higher than a Class A type. At this point, however, the asbestos fiber is reaching the temperature range of substantial loss of water of crystallization and is itself deteriorating, actually forming new materials such as olivene.

Class C or semimetallic linings have a wear versus temperature curve of considerably less slope than the Class A and Class B organics. The wear versus temperature curves of Class A, Class B, and Class C materials, as taken from actual constant torque sample dynamometer tests, are shown in Fig. 1. It will be noticed that the Class C semimetallic is essentially insensitive to temperature in the 250-650 F temperature range, while the Class B starts to break at +500 F, and Class A starts to break at +400 F. Also note that up to 500 deg or so the Class B material wears at a rate somewhat greater than either the Class A or Class C types.

Because of the minimal organic content of semimetallics, they also have minimal fade. Based on the previous fade = self-protection discussion, one would at first consider this a detriment. In reality the semimetallic has a type of self-protection which organics seldom have—that of repetitive fade or considerably less tendency to antifade. This is quite evident when one looks at what happens on typical vehicle tests involving more than one fade, such as SAE J843b. In Fig. 2, it will be noted that for Class A and Class B organics that the second fade shows considerably less friction loss than the

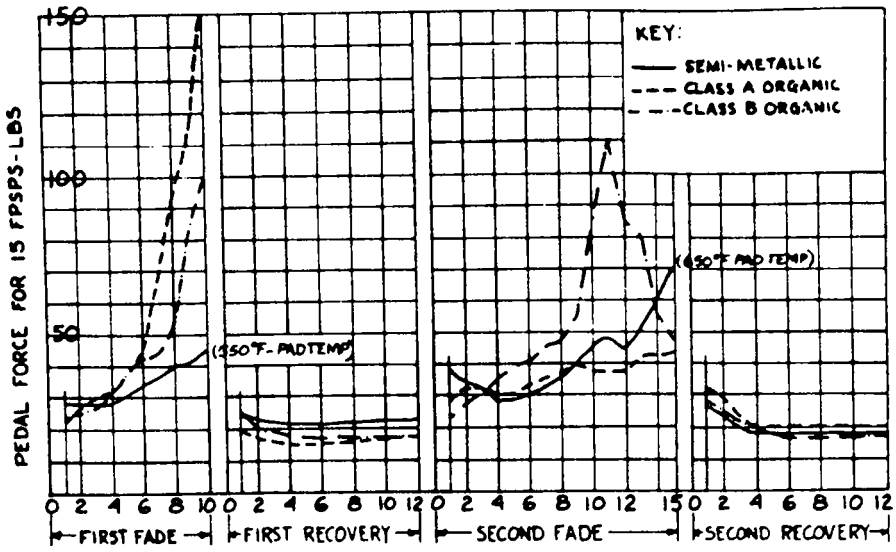


Fig 2 - Vehicle fade test characteristics (5700 lb GVW)

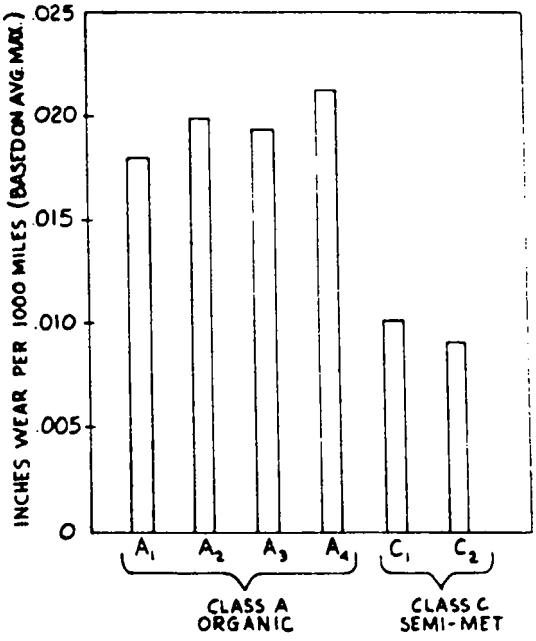


Fig. 3 - Disc pad durability-city traffic test; Class A versus Class C

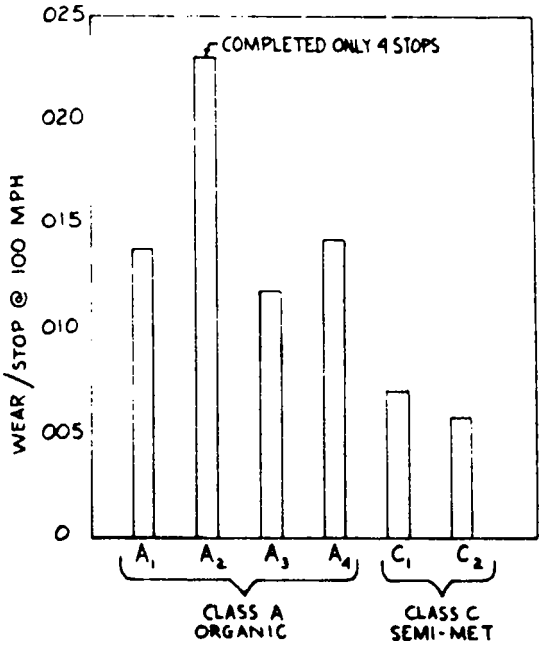


Fig 4 - Disc pad wear at 100 mph Full brake dynamometer, Class A versus Class C, 10-stop test

first fade, while in the case of semimetallic materials, the second fade may show almost equal friction loss.

In the case of semimetallics there is reason to believe that, in addition to the binding action of the resin system there is an inherent mechanical bonding of the metallic components. Such supplementary mechanical bonding, of course, contributes substantially to high temperature strength and wear resistance and can take over at the point the organic binder fails There is also indication that the mechanical bonding is increased with use or duty.

Early semimetallic linings showed low temperature traffic wear slightly poorer than Class A materials and more typical of the Class B types. However, this characteristic has now been improved so that on normal city traffic type driving the semimetallic shows appreciably better wear. Fig. 3 illustrates actual traffic durability test results, generally 350 F max, on four Class A production organic disc pad linings and two Class C semimetallic materials. The C2 material, a more recent development, shows still further gains over the C1 type. At the other end of the duty scale, Fig. 4 illustrates 100 mph wear rate results on a full brake inertia type dynamometer using these same materials. Again, the more recent C2 material shows improvement over the C1.

FRICTION

Class A friction materials as a rule have the highest friction when cold and the lowest friction when hot. Class B materials are generally somewhat lower friction cold and higher friction hot compared to Class A types The semimetallic materials

have substantially different friction characteristics, in that they tend to increase with friction with both increased temperature and increased surface speed. This characteristic has a distinct advantage for high speed effectiveness. Historically, high speed effectiveness of organic materials has been a problem. Since increased surface speed means increased temperature, the organics have usually shown poorer effectiveness, as the speed increased, frequently requiring some extensive power assist to maintain reasonable pedal efforts. In contrast to this, the semimetallic materials have temperature/speed characteristics which tend to reduce pedal effort and stopping distances from high speeds. Also, in contrast to previous full metallic linings (sintered materials), the low speed cold effectiveness is greatly improved. It is acknowledged that there is still some room for additional improvement of this characteristic with semimetallics, but to date, there has been no serious deficiency in this area. Actual tests have been made in the subzero temperatures of a Canadian winter.

Stability of friction throughout the life of the lining has also been a problem with organic types. Their general characteristics of high initial friction have frequently led to initial vehicle braking instability, and their characteristic of friction drop or loss after moderate abuse (fade) or long term light usage has frequently initiated complaints of ineffectiveness. In addition, their characteristic of friction "peaking" with severe use, particularly in the case of Class B materials, has led to vehicle braking stability and controllability problems. By virtue of their minimum organic content, semimetallic materials are much more frictionally stable over a wider range of use or abuse.

