FILE NAME: Phenolic Resins (PHR)

DATE: 1974

DOC#: PHR052

DOCUMENT DESCRIPTION: Patents from Bendix; from AS Bendix File ganics. Vehicle tests also showed a reduction in noise levels, an unexpected bonus!

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.

SMALL CAR SOLID ROTOR APPLICATIONS

As previously discussed, one of the prerequisites of a friction material is its ability to resist wear under various temperatures it will experience in service. We also have seen that smaller cars equipped with solid rotors will subject the friction materials to a wider range of temperatures than the materials used on larger cars equipped with ventilated rotors. It has been our experience that reasonably good predictions of durability life can be made knowing the wear versus temperature characteristics of any material.

The effects which rotor weight and brake configuration have on operating conditions can easily be observed or measured with a Full Brake Dynamometer. A procedure which has been used consists of a series of braking cycles at six different initial brake temperatures. Each cycle is comprised of 300 stops made from 50 mph at 12 fpsps deceleration. The time interval between stops is varied to maintain a constant initial rotor soak temperature. The initial rotor soak temperature is increased from 250° to 625°F in 75° increments. After the 625° cycle, a 250° cycle is repeated to establish the low temperature wear rate after severe usage. The linings are measured after each cycle and the incremental wear plotted. The total rotor wear experienced for the 2400 stop test is also recorded.

The data illustrated in Figure 7a, b and c, were accumulated using a 9" diameter solid rotor, 0.375" thick weighing 6 lbs. Wheel load used was 975 lbs.

The results clearly show the wear superiority of the semi-metallics over both the Class A and Class B organics. While the total rotor wear for both the Class A and Semi-metallic formulations were comparable, the Class B materials showed considerably higher opposing surface wear.

Another inertia dynamometer wear procedure used by some European manufacturers to screen potential friction materials is a series of 4 cycles consisting of 250 snubs, from 50 to 17 mph (13 ft/sec^2 deceleration) in which the time intervals between applications is held constant at 95 seconds. Temperatures generated on this schedule are relatively low, usually peaking at about 250°F for the brake outlined above. As in the previously discussed wear versus temperature data, the semi-metallics showed distinct advantages over both the Class A and Class B organics (see Figure 8).

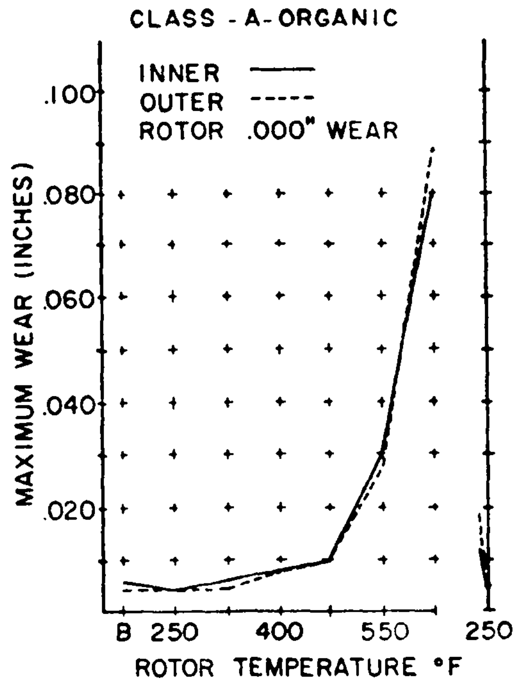

Fig. 7A-Wear versus temperature, inertia dynamometer, 975 lb wheel load, solid rotor

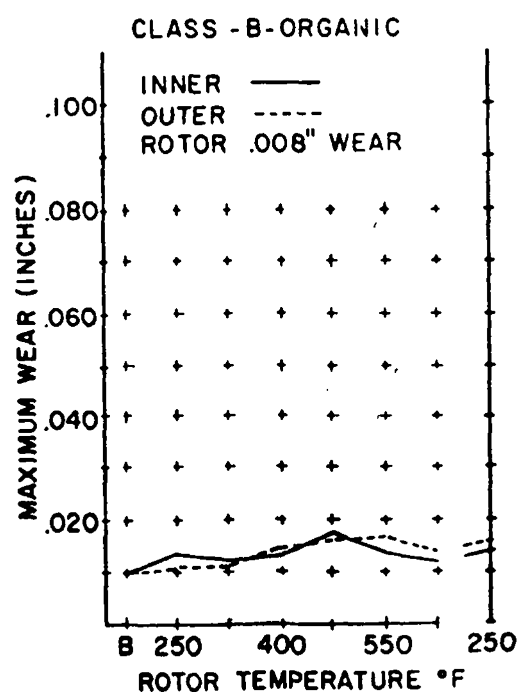

Fig. 7B-Wear versus temperature, inertia dynamometer, 975 lb wheel load, solid rotor

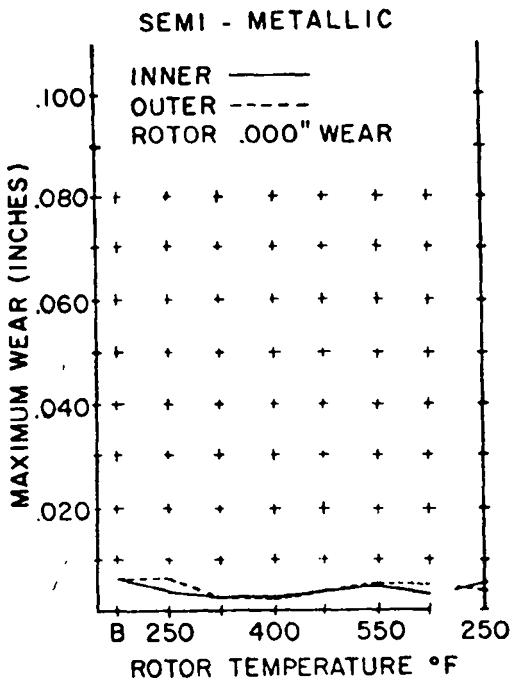

Fig. 7C-Wear versus temperature, inertia dynamometer, 975 lb wheel load, solid rotor

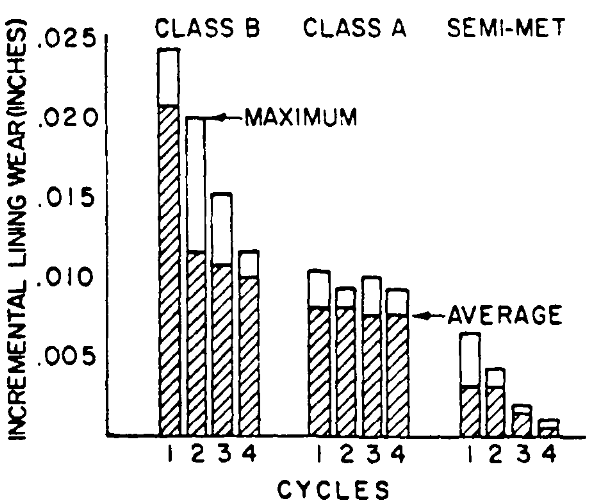

Fig. 8-Incremental lining wear, inertia dynamometer simulation of 2800 lb G.V.W., sedan running low temperature durability

In the introduction, front brake temperature profiles were outlined (Figure 2) for a durability test of a vehicle equipped with solid rotors having a brake test weight of 2800 lbs. Tests conducted on Class A, Class B organics and semi-metallics using this vehicle procedure have repeatedly verified that semi-metallics offer distinct improvements in lining life. The results illustrated in Figure 9 confirm the incremental wear rates previously found in full brake dynamometer tests. The differences between front and rear brake mileage projections are due to the differences in operating temperatures and lining availability. Rear brake operating temperatures were approximately 100°F below the front brakes thereby drastically improving the wear rates of the Class A organic. In the case of the Class B organic and semi-metallics, the lower rear brake mileage projections are the result of differences in available lining thickness.

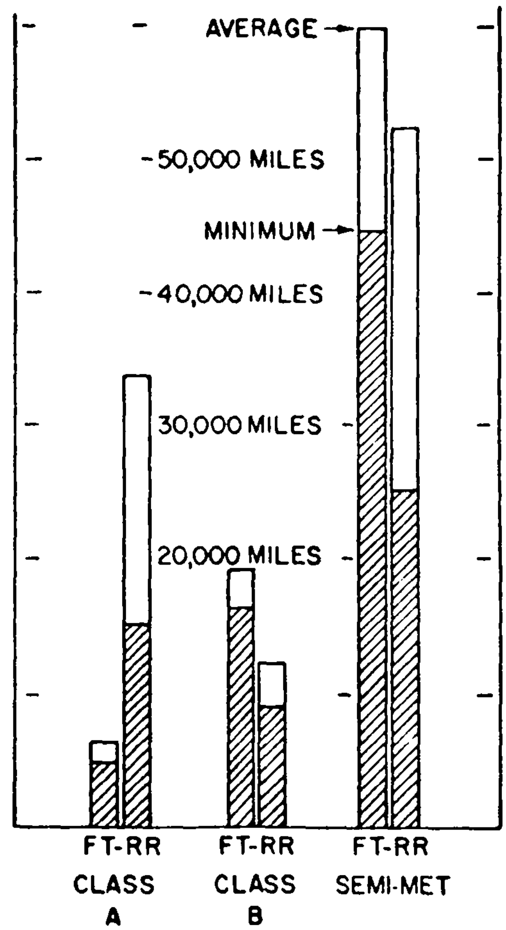

Fig. 9-Mileage projections, 2500 mile durability test, 1973 sedan, 2800 lb G.V.W.