NOISE

This nonfunctional characteristic of brake systems and friction materials has kept industry engineers "hopping" for years. The friction materials engineer may be reluctant to agree that noises are always the linings fault, but he does have to agree that there are linings more or less prone to producing noise. Brake design or lining attachment not considered, class organics generally tend to produce their maximum of audible response in their cold or warming condition. Class B types usually duplicate the Class A in this respect, and supplement this with additional noise when warm or hot. The effect of this characteristic is that the driver of the vehicle has the greatest odds of obtaining noise under the conditions under which he does the majority of his driving.

Again, semimetallic materials tend to reverse these characteristics. They tend to produce minimum noise cold or warming and have their maximum noise while hot (for example, above 350 F). On this basis then, the driver is most apt to hear noise not under normal driving conditions, but rather during the less frequent or abnormal conditions.

COMPRESSIBILITY

In the disc brake, the compressibility of the lining material is a significant contributor to excessive fluid displacement.

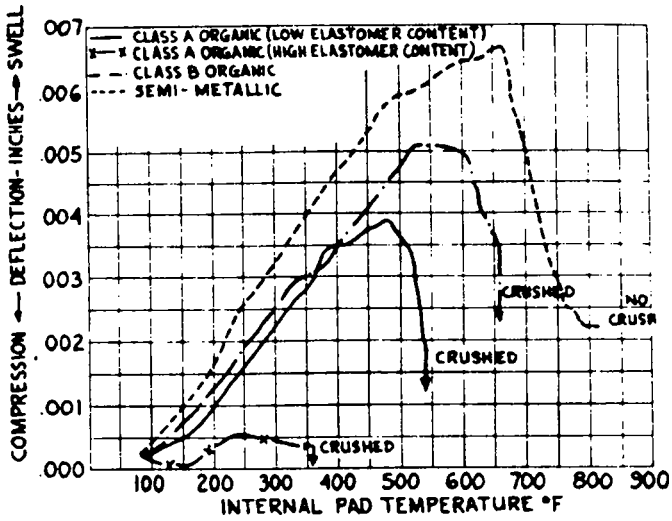


Fig 5 - Disc pad swell and crush comparison (at 5000 psi constant stress)

The actual compression of the pad material is a function of both the inherent compressiblity of the pad and line pressure required, which is a function of the materials fade resistance. This allows us to approach the compression problem from both directions; reduce inherent compressibility and/or reduce line pressures required (improve fade).

Class A materials, because of their high organic content which tends to create inherent compressibility, and also to create fade, generally offer the maximum in fluid displacement. Class B materials with less organic content tend to offer substantial improvement in this area. Class C semimetallic materials with still less organic content and improved fade resistance, have a potential of substantially greater improvement in reducing fluid displacement.

The accurate comparison of compressibility of various friction materials under controlled laboratory conditions is difficult, due to their variable initial swell characteristics on heating. One procedure which has been used involves maintaining a constant 5000 psi load on the sample and plotting, swelling, or compression versus temperature up to 800 F (Fig. 5). It will be noted that the Class A organic with high elastomer content had an initial and immediate compression prior to its showing any degree of swell. All the pad materials displayed the same basic characteristics; that is, they showed swell under initial heating-up to some point in spite of the preload. It will be noted that the Class A organic with high elastomer content actually crushed at a pad temperature below 400 F, while a similar material with low elastomer content showed improvement, but still crushed at less than 550 F. The Class B material started to compress at 550 F and failed at less than 700 F, while the semimetallic material started to compress at 650 deg but would not crush at the 800 deg temperature limit of the oven used.

OTHER CHARACTERISTICS

In the early stages of development, the increased heat conductivity of a metallic type friction material, particularly

for disc pad use, and its effect of fluid boil was considered a potential problem. The use of a two layer, organic backed semimetallic pad with the organic acting as a heat dam was indicated. However, many actual vehicle and dynamometer tests without such insulation failed to produce fluid boil. Controlled tests did indicate fluid temperatures 60-80 deg higher with semimetallics than with organic. A practical consideration, however, is that under extreme temperature conditions or use, the wear of organic materials can be so great as to bring the actual shoe in contact with the rotor, a most critical set of conditions. This possibility is recognized by SAE and certain vehicle manufacturers who appraise their designs for fluid boil in the bare shoe condition.

Compared to organic linings, semimetallic materials have relatively low coefficients of friction against the backing plate or shoe, and a "normal" riveted attachment can result in some shift or loosening and potential cracking. For this reason a roughened or grit blasted shoe surface is recommended, preferably combined with a tapered rivet head. Alternatives to this are a higher cost organic backed pad or integrally molded or bond-molded assembly.

Although the chemical composition of semimetallics varies considerably from that of normal organic friction materials, their mating surface compatibility characteristics are extremely satisfactory. Compared to other materials even approaching their performance and wear level, they are extremely kind to mating surfaces and generally require no special drum or rotor metallurgy or finish. In the case of heavy duty drum brakes for large trucks, they virtually eliminate drum spotting and heat checking typical of most materials in use.

SUMMARY

A new type of friction material of improved frictional and thermal stability has been developed. This new type of friction material, when compared to current conventional types has the following characteristics:

1. Improved wear resistance, particularly at high temperature.
2. Improved fade resistance.
3. Improved high speed effectiveness.
4. Improved frictional stability.
5. Minimal noise.
6. Excellent mating surface compatibility.

United States Patent [19]

Aldrich

[11] **4,119,591**

[45] **Oct. 10, 1978**

[54] **FRICTION MATERIAL REINFORCED WITH STEEL AND CELLULOSE FIBERS**

[75] Inventor: **Francis William Aldrich**, Troy, N.Y.

[73] Assignee: **The Bendix Corporation**, Southfield, Mich.

[21] Appl. No.: **812,541**

[22] Filed: **Jul. 5, 1977**

[51] Int. Cl.² **C08L 1/02**

[52] U.S. Cl. ..... **260/17.2**; 74/190; 188/218 R; 188/251 R; 188/251 A; 260/17.4 BB; 260/17.4 CL; 260/38; 260/42.17; 260/42.18

[58] Field of Search 260/17.2, 38

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3,959,194	5/1976	Adelmann	188/251 A

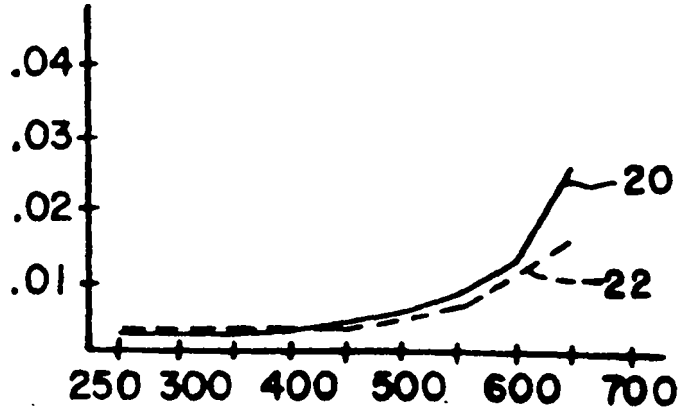
Primary Examiner—Edward M. Woodberry

Attorney, Agent, or Firm—Leo H. McCormick, Jr.; Ken C. Decker

[57] **ABSTRACT**

An asbestos free organic base friction material for use as a friction lining of a brake. A combination of fibers selected from a group consisting of steel, cellulose, glass mineral and rayon fibers and a thermosetting resin binder are combined with cashew nut particles, elastomeric modifiers and inorganic modifiers to produce an organic base friction material having a substantial stable coefficient of friction over the normal operating range of the brake.