The particular brake system evaluated utilized front brakes lined with pads 0.475" thick while the rear brakes had pads which were 0.185" thick. It is interesting to note that similar tests on larger cars equipped with ventilated rotors rarely show life projections over 30,000 miles.

Significant reductions in noise levels were noted when semi-metallics were compared to the Class B organics. While specific noise hunts detected brake noise ratings as low as "7" for the semi-metallics, the Class B organics showed unacceptable noise ratings as low as "4" (see SAE J1060). Further improvement . in noise rating levels were achieved when typical U.S. type insulators were added to the back of the steel shoes.

A series of vehicle tests were initiated over a year ago in Europe in which a new semi-metallic formulation was installed on vehicles subjected to three different types of duty and were compared to a typical O.E. organic lining:

1. Taxi cabs having automatic and standard transmissions.
2. Rental cars.
3. Business travelers (described as country driving).

The estimated annual driving ranges from 12,500 miles (20,000 km) for rental cars to 25,000 miles (40,000 km) for taxi cabs and business travelers. The results tabulated below (Table 1) indicate the semi-metallics reduced lining wear rates significantly, showing 250 to 430% improvement.

With respect to rotor wear the semi-metallic offered similar advantages over the Class B organic (see Table 2).

SUMMARY

The performance and wear advantages of semi-metallic linings over conventional organic types have previously been established. More recent development has made them more comparable for initial friction and low temperature or initial wear characteristics.

The high temperature wear capacity of semi-metallic linings enhances their potential for usage on smaller cars with solid rotor brakes. Actual vehicle comparisons have shown substantial improvements over Class B type organics for projected lining life, rotor life, and noise characteristics under a variety of usage conditions.

The gains in lining and rotor life offered by semi-metallics would appear to make them a most viable and cost effective candidate for use on small cars with solid rotor brakes and relative small lining pad areas.

REFERENCES

1. F. William Aldrich, "Semi-Metallics: A New Type of Friction Material." SAE Paper #710591, June 7-11, 1971.
2. G. R. Wynne, "Development of Police Car Brake Standards." SAE Paper #750397, Feb. 24-28, 1975.
3. Seong Kwan Rhee & John P. Kwolek, U.S. Patent #3,835,118, Sept. 10, 1974.

Table 1 - Lining Wear Rates (MM/1000 Km.)

	Taxi Cabs Automatic	Taxi Cabs Manual	Car Rentals	Business Travelers
Class B Organic (O.E.)	6.5	4.0	1.5	1.5
Semi-Metallics	1.5	1.5	0.5	0.5

Table 2 - Rotor Wear Rates (MM/10,000 Km.)

	Taxi Cabs Automatic	Taxi Cabs Manual	Car Rentals	Business Travelers
Class B Organic (O.E.)	0.57	0.33	0.12	0.10
Semi-Metallics	0.02	0.02	0.06	0.04

United States Patent [19]

Rhee et al.

[11] **3,835,118**

[45] **Sept. 10, 1974**

[54] **SPONGE IRON FRICTION MATERIAL**

[75] Inventors: **Seong Kwan Rhee**, Southfield, Mich.; **John P. Kwolek**, Troy, N.Y.

[73] Assignee: **The Bendix Corporation**, South Bend, Ind.

[22] Filed: **May 14, 1973**

[21] Appl. No.: **360,255**

[52] U.S. Cl. **260/38**, 51/298, 106/36, 106/290, 260 DIG. 39

[51] Int. Cl. **C08g 51/08**

[58] Field of Search 106/36, 290; 260 DIG. 39, 260/38

[56] **References Cited**

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Assistant Examiner—P. R. Michl

Attorney, Agent, or Firm—Leo H. McCormick, Jr.; William N. Antonis

[57] **ABSTRACT**

A semi-metallic friction material for use in a vehicle brake as a friction lining or pad. The semi-metallic friction material utilizes the abrasive surface produced in coarse sponge iron to provide a high coefficient of friction and good wear resistance up to 250°F to compliment the coefficient of friction and wear resistance capable of being produced by the interaction of metallic and ceramic powders, steel fibers, rubber particles and graphite above 250°F.

7 Claims, 2 Drawing Figures

PATENTED SEP 10 1974

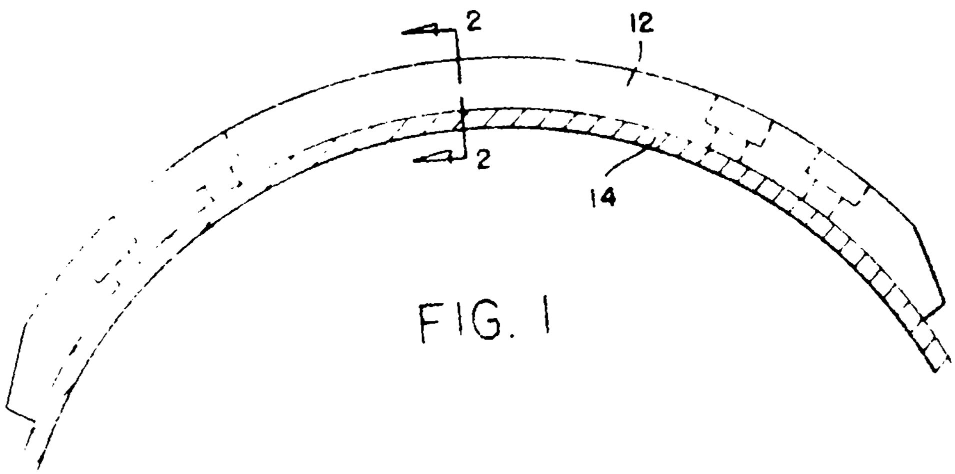


FIG. 1

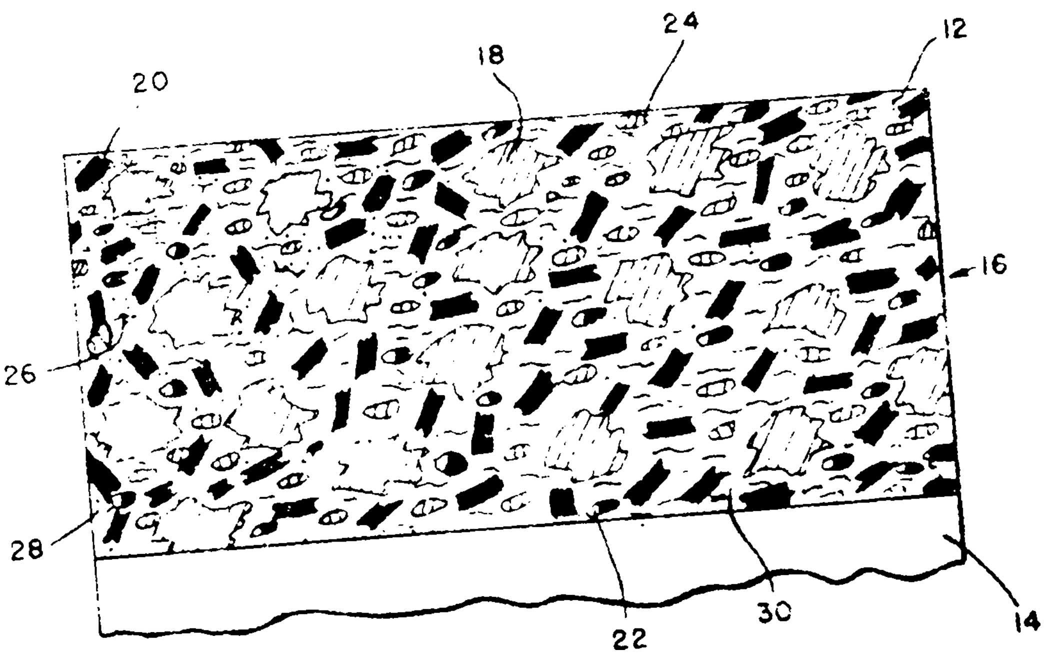


FIG. 2

SPONGE IRON FRICTION MATERIAL

BACKGROUND OF THE INVENTION

Friction materials consisting of graphite, metallic, ceramic and rubber powders held together by a thermosetting resin have been used as brake pads in braking systems to provide a uniform coefficient of friction without excessive fade. Such a brake lining material is fully described in U.S. Pat. No. 3,434,998 incorporated herein by reference.

The Department of Transportation of the U.S. Government has proposed that acceptable safe braking distances be reduced. It has been determined that if an organic friction material, such as that disclosed in U.S. application Ser. No. 309,011, incorporated herein by reference, could be modified to provide a high coefficient of friction immediately upon engagement of the wear pads with a mating brake surface, the proposed standards could be met. Frictional modifiers having higher coefficient of friction were tried, however, undesirable side effects such as noise, poor wear, fade, grooving in the mating surfaces and reduced structural strength resulted.

SUMMARY OF THE INVENTION

We have discovered a composition for a semi-metallic friction material wherein coarse sponge iron particles are utilized as a frictional modifier. The abrasive surface of the sponge iron will provide a brake lining with a high coefficient of friction upon initial engagement with a corresponding braking surface. Because the sponge iron particles are unannealed and coarse, initial burnish (low temperature wear) on the friction pad will be reduced. The irregular surface of the coarse sponge iron, which includes minute pin holes, will compliment the noise attenuating component in the semi-metallic friction material to essentially eliminate squeal associated during a frictional engagement. Since the sponge iron particles have a nominal size of between 20 to 80 mesh which tend to rupture under transverse loads, steel fibers in a proportioned relationship with the sponge iron particles are added to the semi-metallic friction material to provide structural unity for the brake lining.

It is, therefore, an object of this invention to provide a semi-metallic base material with a friction modifier consisting of coarse sponge iron particles to increase cold friction and reduce wear when used as a brake pad.

It is another object of this invention to provide a semi-metallic base material for a brake pad having coarse sponge iron particles as the principle component to compliment noise reducing ingredients therein in attenuating sounds created upon the brake pad engaging a corresponding brake member.

It is still a further object of this invention to provide a semi-metallic material having coarse sponge iron particles uniformly distributed therein to provide a high coefficient of friction at low temperatures and steel fibers therein to provide structural unity when the semi-metallic material is used as a brake pad.

It is still a further object of this invention to produce a semi-metallic friction material consisting of a mixture of metallic and ceramic powders, coarse sponge iron, graphite, rubber particles and steel fibers rigidly positioned in a resin matrix for use in a brake pad having a high coefficient of friction upon initial engagement with a corresponding brake member.

These and other objects will become apparent from reading this specification and viewing the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a friction pad for use in a brake assembly.

FIG. 2 is an enlarged view taken along line 2—2 of FIG. 1 illustrating the relationship of the compositional ingredients in the friction pad.

DETAILED DESCRIPTION OF THE PREFERRED COMPOSITION

Throughout this specification the terms metallic powder and ceramic powder are used to denote a material having a nominal size which will pass through a No. 80 mesh screen and consist of at least 85 percent of a base material with the balance being mainly oxides of the base material. Similarly the term "sponge iron" denotes a material having a nominal size, 85 percent of which will pass through a No. 20 mesh screen, yet will be retained on an 80 mesh screen, and consist of at least 90 percent metallic iron.

The brake pad **12** for a shoe **14** shown in FIG. **1** is constructed of a semi-metallic material whose principal ingredients are sponge iron, graphite and modifiers held together by a thermosetting phenolic resin which is then cured under heat and pressure to form a blended rigid mass **16**, as illustrated in FIG. **2**. While disc brake pads are not illustrated, test results indicate the same advantages can be found when this material is used on disc brakes.

The sponge iron particles **18** are irregular in shape with a surface having pin hole voids therein. The sponge iron is produced by a method known as the Sieurin process. In this process, powdered magnetite iron ore, carbon, coke and lime are charged in layers into covered crucibles. These ingredients are heated in kilns until reduction is complete. After cooling, the iron produced which is removed will have a physical appearance of a round porous cake about 10 inches in diameter and 2–2½ inches thick. The reduced sponge cakes are then crushed and disintegrated into particles. Hoeganaes Sponge Iron Corporation, Riverton, N.J. produces sponge iron particles that are unannealed, designated M 20/80, having a nominal size which can vary from 20 mesh to 80 mesh have proven satisfactory for brake pads. These sponge iron particles have an abrasive surface sufficient to provide a high coefficient of friction upon initial engagement of the pad **12** with a corresponding braking surface, yet are large enough to resist abrasive wear at low operating temperatures, thereby reducing low temperature wear.

A typical composition for the semi-metallic brake pad **12** is as follows:

	Volume Percent	Volume Percent
Metallic powders (copper, iron & zinc)	[illegible]	0 to 30
Sponge Iron Particles	2[illegible]	10 to 45
Ceramic Powders (sillimanite, mullite, magnesium oxide, barium sulfate, aluminum oxide and [illegible], silica, iron oxide)	[illegible]	2 to 15
Steel Fiber		0 to 20
Rubber particles	[illegible]	[illegible]
Graphite	[illegible]	10 to [illegible]

-Continued

	Volume Percent	Volume Percent
Phenolic resin binder	25	13 to 41
	100%	

The ingredients are mixed together and formed into a desired shape. Then the mixture is placed in an oven where the resin is cured to hold the other ingredients in a fixed position with respect to each other. After curing the resin the material is shaped into a finished product such as the brake pad **12**. The relationship of the various ingredients are illustrated in FIG. 2 as follows: sponge iron particles **18**, graphite particles **20**, rubber particles **22**, ceramic powders **24**, steel fibers **26**, iron powder **28** and resin **30**.

Brake pads manufactured according to a formula as represented above were compared with brake pads of a conventional semi-metallic friction composition wherein the metallic powder constituted about 20% by volume of the total mixture with the following results:

Material	Coefficient of Friction				Wear (in × 10⁻³) for 300 Stops			
	250°F	325°F	475°F	550°F	250°F	325°F	475°F	550°F
Standard Semi-Metallic	0.32	0.34	0.33	0.32	25	15	5	10
Semi-Metallic Sponge Iron	0.38	0.36	0.35	0.32	10	8	5	10

The importance of providing an initially high coefficient for the brake pads can readily be realized from the following formula through which the effective braking distance on a level roadway may be approximated:

$$d = V^2/30f$$

where

d = braking distance in feet

V = initial speed, miles per hour

f = coefficient of friction between friction members such as brake pad and drum

Assuming that the coefficient of friction will remain substantially uniform the period of time required to bring a vehicle to a stop will be proportionally reduced.

As an example, assume identical vehicles wherein one has brake pads constructed of a standard semi-metallic material and the other of a semi-metallic material with sponge iron particles and both are traveling at 60 miles per hour, the effective braking distance will be as follows:

$$d = 60^2/(30 \times 0.32) = 3600/9.6 = 375'$$

$$d/\text{sponge iron} = 60^2/(30 \times 0.38) = 3600/11.4 = 306'$$

Thus the vehicle with the brake pads having a semi-metallic material with sponge iron particles therein exhibits a shorter effective braking distance which will conform to the proposed stopping distance of the Department of Transportation.

The wear resistance of conventional semi-metallics are equivalent to organic materials between 350° and 450°F and are superior to organics at temperatures above 450°F. However, one of the major obstacles to the accepetance 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. Average driving seldom results in temperatures above 325°F and is generally considered to generate brake temperatures of around 250°F. Thus, the wear rate of any potentially commercial friction material must be equivalent to organic materials at these lower operating temperatures. The use of coarse sponge iron particles has shown a significant reduction in both the 250°F and 325°F wear levels, thereby improving the chances for commercial acceptance.

As previously discussed, the proposed Department of Transportation reduction in acceptable safe brake stopping distances requires that the brake systems remain balanced throughout the test. This requires a friction material which will exhibit the same friction levels throughout the test. While conventional semi-metallic materials exhibit better friction stability than most organics throughout the test, one problem was found with conventional semi-metallic materials, that was low initial (pre-burnished) friction. As a result, conventional semi-metallic materials were unable to meet the pre-burnished stopping distances proposed by the Department of Transportation. The use of coarse sponge iron particles in semi-metallics have demonstrated significant improvement in initial (pre-burnished) friction, which will be required if semi-metallic materials are to be considered for commercial usage.

Further, upon investigating the semi-metallic material, it was determined that the sponge iron will compliment the rubber particles therein to attenuate noise or squeal caused upon engagement of the brake pad with a corresponding member.

It is assumed that the voids in the sponge iron particles act as acoustical absorbers by breaking up the path through which sounds may travel.

The over-all transverse structural unity of the brake pads may be varied by the amount of steel fiber **26** used in the mixture. However, due to the disparity in price between steel fiber and sponge iron (about 6 times), for mass production a volumetric change in steel fiber content will usually be adjusted by a proportional change in the quantity of sponge iron particles.

Thus, we have developed a semi-metallic composition wherein the structural characteristics are enhanced by the use of sponge iron particles when used as a friction pad in a braking system.

We claim:

1. A semi-metallic base material for use in a vehicle brake as a friction lining, said material consisting of a mixture of:

metallic powder selected from a group consisting of iron, copper, zinc and mixtures thereof from 0 to 30 percent of the total mixture;

sponge iron particles from 10 to 40 percent by volume of the total mixture, said particles having a nominal size which can vary from 20 to 80 mesh, ceramic powders selected from a group consisting of sillimanite, mullite, magnesium oxide, barium sulfate, aluminum oxide, silica, iron oxide and zirconium oxide from 2 to 15 percent by volume of the total mixture;

rubber particles from 0 to 10 percent by volume of the total mixture,

steel fibers from 0 to 20 percent by volume of the total mixture,

graphite particles from 19 to 39 percent by volume of the total mixture, said graphite particles absorbing thermal energy created during engagement of said friction lining with a corresponding member, and

a phenolic resin binder from 13 to 41 percent by volume of the total mixture, said phenolic resin binder being responsive to heat to form a solid matrix for holding the selected metallic powders, sponge iron particles, ceramic powders, rubber particles and steel fibers in a fixed relationship.

2. The semi-metallic base material, as recited in claim 1, wherein said sponge iron particles and rubber particles attenuate any noise created during said engagement

3. The semi-metallic base material, as recited in claim 2, wherein said sponge iron particles, ceramic powder, metallic powders, and steel fibers combine to provide said friction lining with a coefficient of friction between 0.34 to 0.45 in a temperature range up to 250°F.