10 Claims, 25 Drawing Figures



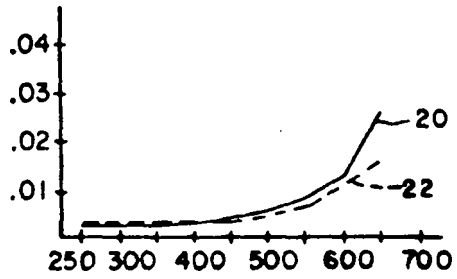


FIG. 1

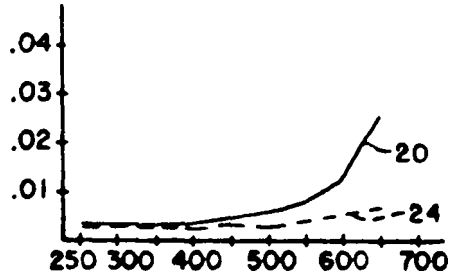


FIG. 2

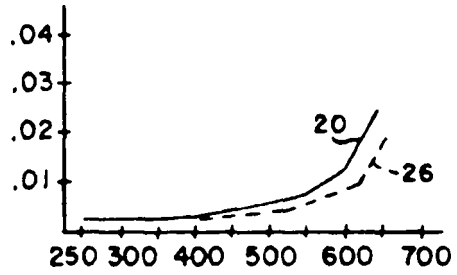


FIG. 3

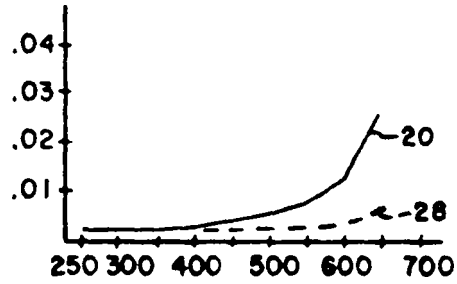


FIG. 4

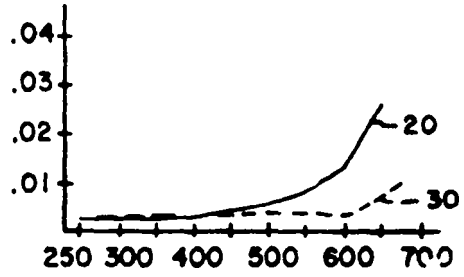


FIG. 5

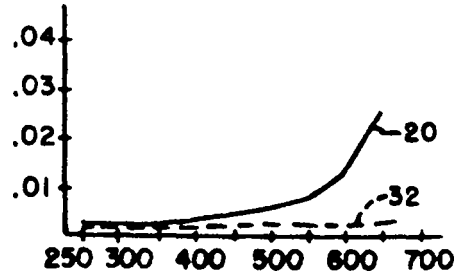


FIG. 6

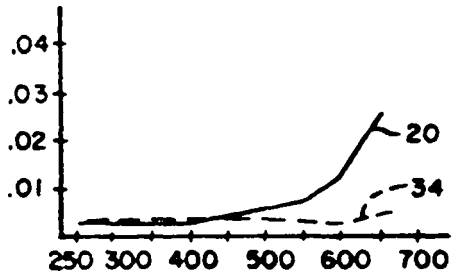


FIG. 7

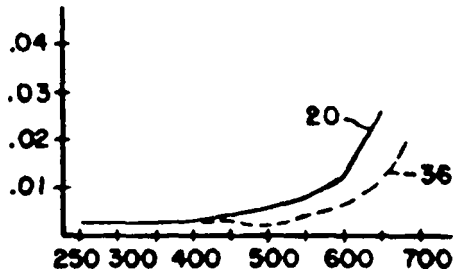


FIG. 8

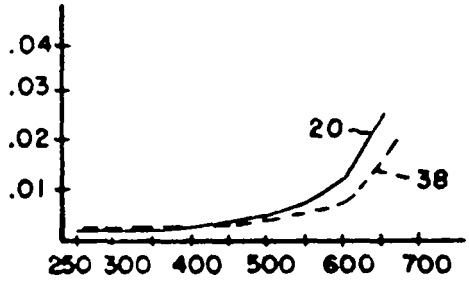


FIG. 9

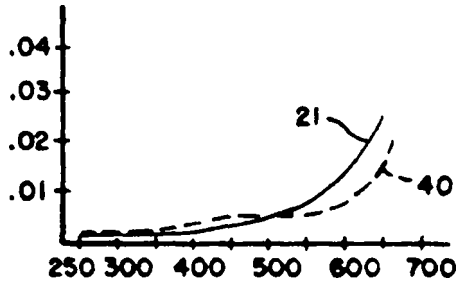


FIG. 10

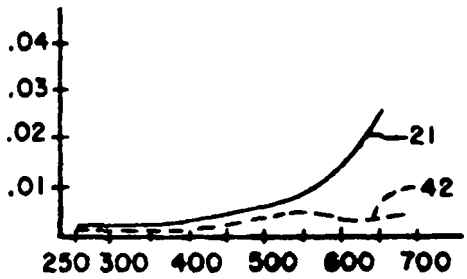


FIG. 11

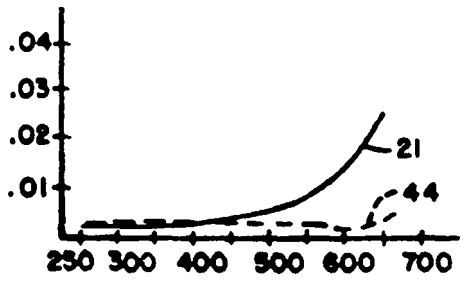


FIG. 12

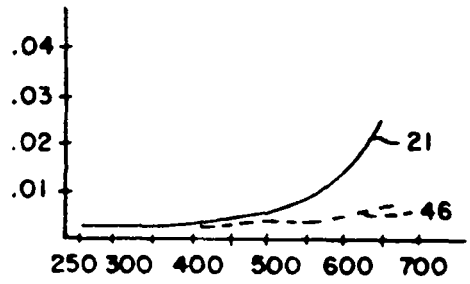


FIG. 13

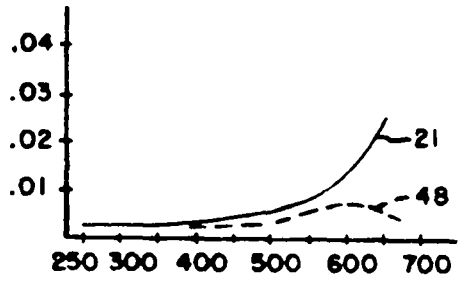


FIG. 14

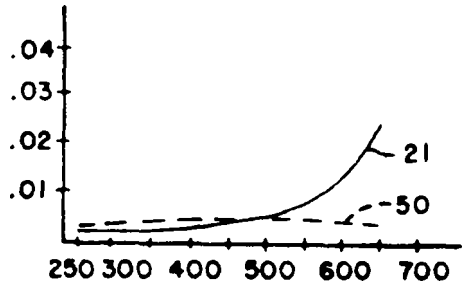


FIG. 15

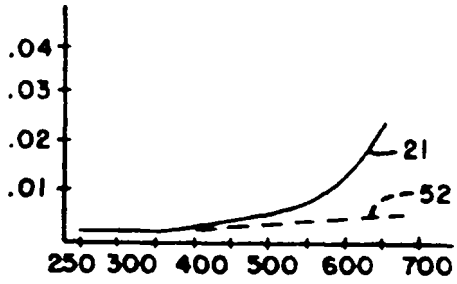


FIG. 16

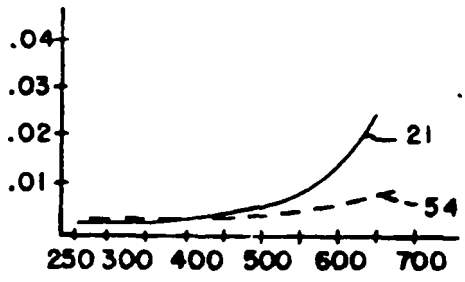


FIG. 17

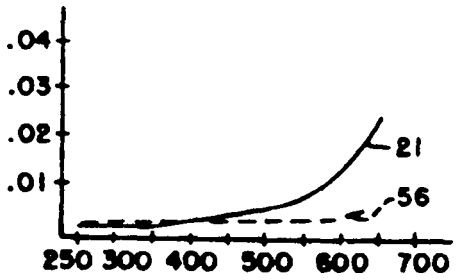


FIG. 18

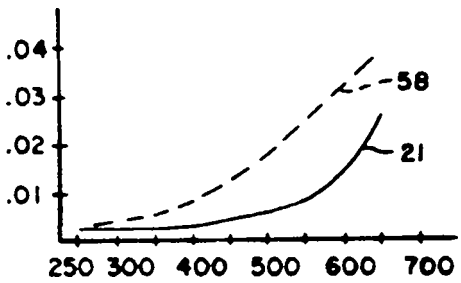


FIG. 19

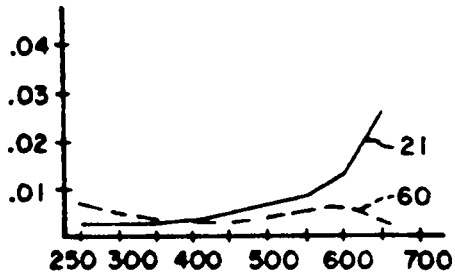


FIG. 20

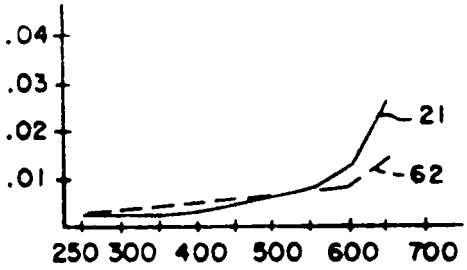


FIG. 21

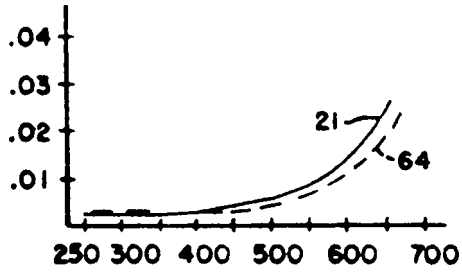


FIG. 22

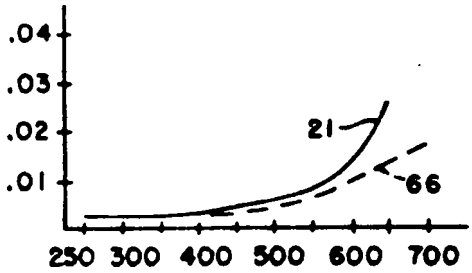


FIG. 23

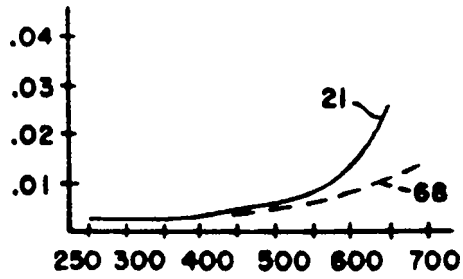


FIG. 24

FRICTION MATERIAL REINFORCED WITH STEEL AND CELLULOSE FIBERS

BACKGROUND OF THE INVENTION

Organic friction material compositions currently used in clutch and brake linings of vehicles must be capable of withstanding severe operating temperatures and dynamic pressures experienced during repeated applications. To prevent a deterioration in performance and physical degradation during an application, the linings are reinfoced by asbestos fibers randomly dispursed throughout a resin matrix. However, recent medical evidence indicates that asbestos fibers can cause health hazards of the lungs in persons exposed to asbestos fibers of the type used in the manufacture of clutch and brake lining. The health hazard is caused by the polution of the surrounding environment with small particles of asbestos during the mixing of the friction composition in a manufacturing facility.

In an effort to reduce the environment contamination by the asbestos fiber and thereby continue manufacturing asbestos based organic friction linings, a water slurry process is disclosed in U.S. patent application Ser. No. 754,477 has been evaluated. The water slurry can be transmitted throughout a manufacturing facility without contaminating the surrounding environment with asbestos fibers. However, before the friction material can be cured, the water in the slurry must be removed in order to be assured that any resulting lining has essentially the same operating characteristics as a lining made from a dry mix.

In another attempt to reduce the occupational health hazards in the manufacture of linings it has been suggested that the asbestos fiber be replaced with glass fibers.

U.S. Pat. No. 3,967,037 discloses several lining compositions utilizing fiber glass. From experimentaion it has been determined that such lining compositions are acceptable, however, in admixing the ingredients the fiber glass tends to ball and thereby reduce the continuity of the friction material. In addition, when fiber glass base friction materials are mated with a steel brake rotor or drum, an unacceptable wear condition occurs.