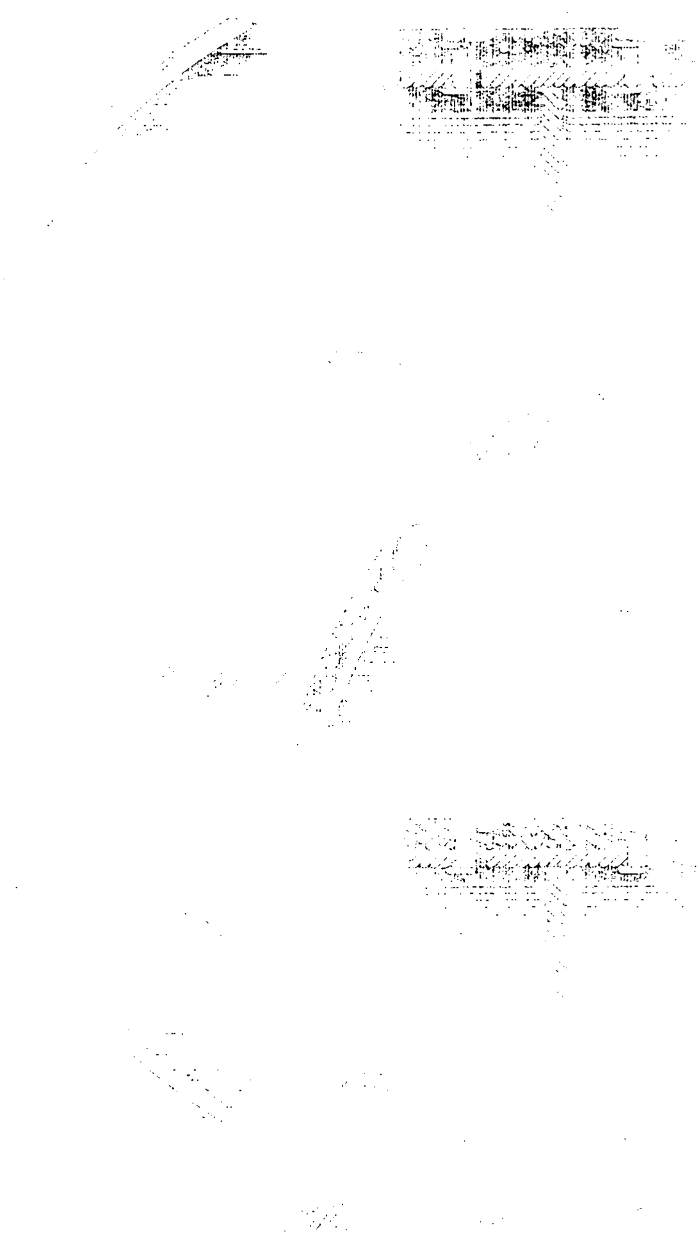
4. The semi-metallic base materials, as recited in claim 1, wherein said steel fibers constitute between 3 to 16 percent by volume of the total mixture to provide structural unity for the friction lining.

5. The semi-metallic base material, as recited in claim 4, wherein said sponge iron particles uniformly distributed throughout the total mixture are unannealed to provide reduced low temperature wear rates.

6. The semi-metallic base material, as recited in claim 5, wherein said sponge iron particles uniformly distributed throughout the total mixture are to provide increased friction in the preburnished state.

7. The semi-metallic base material, as recited in claim 6, wherein said sponge iron particles uniformly distributed throughout the total mixture are to provide less frictional change from preburnished, to burnished, to faded state

* * * * *



[illegible] means to engage said parts [illegible]

[illegible] brake [illegible] shoe [illegible] friction layer secured [illegible] said layer including fibers of spun glass [illegible] suitable binder.

[illegible] brake [illegible] shoe [illegible] friction layer secured [illegible] said layer including fibers of spun glass [illegible] into [illegible] fabric, and means securing said [illegible] to said shoe.

[illegible] invention defined in claim [illegible] said [illegible] [illegible] plastic material.

7. In a friction brake [illegible] of glass fabric secured to the [illegible] to frictionally engage the drum.

8. In a friction device [illegible] members, one of said members [illegible] composition [illegible] glass.

9. The invention defined [illegible] glass being [illegible]

[illegible]

FRICTION MATERIAL

Filed Nov. 28, 1958

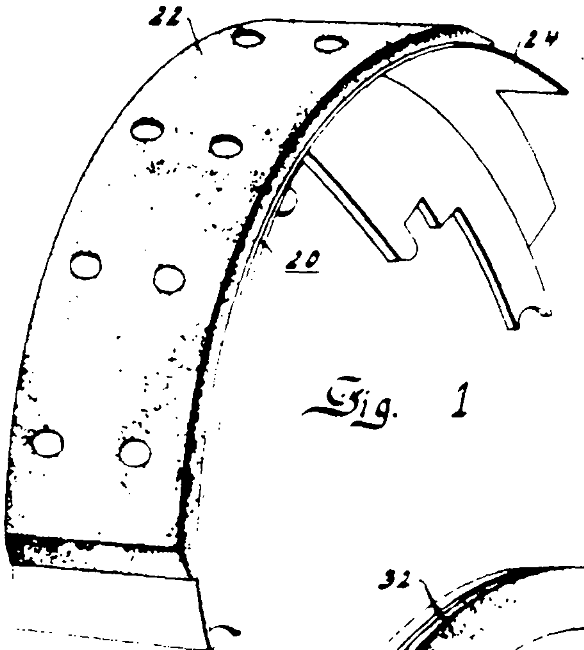


Fig. 1

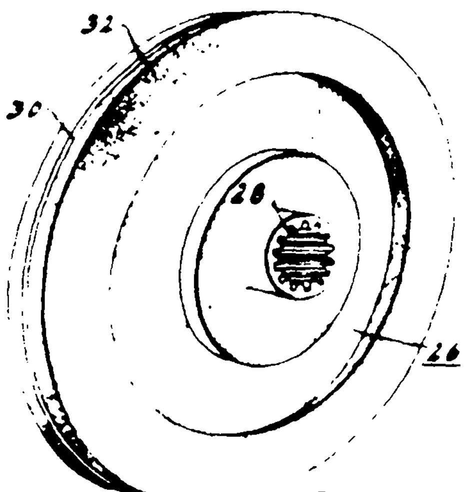


Fig. 2

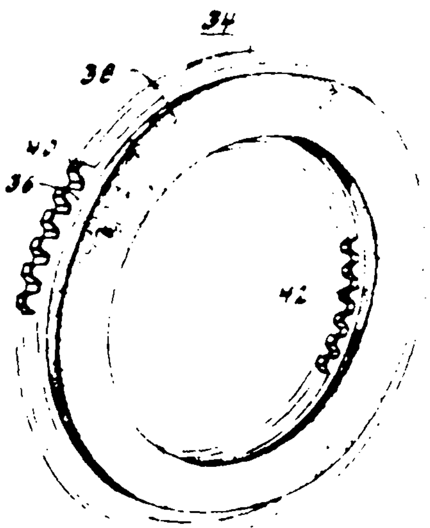


Fig. 3

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Filed Nov. 28, 1958 2 Sheets-Sheet 2

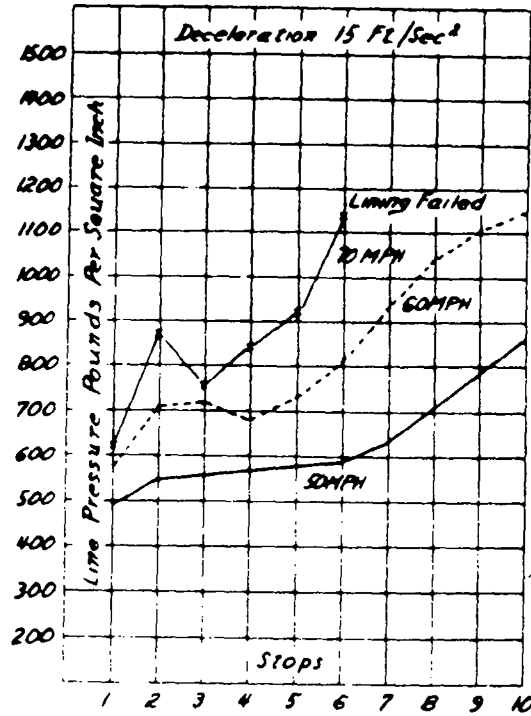

Fig. 4

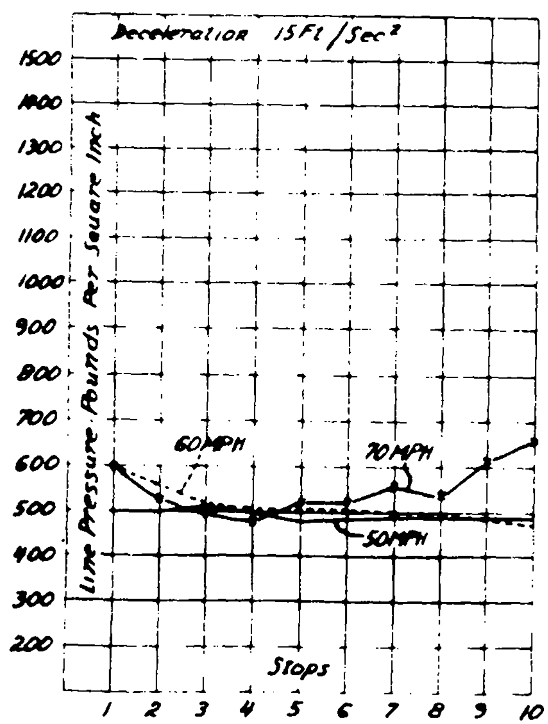

Fig. 5

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United States Patent Office

2,945,291

Patented July 19, 1960

2,945,291

FRICTIONAL MATERIAL

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Filed Nov. 28, 1958, Ser. No. 776,973

8 Claims. (Cl. 29—182.5)

This invention relates to friction materials and is particularly concerned with ferrous friction members for use as clutches, brakes and the like.

This application is a continuation-in-part of application S.N. 540,842, filed October 17, 1955, now abandoned.

An object of the invention is to provide a ferrous friction facing consisting essentially of iron, graphite and molybdenum disulfide.

In carrying out the above object, it is a further object of the invention to form the friction member from a sintered mixture consisting essentially of iron powder, graphite and molybdenum disulfide wherein the graphite makes up between one-fifth and one-fourth of the weight of the member.

A still further object of the invention is to provide a ferrous friction member wherein the member consists essentially of graphite ranging between 20% and 25% by weight; molybdenum disulfide between 2% and 6% by weight with iron making up substantially all the remainder.

Another object of the invention is to provide the ferrous friction element as heretofore disclosed wherein the element is coextensively bonded to a strong metal supporting member for facilitating mounting of the friction element.

More specifically, it is an object of the invention to provide a sintered ferrous friction facing consisting essentially of 20% graphite, 5% molybdenum disulfide with substantailly all the remainder being iron with or without small additions of modifying materials wherein said percentages are expressed on a weight basis.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

Figure 1 is a view in perspective of a typical brake band.

Figure 2 is a view in perspective of a clutch disc.

Figure 3 is a view in perspective of a clutch or brake disc for use in a clutch or brake pack.

Figures 4 and 5 are charts showing a comparison between conventional and metallic brake linings in deceleration tests.

Modern automotive developments have imposed extreme operating conditions on the conventional type of clutches and brakes. The friction surfaces of conventional clutches and brakes are usually composed of molded nonmetallic material such as asbestos, cotton linters and the like bonded together with a synthetic resin such as a phenol-formaldehyde resin, the mixture may also include friction fortifying materials. This mixture of ingredients is molded into a brake band or disc surface which may be bonded or riveted to a metal support. While these friction elements and facings are satisfactory under normal driving conditions, it has been found that repeated stops from high speeds causes a tremendous overheating and

eventual breakdown of the materials used in the brakes. In most cases, nonmetallic brake materials are not useful at temperatures above 750° F. and such temperatures are frequently exceeded in repeated high speed stops under extreme conditions.

Since the trend in automotive design is toward heavier and/or higher powered vehicles, it is apparent that the friction materials used in the brake and clutch surfaces must be improved in order to keep up with the development of the industry.

It has been found that metallic friction materials offer an interesting field of development. However, most metallic friction materials while highly satisfactory, for example, in wet clutch applications are not useful for brakes since they tend to squeak and grab in the dry condition. Furthermore, due to the abrasion of the materials in the dry condition, much of the friction facing is abraded from the friction surface which, in turn, self-aggravates the wear condition. Furthermore, the noisiness of these materials has made them unsuitable in the past for passenger vehicles.

There are, however, many advantages in the use of metallic friction materials, some of the more important being ability to withstand high temperature conditions, ability to withstand higher engaging pressures and, in most cases, longer wearing characteristics.

We have developed a friction material which overcomes these past disadvantages of metallic friction materials when used in the dry state and which has maintained all of the advantages of metallic facing materials. We have found that our friction material when used in conjunction with a disc or band type brake, will outlast nonmetallic friction materials many times, and will not be deleteriously affected at the high temperatures reached during repeated high speed stops. In fact, wear tests show that the present friction material will outwear several sets of conventional nonmetallic frictional material under identical operating conditions. Furthermore the metallic friction material does not exhibit the fade-out of frictional qualities normally present in nonmetallic materials when excessive temperatures are encountered. Under actual road conditions, the present friction material operates smoothly and silently throughout extended use. In fact the facing material operated well under tests comprising ten consecutive stops from a maximum speed of one hundred miles per hour, a condition which could not be duplicated with nonmetallic linings which failed completely after three to four of such stops.

Our new friction material is a sintered ferrous material having varying degrees of porosity and made from a mixture consisting essentially of iron powder, graphite and molybdenum disulfide; to this basic mixture may be added small quantities of sulfur and ceramic materials such as calcined mullite together with copper and lead for modifying the action of the friction material. The friction material is preferably bonded to a strong metal support through which it may be suitably secure to the brake or clutch mechanism in which it is to be subsequently used. Due to the presence of a large quantity of graphite, the material does not have a high degree of flexibility and is not readily bendable and, therefore, the strong metal support such as a steel backing is generally preferred.

Specifically, the material contains graphite in quantities of from 20% to 25% by weight together with molybdenum disulfide in quantities of from 2% to 6% by weight with substantially all the remainder being iron. The material is made by mixing the ingredients in finely divided form wherein, for example, the iron powder ranges between 150 and 325 mesh. This mixture is then briquetted to the desired shape under briquetting pressures ranging from 40,000 to 100,000 pounds per square inch, preferably at 70,000 pounds per square inch. The briquettes are next sintered for about 45 minutes at a temperature ranging between 1850° F. and 2050° F. under non-oxidizing conditions, for example, in dehydrated, incompletely burned natural gas, cracked ammonia or hydrogen. The resulting material presents a highly desirable friction material that will withstand high temperatures, maintain its frictional qualities over a wide range of temperatures, and which is long wearing and quiet.

In most cases, as previously stated, it is desirable to bond the material to a strong backing member, and this is accomplished by placing the briquettes upon supporting members of steel that have preferably been flash-coated with copper. A number of these "sandwiches" are stacked on top of one another with suitable spacers therebetween and the bonding is accomplished with the stack under pressure. A procedure of this character is fully disclosed in Wellman Patent 2,178,527 and is well known in the art. It is preferable to accomplish the sintering and bonding in a single operation although it is also possible to first sinter and then bond. In this case, the briquettes are sintered between sheets of graphitic material or metal having a nonadhering refractory coating thereover.

Another modification of the process contemplates a presinter of the briquetted powder at a temperature in the order of 1600° F. to 1950° F. for a period of 30 to 45 minutes. This partially sinters the briquette and makes it easier to handle. The presintered briquette is then assembled with the backing member and is bonded in the usual manner at about 1750° F. for 30 minutes. These conditions may vary, for example, the bonding temperature may be between 1750° F. and 2100° F. while the time may be between 20 minutes and 45 minutes varying inversely as the temperature. During the bonding step, the porous part is completely sintered. These variations in operating conditions may vary widely and are not critical so long as a good sinter and bond is obtained.

A preferred embodiment of the invention comprises the following formulation:

Example 1

22% Acheson #38 graphite
4% molybdenum disulfide, 100 mesh
74% 250 mesh reduced oxide iron powder

A mixture of this material is briquetted at 80,000 pounds per square inch and is sintered on a steel supporting member of the desired configuration which has a flash copper plate thereon for a period of about 45 minutes at 2050° F. under pressure whereupon the material forms a strong sintered layer coextensively bonded to the supporting member. The friction and wear characteristics of this material may be modified by small additions of sulfur and ceramic materials such as mullite, clays, etc. In this case, the sulfur is preferably combined with the iron or may be an impurity therein and may range up to 1% by weight of the total mix. This addition appears to improve wear. The ceramic material, such as mullite, may range up to .75% by weight of the total mix. This addition acts as a friction modifying material and generally raises the coefficient of friction slightly. In any case, these additions are optional and should not exceed a total of 2% by weight of the element. It is understood that, in many cases, the effects of sulfur and ceramics can be attained without adding any material to the mix. In these cases, reduced oxide iron powder may be chosen which contains sulfur and insoluble ceramic material within the ranges noted as impurities therein.

Similarly, small additions of lead and/or copper may be added to modify friction characteristics as is well known in the art. For example, copper up to 5% by weight and/or lead up to 5% by weight may be added. These modifications prove useful under certain conditions. Our invention, however, is directed specifically to the basic formulation of a high percentage of graphite (20% to 25%) with molybdenum disulfide in controlled amounts wherein the remainder of the element consists essentially of iron with or without the modifying ingredients set forth herein.

Some specific examples of other mixes which are satisfactory are as follows wherein all percentages are expressed by weight:

Example 2

20% Acheson graphite
3% 150 mesh copper powder
5% 100 mesh lead powder
5% 100 mesh molybdenum disulfide
.75% calcined mullite
66.25% 100 mesh reduced iron oxide powder containing combined sulfur therein equal to 1% of the iron

This mixture of powdered materials is briquetted at 70,000 pounds per square inch and may be sintered on a steel supporting member which has been flash-copper plated for a period of forty-five minutes at a temperature of 2050° F. in a nonoxidizing atmosphere under pressure. The powdered material forms a strong, sintered layer coextensively bonded to the supporting layer.

Example 3

22% Acheson graphite
4% 100 mesh molybdenum disulfide
74% 250 mesh reduced iron oxide powder containing in combined form sulfur together with insoluble ceramic material in quantities equal to about 1% and .75% respectively of the total mix

The mixture of these powdered materials may be prepared and sintered as in Example 2.

Example 4

20% Acheson graphite
2.5% 200 mesh copper powder
4.5% 100 mesh lead powder
4% 100 mesh molybdenum disulfide
.75% sulfur
.65% calcined mullite
Remainder 100 mesh reduced iron oxide powder

The same procedure for forming the material and sintering the same as in Example 2 may be followed.

Example 5

21% Acheson graphite
4% 100 mesh lead powder
5% 100 mesh molybdenum disulfide
Remainder 250 mesh reduced iron oxide powder containing combined sulfur equal to about 1% of the total mix.

A mixture of this material may be formed and sintered as in Example 2.

In the drawing, several forms of the friction member described in this disclosure are shown. For example, in Figure 1, a conventional type of brake band 20 is shown which has a ferrous friction surface 22 and a metal supporting back 24. This band may be made as herein described by placing preformed friction layers 22 upon the preformed supporting members 24 and stacking the sandwiches under pressure in a suitable furnace for sintering. Figure 2 shows one type of clutch plate at 26 which includes a splined hub 28, a steel disc 30 and friction surfaces 32 bonded thereto. The friction surface 32 may be provided at both sides of the clutch (as shown) if desired.