U.S. Pat. No. 3,896,075 discloses another friction composition wherein the asbestos in an organic lining is replaced with basalt fibers. Because of the process required to reduce the mineral basalt into a fiber state, the use of such friction composition to date has not received open acceptance as a substitute for asbestos based organic friction materials.

Later as disclosed in U.S. Pat. No. 4,019,912 the reinforcing of the structure of a resulting friction lining was achieved through the use of carbon fibers. However, the pyrolysis step required to reduce the rayon or cellulose fiber to a carbon fiber would destroy the elastomers and inorganic fillers found in organic friction compositions.

SUMMARY OF THE INVENTION

I have developed an organic friction material composition consisting of an asbestos free foundation material, organic and inorganic friction modifiers retained in a matrix of a thermosetting resin. The asbestos free foundation material includes as a minimum of 3 percent steel fiber and 5 percent cellulose fiber and other fibers such as carbon, mineral and fiber glass. The steel and cellulose fibers when randomly orientated and uniformly

dispursed throughout a friction lining provide sufficient strength to allow a friction lining made of the composition to withstand dynamic loadings without deteriorating under normal operating conditions.

It is therefore the object of this invention to provide an asbestos free organic friction lining with sufficient structural strength to repeatedly withstand dynamic loads without deteriorating when used in a brake lining.

It is another object of this invention to provide an organic friction material with a foundation material made up of a combination of at least 3 percent steel fiber and 5 percent cellulose fiber. The steel and cellulose fibers being dispursed throughout the friction material to uniformly distribute forces exerted on a brake lining and thereby prevent degradation thereof during repeated dynamic brake engagements.

It is another object of this invention for providing an organic friction material with a base material of steel fiber and cellulose fiber to establish a substantially uniform wear characteristic over the operating range of friction lining.

These and other objects should be apparent from reading this specification and viewing the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIGS. 1-24 of the drawing are graphs comparing the wear characteristics of the non-asbestos organic friction material composition made according to this invention with a typical asbestos organic friction lining; and

FIG. 25 is a table illustrating non-asbestos friction material composition made according to this invention

DETAILED DESCRIPTION OF THE INVENTION

In order to evaluate the non-asbestos friction material compositions disclosed by this invention, typical asbestos base friction material compositions were used as a standard to determine the wear rate and coefficient of friction characteristics of the non-asbestos base friction material when used in a brake.

FIG. 25 illustrates the relationships of the various combinations of the fibers substituted for asbestos as disclosed by this invention.

The ingredients in the asbestos and non-asbestos friction material formulations were processed into brake friction lining in the following manner as described in detail for the base line asbestos material composition A.