Figure 3 shows still another form of clutch or brake at 34. In this form, the steel disc 36 supports a friction surface 38 at one or both sides thereof and the disc may be splined as at 40 on the outer periphery or as at 42 at the inner periphery thereof. This type of plate is generally used in a pack wherein alternate plates are splined at the inner and outer periphery respectively. These plates may be used in disc brakes, for example, as disclosed in Lambert Patent 2,405,219 which shows one type of automotive disc bra'e, or multiple plate clutches as disclosed in Almen and Carnegie application S.N. 392,596, now Patent 2,733,797, assigned to the assignee of the present invention.

The three curves in Figure 4 show consecutive stops at one minute intervals at 50, 60 and 70 miles per hour with a commercial molded nonmetallic lining wherein the rate of deceleration is maintained at fifteen feet per second per second. The "fade" characteristics of the lining are indicated by the increasing hydraulic pressures required to maintain constant deceleration. Thus, at 50 miles per hour, the pressure required to maintain this deceleration varied from 490 pounds per square inch for the first stop to 855 pounds per square inch for the tenth stop. At 60 miles per hour, these figures were 560 pounds per square inch for the first stop and 1145 pounds per square inch for the tenth. At 70 miles per hour, the lining failed on the sixth stop.

By way of comparison, Figure 5 shows the same curves for our improved metallic lining as described herein and made in accordance with Example I. It will be seen that the pressures required for the first stop are consistently lower and that the pressures required for subsequent stops are substantially constant. No failures were noted. All tests were made on identical equipment and with identical braking elements with the exception of the brake material per se. In this instance, the commercial lining tested was of a 40.8 square inch area while the ferrous lining was only 36 square inches in area.

The present invention, therefore, is directed basically to a porous ferrous friction element including a relatively high percentage of graphite together with significant quantities of molybdenum disulfide wherein said element may or may not contain small additions of wear and friction modifying ingredients. The friction element may also include an impregnant within the pores thereof if it is desired for sealing the pores against the ingress of the atmosphere where the material is to be stored over appreciable periods of time. This material is preferably a heat resistant resin which can be impregnated into the material and which does not markedly influence the frictional characteristics of the material. Therefore, it is understood that impregnants may be used without departing from the concept of the invention.

Throughout this specification, the term ceramic material is used together with mullite as one embodiment thereof. It is to be understood that this example is illustrative only and that clays, silica magnesium oxide, mica or any of the other refractory ceramic materials may be used with varying useful results.

While the forms of embodiment of the present invention as herein disclosed constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. A new article of manufacture, comprising, a friction facing consisting essentially of a compacted and sintered body formed from a powdered mixture of 20% to 25% graphite, 2% to 6% molybdenum disulfide and the balance iron.

2. A new article of manufacture, comprising, a friction facing consisting essentially of a compacted and sintered body formed from a powdered mixture of 22% graphite, 4% molybdenum disulfide and the balance iron.

3. The article as claimed in claim 1 wherein the friction facing is coextensively bonded to a metal backing member.

4. The article as claimed in claim 2 wherein the friction facing is coextensively bonded to a metal backing member.

5. A new article of manufacture, comprising, a friction facing consisting essentially of a compacted and sintered body formed from a powdered mixture of 20% to 25% graphite, 2% to 6% molybdenum disulfide, and the balance iron wherein the iron includes as impurities insoluble ceramic material up to .75% and sulfur up to 1% by weight of the powdered mixture.

6. The article claimed in claim 5 including lead and copper in quantities less than 5% by weight each.

7. A new article of manufacture, comprising, a friction facing consisting of a sintered compact of graphite 20% to 25%, molybdenum disulfide 2% to 6%, sulfur up to 1%, mullite up to .75%, copper up to 5%, lead up to 5% and the balance iron, said quantities being expressed by weight.

8. A new article of manufacture, comprising, a friction facing consisting of a sintered compact of graphite 20%, copper 3%, lead 5%, molybdenum disulfide 5%, calcined mullite .75%, sulfur .67% and the balance iron, said quantities being expressed by weight.

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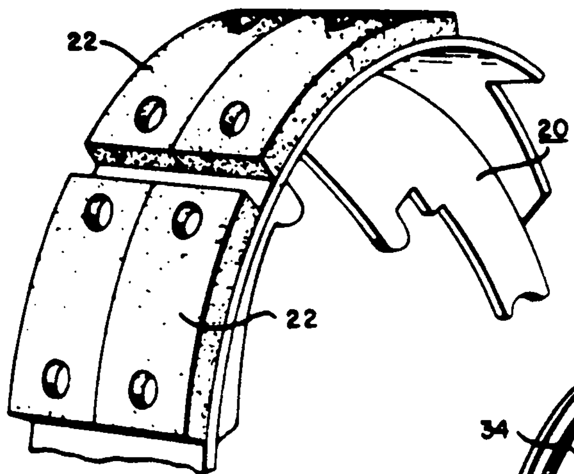

Fig. 1

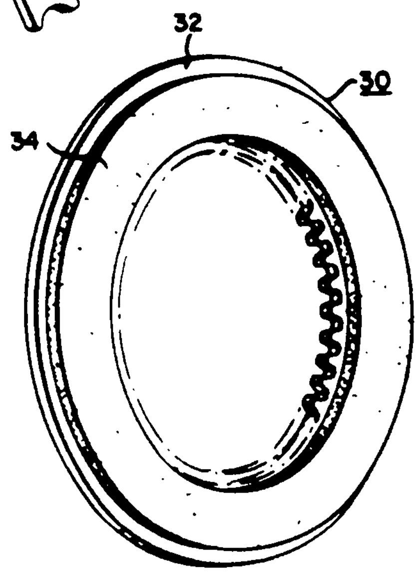

Fig. 2

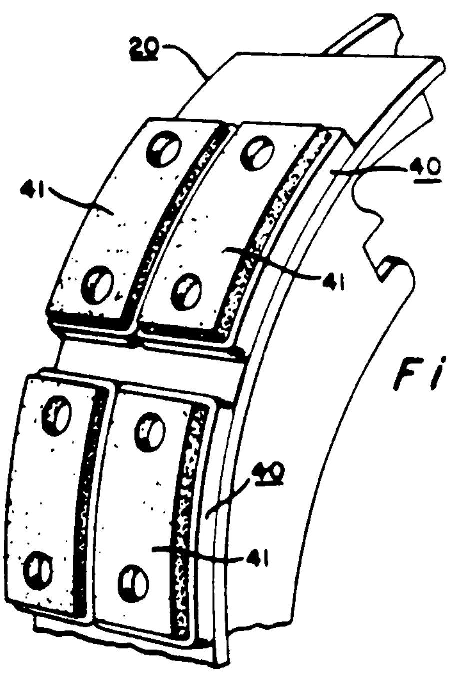

Fig. 4

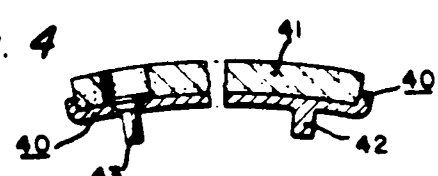

Fig. 5

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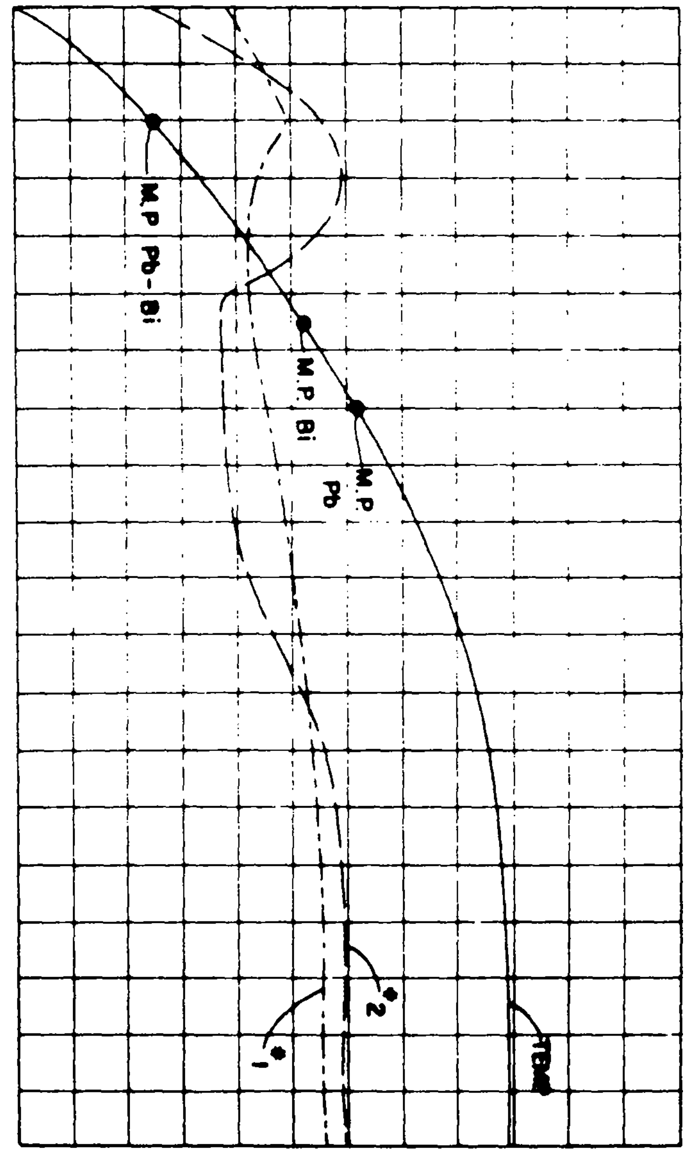

Fig. 3

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United States Patent Office

2,945,292

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1

2,945,292

FRICTION MATERIAL

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Filed Nov. 28, 1958, Ser. No. 776,978

10 Claims. (Cl. 29—182.5)

This invention relates to friction materials and is particularly concerned with ferrous friction members for use as clutches, brakes and the like.