The asbestos fiber, dry phenolic resin, equal parts of cashew nut powder and synthetic rubber scrap and barytes were mixed together until a homogeneous mixture was achieved. Thereafter, the mixture was placed in a mold and compacted into a briquette. The briquette was then transferred to a press and compressed by a force of about 5,000 pounds per square inch while the temperature of the briquette was raised to about 250° F. temperature. The 250° F. causes the phenolic resin to flow throughout the mixture and establish a matrix for holding the other ingredients in a fixed position. The briquette was then transferred to a curing oven having a temperature of about 500° F. to further set the resin. The briquette was then ground to a specific size corresponding to a brake pad. This brake pad was then placed on a dynamometer and from the tests performed thereon it was established that the composition Formula A had an average coefficient of friction of 0.36 at 450° F. and a wear rate as illustrated by base line 20 shown in FIGS 1-9, 20 and 21

In order to establish a broader base for evaluating the non-asbestos friction material compositions, a second asbestos friction material identified as Formula B was compounded. In Formula B the large amount of asbestos in Formula A is replaced by additional cashew friction powder and a filler of graphite particles to produce a brake lining. The average coefficient of friction of Formula B a brake pad made from, using the same dynamometer test as used to evaluate Formula A was found to be 0.35 and the wear rate is illustrated by line **21** in FIGS. **10-19** and **22-24**

Upon initial evaluation of the non-asbestos friction materials it became evident that the removal of asbestos from the mixture left the remaining ingredients in a dry crumbly state during the briquette forming stage. Therefore, it was necessary to add part of the phenolic resin as a liquid to all the non-asbestos composition in order to produce a composition capable of being handled as a preformed briquette.

The non-asbestos friction material composition No 1 shown in FIG. **25** wherein a combination of steel fiber and cellulose fiber were substituted for the asbestos fiber was formulated in the same manner as Formula A and formed into a brake lining When the dynamometer tests were performed, composition No 1 had an average coefficient of friction 0 34 at 450° F and a wear rate illustrated by line **22** in FIG **1** As can be seen, the wear rate approaches that of the asbestos material of Formula a, which is currently accepted by the vehicle industry

In order to establish a group of inorganic fillers accepable for use in a non-asbestos friction material, talc was substituted for the whiting of composition No 1 and composition No 2 shown in FIG **25** was established The dynamometer test for the brake lining made from composition No 2 indicated than an average coefficient of friction of 0 30 at 450° F and a wear rate as illustrated by line **24** in FIG 2 could be expected from this composition

Because of the availability of barytes and its low cost, a series of compositions including barytes were developed

As shown in FIG **25**, composition No 3 was formulated When the brake lining made from composition No 3 was evaluated by the dynamometer test a coefficient of friction of 0.31 at 450° F was obtained and a wear rate illustrated by line **26** in FIG 3 was produced

Even though the wear rate of composition No 3 could be expected to be better than that of Formula A, it was felt that the coefficient of friction could be improved through the addition of either a different filler or fiber material Through experimentation it was determined that glass fiber has a higher coefficient of friction than cellulose fiber. Therefore, glass fiber was substituted for the cellulose fiber and composition No 4 shown in FIG **25** was produced. When the brake lining of composition No. 4 was tested through the dynamometer test, a coefficient of friction 0.35 at 450° F was produced and a wear rate illustrated by line **28** in FIG **4** was achieved. Unfortunately, with this amount of glass fiber in composition No. 4 surface polish or wear of a rotor or drum brake could be expected.

Therefore, the amount of glass firber was reduced and cellulose fiber added to produce composition No. 5 shown in FIG. **25**. When the resulting brake lining made by composition No. 5 was evaluated in the dynamometer test, a coefficient of 0.32 at 450° F. was obtained and a wear rate illustrated by line **30** in FIG **5** was achieved.

In an attempt to smooth out the wear rate of composition No. 5 as illustrated by line **30** in FIG. **5**, a filler of 3% by volume of carbon was added to composition No 5 to produce composition No. 6 in Table 1 The composition No. 6 was made into a brake friction lining and when evaluated in the dynamometer test, an average coefficient of friction of 0.28 at 450° F. was obtained and a wear rate illustrated by line **32** in FIG. **6** was produced.

In a further attempt to broaden the base for the inorganic filler modifiers, a composition No. 7 as shown in FIG. **25**, was produced In composition No. 7 a minimum of 3% by volume of rotten stone was added to the basic steel and cellulose fiber compositon. When the brake lining of composition No. 7 was tested on the dynamometer and an average coefficient of friction of 0.32 at 450° F. was obtained and a wear rate as illustrated by line **34** in Flg. 7 was achieved

In order to improve the wear rate of the non-asbestos friction material whiting was selected as the inorganic modifier, and composition No. 8 shown in FIG **25** was produced When the dynamometer test was run for the brake lining made from composition No 8, an average coefficient of friction of 0.30 at 450° F was obtained and a wear rate illustrated by line **36** in FIG **8** was produced

In an attempt to improve the coefficient of friction of composition No 8 the friction producing material kryolite was added thereto to produce composition No 9 shown in FIG **25** When the brake lining of composition No. 9 was evaluated in the dynamometer test, an average coefficient of friction of 0 37 at 450° F was obtained and a wear rate illustrated by line **38** in FIG. **9** was produced

Composition No 10 shown in FIG **25** includes the same type ingredients as Formula B with the exception of the asbestos friction material To establish broad base for the friction material and improve the coefficient of friction of the non-asbestos material the cellulose fiber was replaced with glass fiber When the brake lining composition No 10 was evaluated by the dynamometer test, an average coefficient of friction of 0 35 at 450° F was obtained and a wear rate illustrated by line **40** in FIG **10** was achieved From this test it was determined that while glass fiber when added to non-asbestos friction material compositions, does increase the coefficient of friction, however, the wear rate is also increased

Thereafter, composition No 11 shown in FIG **25** was developed with wood flour added in place of the glass fiber of composition No. 10 When the brake lining of composition No 11 was evaluated through the dynamometer test, a coefficient of friction 0 37 at 450° F was obtained and a wear rate as illustrated by line **42** in FIG. **11** was produced From this test it was determined that cellulose type fibers when combined with steel fibers produced a more satisfactory non-asbestos friction material composition than when a single fiber material is used.

Thereafter, an attempt was made to establish the optimum limits for steel, cellulose, and other fibers when used as the foundation material .or a non-asbestos friction material. Thus, composition No. 12 shown in FIG **25** was produced. In composition No 12, the volume of cellulose fiber was double that of the steel fiber When the brake lining made from composition No 12 was evaluated through the dynamometer test, a coefficient of friction of 0.35 at 450° F. was obtained and a wear rate as illustrated by line **44** in FIG 12 was

ORGANIC FRICTION MATERIAL COMPOSITION

INGREDIENTS		*TYPICAL ASBESTOS FRICTION MATERIAL FORMULAS A	B	NON-ASBESTOS FRICTION MATERIAL FORMULAS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ASBESTOS FIBER		52	43																								
STEEL FIBER				5	5	8	8	8	8	8	5	5	8	8	8	8	8	8	8	8	8	15	5	8	8	8	8
CELLULOSE FIBER				7	7	10		7	7	10	10	10			16	10	13	13	13	13	13					25	15
GLASS FIBER							5	3	3				10								3						
WOOD FLOUR														10													
PHENOLIC RESIN	DRY	25	16	15	15	17	20	20	20	20	17	20	20	18	20	25	20	20	20	20	20	20	20	20	17	20	18
	LIQUID			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	10
(a) ORGANIC MODIFIERS		22	34	Ø 47	Ø 47	Ø 45	Ø 47	Ø 45	Ø 42	Ø 45	Ø 43	Ø 40	Ø 45	Ø 48	Ø 40	Ø 40	Ø 40	Ø 40	Ø 40	Ø 40	Ø 40	Ø 45	Ø 45	Ø 45	Ø 40	17	25
(b) INORGANIC MODIFIERS		1	7	(1) 21	(2) 21	(3) 23	(4) 15	(5) 12	(6) 15	(7) 12	(8) 20	(9) 23	(10) 12	(11) 11	(12) 11	(13) 12	(14) 12	(15) 14	(16) 14	(17) 14	(18) 11	(19) 15	(20) 25	(21) 22	(22) 30	(23) 25	(24) 24

(a) CASHEW NUT POWDER, NATURAL RUBBER, SYNTHETIC RUBBER SCRAP, LATEX, CRUDE MOLASSES, ASPHALTIC BASE MATERIAL, ETC.