This application is a continuation-in-part of application S.N. 684,954, filed September 19, 1957, now abandoned.

An object of the invention is to provide a ferrous friction facing consisting essentially of iron, graphite and a metallic lubricant consisting of bismuth or alloys of bismuth with metals that are substantially insoluble in iron.

In carrying out the above object, it is a further object of the invention to form the friction member from a sintered mixture of iron powder with graphite which member also contains a lubricant metal in the form of bismuth, bismuth-lead alloys, and bismuth-cadmium alloys and wherein graphite makes up a substantial portion of the member.

A still further object of the invention is to provide a ferrous friction member which consists essentially of graphite ranging between 20% and 30% by weight and a lubricating metal such as bismuth or bismuth alloys wherein the alloy has a melting point not greater than the melting point of bismuth and wherein the other metals in the alloy are substantially insoluble in iron.

In carrying out the above object it is a further object where bismuth or a bismuth-lead alloy is used as a lubricating metal, to include small quantities of an additional metal substantially nonalloyable with the lubricating metal, one of such metals being copper.

It is a further object in some cases to utilize small quantities of sulfur not over 1% in combination with the iron either as an added ingredient or as an impurity in the iron used and/or a ceramic material such as mullite in quantities of less than 1%.

Another object of the invention is to provide the ferrous friction element as heretofore disclosed with a strong metal supporting member for facilitating the mounting of the friction element, said member taking the form of a sintered ferrous material of different composition and greater strength than the friction element and bonded coextensively thereto.

More specifically, it is an object of the invention to provide a sintered ferrous friction element consisting essentially of graphite 30 to 45 parts by weight, copper 0 to 15 parts by weight, bismuth or insoluble alloys thereof 6 to 10 parts by weight and iron 100 parts by weight.

In carrying out the above object, it is a further object to optionally include sulfur and mullite in the above formulation.

Another object of the invention is to provide a ferrous friction member containing substantial quantities of graphite together with a lubricating metal which is substantially insoluble in the metals making up the ferrous friction member, said lubricating metal having a melting point within the range of temperatures encountered during subsequent use of the friction element whereby the metallic lubricant melts and exudes to the surface of the element during use to stabilize the frictional characteristics of the element.

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Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

Figure 1 is a perspective view of a typical brake band including the ferrous friction element thereon.

Figure 2 is a view in perspective of a conventional clutch disc utilizing the ferrous friction facing thereon.

Figure 3 is a chart of a family of curves for ferrous friction materials including different metal lubricants and showing coefficient of friction plotted against time and temperature.

Figure 4 is a perspective view similar to Figure 1 showing another means of attaching the friction lining to the shoe.

Figure 5 is a view of one segment of the friction material and its support.

In modern automotive development, extreme operating conditions are encountered at friction surfaces used for brakes, clutches and the like. These extreme conditions make conventional nonmetallic clutch facings and brake linings costly to use since these materials must operate below certain limiting temperatures if their efficiency is to be maintained which requires cooling media and other devices to limit the temperatures. It is, therefore, desirable to provide facing materials for clutches, brakes and the like which can withstand considerably higher temperatures than the usual nonmetallic materials and which maintain substantially constant frictional characteristics throughout their operating temperature range.

Metallic facing materials made from sintered metals such as sintered bronze, sintered iron and the like have been used sparingly in the past and while the wear characteristics on these elements are considerably better than nonmetallic elements, it has been found difficult to control the coefficients of friction thereof through the wide range of temperatures that are encountered in normal operation whereby the build-up in friction during successive stops makes them erratic in their operation and, therefore, generally undesirable.

Recently, improved friction facings have been proposed of the metallic type wherein substantial quantities of graphite have been incorporated therein to smooth out the coefficient of friction to some extent over a wide range of temperature. These facings provide considerably better operating characteristics and are frequently entirely satisfactory under normal operating conditions. However, when heavy duty service is encountered such as, for example with taxicabs, busses or stops from high speeds, these friction materials do not always maintain their stability within the range desired.

The present invention is directed to a friction material which has a stabilized coefficient of friction and, therefore, is extremely useful in any application such as a clutch or brake wherein stabilized friction characteristics are desired over a wide range of temperatures, whether or not the application falls in the category of a heavy duty application. We believe that this stabilization of friction characteristics is accomplished through the use of a metallic lubricant which is transitory in character at the surface of the element, that is to say, the lubricating metal is held in the solid state within the pores of the friction element at temperatures below its melting point and, when these temperatures are exceeded, this metal, due to its insolubility with the other components of the element and due to its expansion, will exude onto the surface of the element and provide a fluid lubricant which stabilizes the frictional characteristics of the element while maintaining the desired frictional characteristics thereof as provided by other components of the element.

It is understood that, in the description to follow, the ferrous friction element may be used in connection with brake bands or clutch discs or brake discs as the case may be. For example, in Figure 1, a conventional brake band is shown at 20 which includes a plurality of pads of friction material 22 attached thereto. In Figure 2, a clutch disc or brake disc is shown at 30 which includes a steel disc 32 having a friction layer 34 attached thereto.

Specifically, we have found that, in a ferrous friction element wherein the major component is iron, large quantities of graphite are highly desirable to supply the desired frictional characteristics to the element. In this connection, graphite ranging from 20% to 30% by weight of the element is incorporated in the element together with a lubricating metal such as bismuth, or alloys of bismuth with metals which are insoluble in iron and wherein the melting point of the alloy does not exceed the melting point of bismuth, for example, lead-bismuth alloys and cadmium-bismuth alloys. The low melting metal may be bismuth alone which melts at about 520° F. or it may be an alloy of bismuth and lead which melts at or below the melting point of bismuth. In this connection, an alloy of 88% lead and 12% bismuth has substantially the same melting point of bismuth whereas the eutectic alloy of lead and bismuth which contains 55½% bismuth and 44½% lead melts at about 255° F. Thus, bismuth-lead alloys where the minimum bismuth percentage is 12% may be used as a substitute for pure bismuth according to use since any alloy having this composition will melt at or below the melting point of bismuth. In this connection the service requirements of the brake should be taken into consideration. Heavy duty applications are best served by the higher melting point alloys whereas light duty applications may make use of the lower melting point alloys. In all cases it is desirable that the melting point of the lubricating metal is in the range of temperature attained during normal use of the friction element and these conditions therefore govern to a large degree the choice of material. Similarly, alloys of bismuth and other metals may be used wherein the other metal in the alloy is substantially insoluble in iron for example, cadmium is insoluble in iron and alloys with bismuth to form low melting point alloys. In this connection, an alloy of 25% bismuth and 75% cadmium has substantially the same melting point of pure bismuth whereas the eutectic alloy of 60% bismuth and 40% cadmium melts at about 292° F. Stated broadly therefore, alloys of bismuth with metals insoluble in iron wherein the alloy has a melting point not in excess of the melting point of bismuth are useful as the lubricating metal.

Thus, it will be seen that we have chosen a lubricating metal which is insoluble in the iron and which melts within a range of temperature generally reached by the friction element during use. Other insoulble metals could possibly be used but, in these cases, the melting point is sufficiently high that the liquidus state of the metal is not reached upon operation of the friction element whereby erratic results occur due to the fact that the so-called lubricating metal may be liquid in one case and solid in another.

Therefore, in each instance, the low melting point metal, which acts as a lubricating metal, melts at temperatures within the normal operating temperature range of the friction element and, in each instance, where combinations of these low melting point metals are used, the eutectic mixtures thereof melt at relatively lower temperatures to quickly stabilize the frictional characteristics of the element by presenting a liquid phase at the interface between the element and the brake drum or other rubbing surface, etc.

Some examples of suitable mixtures are as follows, all proportions being in parts by weight:

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6
Sponge or Reduced Oxide Iron (with or without 1% combined sulfur)	100	100	100	100	100	100
Graphite	20	45	20	45	45	20
Bismuth	6	6	6	6	6	10
Copper	----	----	9	9	15	15
Lead	----	----	----	4	6	----
Mullite	.7	----	.75	----	5	----

These ingredients in finely divided form, for example, capable of passing through a 100 mesh screen are intimately mixed and are briquetted into the desired shape under briquetting pressures ranging from 60,000 to 80,000 pounds per square inch and are then sintered under nonoxidizing conditions for from 30 to 40 minutes at temperatuers ranging from 1800° F. to 2000° F. In each case, a sintered friction element is formed which will exude bismuth, bismuth-lead, etc., as the case may be, at the surface thereof.

More specific examples comprise

Example 7

67 parts −250 mesh sponge iron powder (combined sulfur up to 1% by weight)
20 parts artificial graphite (density 1.85 grams per cc., −325 mesh)
8 parts 150 mesh copper powder
5 parts 100 mesh bismuth powder

These ingredients are intimately mixed and are briquetted at 60,000 pounds per square inch and are then sintered for 40 minutes in a nonoxidizing atmosphere at 1800° F. The resulting friction facing has a fiber strength in the order of 3720 pounds per square inch.