(b) BARYTES, WHITING, TALC, ROTTEN STONE, CARBON PARTICLES, GRAPHYTE PARTICLES, CRYOLITE, IRON OXIDE, COPPER POWDER, WOLLASTONITE, KRYOLITE, ETC.

* ALL PERCENTAGES GIVEN IN VOLUME OF TOTAL COMPOSITION

Ø AT LEAST 25% OF WHICH IS CASHEW NUT POWDERS

(1) AT LEAST 16% OF WHICH IS WHITING
(2) AT LEAST 16% OF WHICH IS TALC
(3) AT LEAST 10% OF WHICH IS BARYTES
(4) AT LEAST 15% OF WHICH IS BARYTES
(5) AT LEAST 12% OF WHICH IS BARYTES
(6) AT LEAST 3% OF WHICH IS CARBON
(7) AT LEAST 3% OF WHICH IS ROTTEN STONE
(8) AT LEAST 11% OF WHICH IS WHITING
(9) AT LEAST 3% OF WHICH IS KRYOLITE
(10) AT LEAST 12% OF WHICH IS BARYTES
(11) AT LEAST 11% OF WHICH IS BARYTES
(12) AT LEAST 11% OF WHICH IS BARYTES
(13) AT LEAST 12% OF WHICH IS BARYTES
(14) AT LEAST 3% OF WHICH IS CRYOLITE
(15) AT LEAST 3% OF WHICH IS ROTTEN STONE
(16) AT LEAST 3% OF WHICH IS IRON OXIDE
(17) AT LEAST 3% OF WHICH IS COPPER POWDER
(18) AT LEAST 11% OF WHICH IS BARYTES
(19) AT LEAST 5% OF WHICH IS WOLLASTONE
(20) AT LEAST 5% OF WHICH IS CARBON
(21) AT LEAST 12% OF WHICH IS BARYTES
(22) AT LEAST 10% OF WHICH IS SILANIZED MINERAL FIBER
(23) AT LEAST 25% OF WHICH IS BARYTES
(24) AT LEAST 10% OF WHICH IS CARBON

FIG. 25

produced Unfortunately, composition No. 12 was spongy and therefore, it was determined that the cellulose fiber should be reduced.

Thereafter, the cellulose fiber of composition No 12 was reduced to produce composition No. 13 shown in FIG 25. A brake lining made from composition No. 13 was evaluated in the dynamometer test, had an average coefficient of friction of 0.32 at 450° F. and a wear rate as illustrated by line 46 in FIG 13. This composition was not spongy, however, it should be noted that the coefficient of friction was reduced.

Therefore, in order to increase the coefficient of friction, cryolite was added to the composition No. 13 and composition No. 14 shown in FIG. 25 was produced. A brake lining made from composition No. 14 was evaluated through the dynamometer test had an average coefficient of friction of 0.37 at 450° F. and a wear rate illustrated by line 48 in FIG. 14.

Since the wear rate and coefficient of friction of composition No 14 was much improved over Formula B, the organic modifier base was expanded through the substitution of rotten stone for the cryolite to produce composition No 15 shown in FIG. 25 When a brake lining made of composition No 15 was evaluated through th dynamometer test, an average coefficient of friction of 0 33 at 450° F was obtained and a wear rate illustrated by line 50 in FIG 15 was produced.

Composition No 14 was further expanded through the substitution of iron oxide for the cryolite to produce composition No. 16 shown in FIG. 25 When a brake lining made of composition No 16 was evaluated through the dynamometer test, a coefficient of friction of 0 34 at 450° F was obtained and a wear rate as illustrated by line 52 in FIG 16 was produced

Composition No 14 was still further expanded through the substitution of copper powder for the cryolite and glass fiber to produce composition No 17 shown in FIG 25 A brake lining made from composition No 17 when evaluated through the dynamometer test had a coefficient of friction of 0.34 at 450° F and a wear rate as illustrated by line 54 in FIG 17.

Composition No 14 was still further expanded through the addition of fiber glass to the base material to produce composition No 18 shown in FIG 25 A brake lining made from composition No 18 when evaluated through the dynamometer test had a coefficient of friction of 0.37 at 450° F and a wear rate as illustrated by line 56 in FIG 18

In order to establish relationship between steel fiber and cellulose fiber in the non-asbestos friction material, the cellulose fiber was eliminated from the basic composition and composition No 19 shown in FIG 25 was produced In an attempt to provide composition No. 19 with an adequate coefficient of friction, at least 5% by volume of Wallastonite was added to the composition A brake lining made from composition No 19 when evaluated through the dynamometer test, had a coefficient of friction of 0.32 at 450° F. and a wear rate illustrated by line 58 in FIG. 19.

As seen in FIG. 19, the wear rate for composition No. 19 was not as good as asbestos Formula B. Thus, the steel fiber in composition No. 19 was reduced and carbon particles were added to produce composition No. 20 as shown in FIG. 25. When a brake lining made of composition No. 20 was evaluated through the dynamometer test, a coefficient of friction of 0.37 at 450° F. was obtained and a wear rate illustrated by line 60 was produced. In some applications in order to achieve structural strength in the friction lining, the carbon particles can be replaced with carbon fibers.

In a further attempt to establish a base for the inorganic friction modifiers, the volumetric percentage of the steel fiber was increased and a minimum volumetric percentage of barytes was established at 12% to produce composition No. 21 shown in FIG 25. When a brake lining made from composition No. 21 was evaluated through the dynamometer test a coefficient of friction of 0.32 at 450° F. was obtained and a wear rate illustrated by line 62 in Fig. 21 was produced.

Thereafter, the steel fiber was maintained at 8% by volume and silanized mineral fiber was added to produce composition No. 22 shown in FIG. 25. A brake lining made from composition No 22 was produced, and when evaluated in the dynamometer test a coefficient of friction of 0.28 at 450° F., and a wear rate as illustrated by line 64 in FIG. 22 was produced.

From the foregoing test it should be evident that the range of steel fiber should be maintained between 3 to 15 volume percent of the total mixture. However, since the optimum range of cellulose and other fibers had not been established, therefore, composition No. 23 shown in FIG 25 was devised. In composition No. 23 the cellulose fiber was increased to a maximum of 25 percent of the total volumetric percentage of the composition while at the same time the cashew nut powder was reduced to 15% When a brake lining made from composition No. 23 was evaluated through the dynamometer test, a coefficient of friction of 0.45 at 450° F was obtained and a wear rate as illustrated by line 66 in FIG. 23 was produced. As seen, composition No 3 almost matches the wear rate for currently acceptable asbestos lining and could be accepted by most vehicle manufacturers without extended qualification testing Thus, the industry would be able to meet the Federal Clean Air and Health Standards of 1975 within the prescribed time set for compliance.

To substantiate the results of composition No 23 another composition No. 24 shown in FIG 25 was prepared by reducing the percentage of cellulose fiber while increasing the resin content and substituting carbon in powder form for a portion of the barytes Thereafter, when a friction lining made from composition No 24 was evaluated through the dynamometer test, a coefficient of friction of 0.28 at 450° F was obtained and a wear rate as illustrated by line 68 in FIG 24 was produced

From the foregoing compositions it was determined that while steel and cellulose fiber produce an acceptable non-asbestos friction material, when combined together with inorganic modifiers, which can include glass, mineral and carbon fibers produce a friction material with a substantially uniform wear rate throughout the operating range of most brake linings

I claim.

1. An organic friction material for use as a friction lining consisting of a mixture of:

8-50% by volume of a combination of non-asbestos fibers selected from a group consisting of fiber glass, mineral fiber, at least 3% by volume of steel fibers, and at least 5% by volume of cellulose fibers,

12-35% by volume of thermosetting phenolic resin,

5-35% by volume of cashew nut particles;

3-20% by volume of elastomeric modifiers; and

10-55% by volume of inorganic modifiers, said thermosetting phenolic resin being responsive to heat to form a matrix for holding said non-asbestos fibers,

cashew nut particles, elastomeric modifiers and inorganic modifiers in a fixed relationship, said non-asbestos fibers and phenolic resin matrix providing structural strength for allowing the friction lining to withstand dynamic repeated engagements with a rotating member and providing a substantially uniform wear rate up to 600° F. during a dynamic engagement.

2. The organic base friction material, as recited in claim 1, wherein said phenolic resin includes at least 12% dry phenolic resin powder.

3. The organic base friction material, as recited in claim 2, wherein said phenolic resin includes up to 18% liquid phenolic resin to attenuate segregation of said elastomeric and inorganic modifiers prior to the application of heat to the mixture

4. The organic base friction material as recited in claim 3, wherein said elastomeric modifiers is selected from a group consisting of natural and synthetic rubber scrap, natural latex, crude molasses, and asphalt

5. The organic base friction material, as recited in claim 4, wherein said inorganic modifiers are selected from a group consisting of barytes, whiting, talc, rottenstone, wollastonite, pumice, iron oxide powder, copper oxide powder, carbon and silanized mineral particles.

6. The organic base friction material as recited in claim 1 wherein said non-asbestos fibers include up to 10% fiber glass fibers.

7. The organic base friction material, as recited in claim 1, wherein said non-asbestos fibers include up to 10% wood flour fibers.

8. The organic base friction material, as recited in claim 1 wherein said non-asbestos fibers include up to 10% silanized mineral fibers.

9 The organic base friction material, as recited in claim 1 wherein said non-asbestos fibers include up to 10% carbon fibers.

10. The organic base friction material as recited in claim 1 wherein said phenolic resin includes at least 5% liquid resin

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Friction Materials for Small Car Solid Rotor Applications

John P. Kwolek
Automotive Control Systems Group, Bendix Corp.

WITH CONSUMER INTEREST in lower priced vehicles and improved fuel economy on the increase, domestic vehicle manufacturers are giving more serious thought towards producing sub-compacts (vehicles having curb weights less than 2600 lbs.). Foreign vehicle manufacturers have produced vehicles equipped with solid rotor disc brakes in this weight category for over a decade, but most American manufacturers have been hesitant to use the solid rotor disc brake systems found on a majority of these lighter weight cars due to several factors.

From the brake engineer's point of view, while solid rotors offer lower cost, the ventilated rotor offers substantial improvement in brake cooling over solid rotors thereby lowering the brake lining temperatures encountered during usage. The front brake temperature profile for a durability test of a 1973 Domestic Disc-Drum Station Wagon is illustrated in Figure 1. This vehicle had standard ventilated rotors, which weigh 27 lbs. each; the brake test weight was 5860 lbs.; operating temperatures generally ranged between 150° and 340°F. The same durability test was also conducted on a 1973 European made vehicle equipped with 4-wheel disc brakes. Brake test weight of this vehicle was 2800 lbs., with the solid rotors weighing only 6 lbs. each. A comparison of the front brake temperature profile for this vehicle (see Figure 2) with that of the 5860 lbs. Station Wagon test indicates the average brake lining temperatures increased 75°F, with peak temperatures 150° hotter than those experienced on the heavier station wagon.

Several differences can explain these results with the most influential factor being rotor weight and design. The purpose of discussing these temperature profiles is to emphasize the fact that the lighter weight vehicles equipped with solid rotors require linings which can successfully operate at higher temperatures than those experienced on the heavier domestic vehicles presently produced with ventilated rotors.

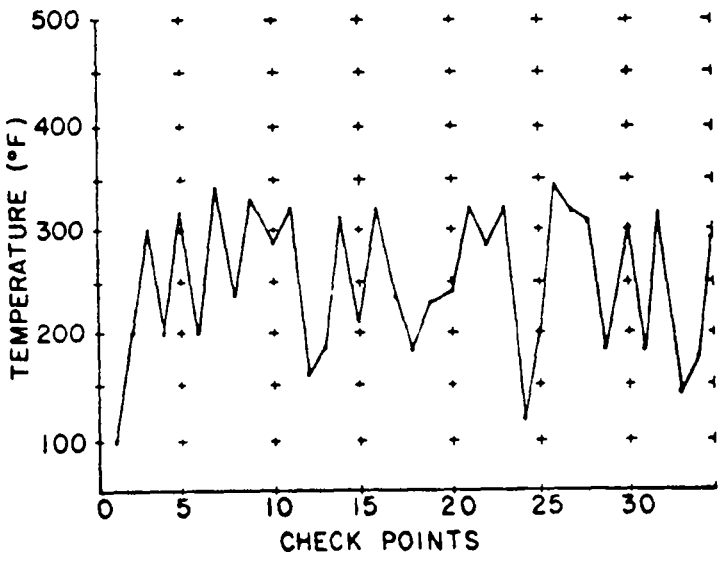


Fig. 1-Average front brake temperature profile, 1973 station wagon @ 5860 lb G.V.W., ventilated rotors, 11 cycles

ABSTRACT

Semi-metallic friction materials recently developed offer significant improvements in lining life, rotor compatability and noise over organic friction materials on small cars equipped with solid rotors. Improvements originally predicted from full brake inertia dynamometer tests have been verified on vehicle durability and fleet tests.

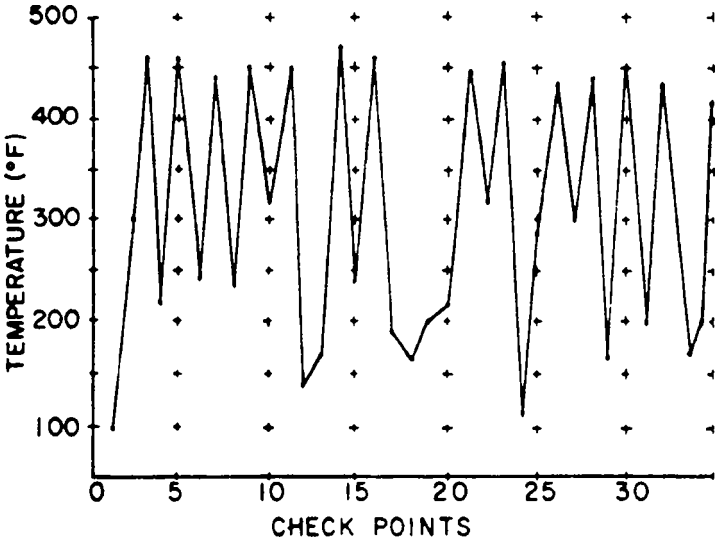


Fig. 2-Average front brake temperature profile, 1973 sedan @ 2800 lb G.V.W., solid rotors, 11 cycles

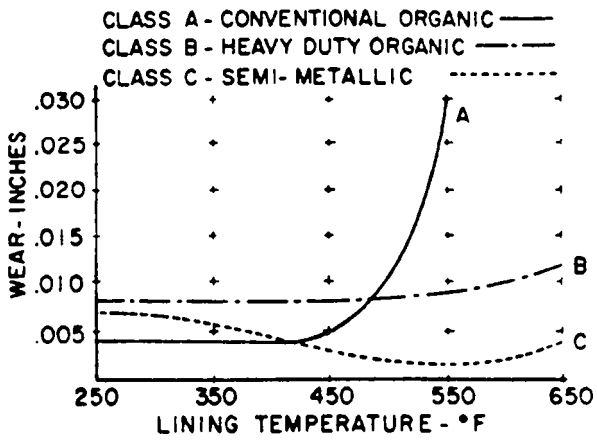


Fig. 3-Average wear versus temperature characteristics, inertia dynamometer, 1740 lb wheel load, ventilated rotor

TYPES OF FRICTION MATERIALS

Friction materials are designed for specific applications, with the composition and method of manufacture determining the particular properties of any specific material. The primary function of the friction material is to produce a relatively high constant coefficient of friction under the conditions anticipated in use. The friction material must also exhibit excellent resistance to wear and opposing surface compatability under these same conditions. A previous classification of friction materials (1)* gives some insight into the fundamental compositional differences and how these differences affect friction and wear in brake lining presently used by vehicle manufacturers.

The organic friction materials presently used on domestic passenger cars equipped with ventilated rotors, which are referred to as Class A materials, are fundamentally organic in nature excluding their inorganic asbestos content. "As a class, these materials are reasonably quiet, give respectable durability and, under most conditions, perform their frictional purposes ..." namely, maintain acceptable friction and fade resistance.

Class A type friction materials are not generally found on solid rotor applications because:

1. Lining wear rates increase exponentially at the higher operating temperatures (Figure 3).

2. They exhibit more fade and over recovery when compared to Class B organics or semi-metallics (Figure 4).

Organic friction materials designed for heavy duty (Class B) generally have higher inorganic contents to improve their high temperature wear resistance and fade resistance. Abrasives are generally added to achieve higher friction. Historically, these types of materials have been used on solid rotor applications because they are more suited to higher operating temperatures than Class A type organics (Figure 3) and the fade performance (Figure 4) demanded by this class of vehicles.

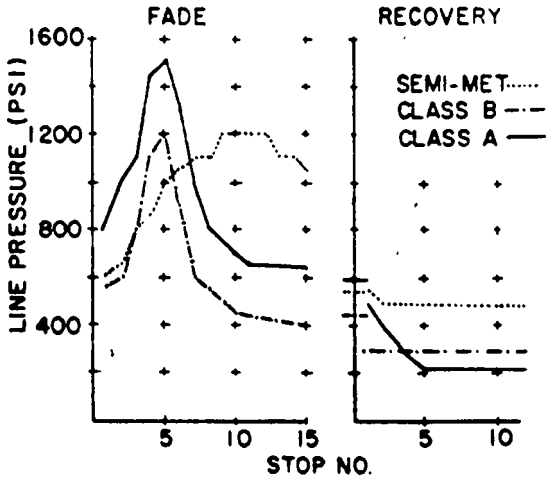


Fig. 4-Green fade and recovery, 1973 sedan @ 2800 lb G.V.W., 4 solid rotors, (fade 60 mph, 15 fpsps, 35 second interval), (recovery 30 mph, 10 fpsps, 1 mile interval)

*Numbers in parentheses designate References at end of paper.

But, as so commonly found in friction material development, improvements in one area usually results in losses in other areas. Class B materials generally exhibit higher low temperature wear rates, and frequently either groove, score or wear the mating rotor surfaces. They are also quite prone to generate objectional noise.

The success of sintered metallic-ceramic friction materials for specialized applications such as Jet Aircraft Brakes, Heavy Duty Clutch Facings and Police and Racing Car Brakes suggested metallic composites would some day find usage in Automotive Braking Markets if refinement could be made. Semi-metallics, the third class of materials, rely heavily on iron, steel and graphite substitutions for the organic and asbestos materials usually found in the Class A materials. But, unlike the sintered metallics, semi-metallics can use organic components to add desirable properties. As in all friction materials, the use of abrasives must be minimized in order to maintain acceptable mating surface compatability.

HISTORY OF SEMI-METALLICS

The semi-metallic formulations developed in the 60's for heavy duty ventilated rotor applications were first released on foreign vehicles equipped with solid rotors. These vehicle manufacturers released semi-metallic formulations for police cars and quickly expanded their usage to taxi cabs and a few vehicles sold to the general public.

In 1970 domestic manufacturers released semi-metallic formulations for the front (ventilated rotors) disc brakes of police cars based on the success of these materials in meeting Los Angeles Police Dept. Braking Standards.(2) By this time the advantages of semi-metallics over conventional organics were clearly understood:

1. Improved friction stability.
2. Improved fade resistance.
3. Excellent high temperature wear resistance.
4. Minimal speed spread.
5. Excellent compatability with rotors.
6. High performance with minimal noise.

Even these with advantages, widespread usage could not be anticipated on domestic vehicles sold to the general public because of the additional costs. Raw material mix cost represents the major factor in the premium prices of semi-metallics. These compounds generally weigh approximately twice as much as Class A organics and use materials which cost more per pound than those found in conventional Class A organics. The smaller sized pads used in small car solid rotor applications drastically reduce the affects of raw material mix cost and semi-metallics can be competitive with many of the higher priced heavy duty (Class B) organics on small cars.

With the advent of FMVSS 105-75 testing, it became apparent that, while semi-metallics showed excellent friction stability from 2nd through 4th effectiveness, the pre-burnished friction had to be improved.

Still another area of concern was initial wear (referred to by some as low temperature wear). One particular type of dynamometer test procedure, a wear versus temperature schedule, indicated higher wear rates than those experienced with conventional organics at low temperatures. Subsequent dynamometer tests and microscopic examination of the materials proved this to be an initial wear problem and that conditioning of the lining at higher temperature and by extended usage dramatically improves lining life at low temperatures (see Figure 5). The analysis of numerous vehicle tests conducted confirmed that the wear rate of semi-metallic formulations improves with usage (see Figure 6).

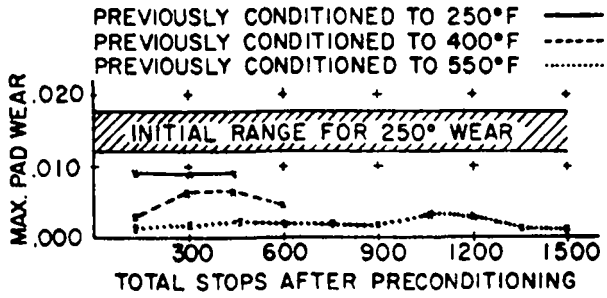


Fig. 5-Effects of preconditioning semi-metallic on subsequent low temperature incremental wear, inertia dynamometer, 1740 lb wheel load, ventilated rotor, all stops from 50 mph, 12 fpsps deceleration

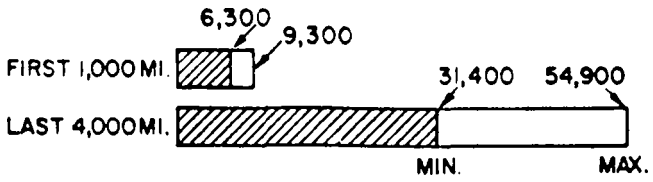


Fig. 6-Incremental mileage projections for Detroit Durability of Semi-Metallic, 1973 domestic sedan, 5560 lb G.V.W.

Even with this knowledge, the development program for semi-metallics concentrated on improving pre-burnished friction and initial wear characteristics. The program led to significant improvements and resulted in the issuance of a patent (3) for this new type of material. Pre-burnished front torque was increased 20% and initial low temperature wear rates were decreased to levels comparable to those obtained with conventional Class A or-