Example 8

67 parts −250 mesh sponge iron powder (with 1% combined sulfur)
15 parts powdered artificial graphite (density 1.85 grams per cc., −325 mesh)
15 parts coarse flake natural graphite (density about 2.1 grams per cc., 20 to 30 mesh)
5 parts 150 mesh copper powder
10 parts 100 mesh bismuth-lead (50–50 mixture) with or without ½ part 60 mesh synthetic mullite

These ingredients are intimately mixed and briquetted at 70,000 pounds per square inch and sintered for about 40 minutes in a nonoxidizing atmosphere at a temperature of about 1800° F. The resulting friction element has a fiber strength in the order of 3045 pounds per square inch.

It is understood that the lubricating metal such as bismuth-lead alloy may be introduced by impregnation if desired, although the usual technique as described heretofore are preferred. Furthermore, due to the sintering step, it is usually not necessary to pre-alloy the bismuth with any other metal to be used therewith since alloying will occur in situ during the sintering.

All of the above friction elements made by any of the aforementioned examples are preferably bonded to a more dense and stronger material during the sintering to enable them to be riveted or spot-welded to a steel shoe or plate. This particular step forms no part of the present invention and is fully disclosed in copending Smiley application, S.N. 596,266, filed July 6, 2956, assigned to the assignee of the present invention. Specifically, a backing material that is particularly useful with the present formulations, since it has similar physical change characteristics during briquetting and sintering, comprises a mixture of about 95 parts 100 mesh sponge iron powder, 5 parts low density powdered graphite (1.68 grams per cc., —325 mesh), and three parts of molybdenum disulphide powder (250 mesh). These ingredients are intimately mixed and the mixture is placed in a die in desired quantity. Any of the aforementioned friction material mixes is then filled into the die and the two layers are simultaneously briquetted at pressures of from 60,000 to 80,000 pounds per square inch. The briquette is sintered under conditions, times and temperatures noted in any of the examples. A coextensively bonded material is formed having a strong backing layer and a friction facing of the desired characteristics. As mentioned before, the application S.N. 596,266 gives a detailed disclosure of the method of making these composite friction elements and the present invention is directed solely to the friction layer and its characteristics.

In place of the composite material described, the friction layer may be supported by and bonded to a retaining device or member made of stamped or cast metal. Such a retainer is shown at 40 in Figures 4 and 5. The retainer 40 is preferably made of stamped steel and is made in the form of a shallow cup or tray which carries a friction material layer 41 therein. The retainer 40 may include fastening means 42 welded or otherwise attached thereto as shown in the right side of Figure 5 or the retainer may be riveted by means of rivets 43 or directly welded to the band 20. In the case of rivets 43 being used, the friction layer 41 is counterbored so that the heads of the rivets bear against the container. In all cases, the friction layer 41 is sintered and bonded in situ to the container 40 by briquetting the powdered material directly in the retainer. Prior to the briquetting operation, the retainer surface is preferably flash copper plated as well known in the art to facilitate the bond.

It will be observed that, when the graphite content of the friction material exceeds 25%, different manufacturing techniques are required in order to form an element having sufficient strength for the intended purpose and, to this end, different types of graphite are used to overcome problems which arise when using either type of graphite alone. These manufacturing techniques form no part of this invention and are fully disclosed in copending application S.N. 684,853 (Docket No. MP-2712), filed September 19, 1957, wherein the full disclosure of the reasons for mixing the different types of graphite are set forth. In this connection, so far as the finished friction element is concerned, there is no substantial difference in the operational characteristics of the different types of graphite but the strength of the finished element is markedly enhanced by mixing two types of graphite.

While the friction elements utilizing graphite in the order of 20% have good frictional characteristics and under normal operating conditions function well, there is some tendency toward noisy operation under certain specific conditions. As the graphite content is increased, this noise condition decreases to a point where the element is comparable with conventional nonmetallic elements at 25% of graphite and above. In other words, as the graphite increases, the tendency toward noise decreases under all conditions.

The new friction facings described herein function well with conventional mating surfaces such as steel or cast iron which is normally used as clutch disc and brake drum material. It will also function in combination with other metals providing the lubricant metal does not alloy therewith at operating temperatures. For this reason, the metal of the mating surfaces should be chosen from metals and alloys that do not form intermetallic compounds with the low melting point metals such as lead, bismuth or cadmium used in the friction material.

The curves shown in Figure 3 are for two different friction linings. Curve #1 is for the material disclosed in Example 8. Curve #2 is the material using 5% bismuth alloy instead of the bismuth-lead alloy. In each case, it will be noted that the coefficient of friction of the lining is unstable until the temperature of operation exceeds the melting point of the lubricant metal at which time the coefficient of friction levels off and becomes stabilized.

Throughout this specification, the term ceramic material is used together with mullite as one embodiment thereof. It is to be understood that this example is illustrative only and that clays, silica magnesium oxide, mica or any of the other refractory ceramic materials may be used with varying useful results.

While the embodiments of the present invention as herein disclosed constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. A friction material for use as a friction facing element, consisting essentially of: a sintered ferrous base having dispersed therethrough graphite in quantities of from 20% to 30% by weight, together with at least one metal taken from the class consisting of: bismuth, bismuth-lead and bismuth-cadmium alloys wherein the melting point of the alloys does not exceed the melting point of bismuth, said last-mentioned metal being present in quantities of from 3% to 10% by weight.

2. A friction material for use as a friction facing element, consisting essentially of: a sintered ferrous base having dispersed therethrough graphite in quantities of from 20% to 30% by weight, together with bismuth in quantities of from 3% to 10% by weight.

3. A friction material for use as a friction facing element, consisting essentially of: a sintered ferrous base having dispersed therethrough graphite in quantities of from 20% to 30% by weight together with a bismuth-lead alloy having a melting point not exceeding the melting point of bismuth in quantities of from 3% to 10% by weight.

4. A friction material for use as a friction facing element, consisting essentially of: a sintered ferrous base having dispersed therethrough graphite in quantities of from 20% to 30% by weight, together with a metal taken from the class of bismuth and bismuth alloys with metals insoluble in iron wherein said alloys have a melting point not in excess of the melting point of bismuth in quantities of from 3% to 10% by weight.

5. A sintered friction material for use as a friction facing element, consisting essentially of: iron including sulfur up to 1% by weight thereof, 100 parts, graphite 30 to 45 parts, copper up to 15 parts, and a metal taken from the class consisting of bismuth and bismuth alloy with metals insoluble in iron wherein said alloys have melting points not in excess of the melting point of bismuth, 6 to 10 parts, said proportions being expressed as parts by weight.

6. A sintered friction material for use as a friction facing element, consisting essentially of: iron, including sulfur up to 1% by weight thereof, 100 parts, graphite 30 to 45 parts, copper up to 15 parts, mullite up to 2% by weight, and a metal, taken from the class consisting of bismuth and bismuth alloys with metal insoluble in iron wherein said alloys have melting points not in excess of the melting point of bismuth, 6 to 10 parts, said proportions being expressed as parts by weight.

7. A sintered friction material for use as a friction facing element, consisting essentially of: iron 100 parts, graphite 30 to 45 parts, copper up to 15 parts, and bismuth 6 to 10 parts, said proportions being expressed as parts by weight.

8. A sintered friction material for use as a friction facing element, consisting essentially of: iron 100 parts, graphite 30 to 45 parts, copper up to 15 parts, together with sulfur and mullite in quantities not in excess of 2%, and bismuth 6 to 10 parts, said proportions being expressed as parts by weight.

9. A sintered friction material for use as a friction facing element, consisting essentially of: iron 100 parts,

graphite 30 to 45 parts, copper up to 15 parts, and a bismuth-lead alloy 6 to 10 parts, said proportions being expressed as parts by weight.

10. A heavy duty brake comprising a friction element, consisting essentially of: iron 67 parts, graphite 20–30 parts, a bismuth-lead alloy wherein the bismuth and lead are in equal proportions 5–10 parts, copper 8 parts, all proportions being expressed in parts by weight, said element being coextensively attached at one surface thereof to a strong metal supporting member.

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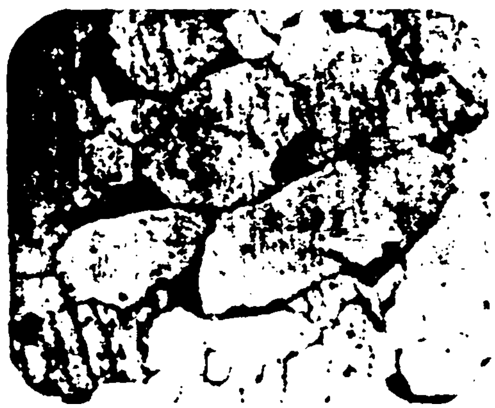

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Fig. 1.

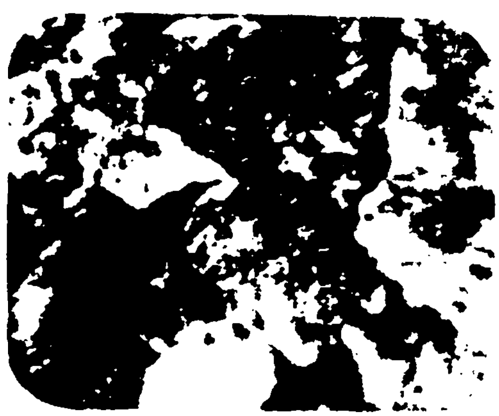

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Fig. 2.

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Earl W Reinsch
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BY John T Mann
Their Attorney

United States Patent Office 3,184,001

Patented May 18, 1965

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3,184,001

BRAKE DRUM AND LINING

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Filed Aug. 16, 1962, Ser. No. 217,426

5 Claims. (Cl. 188—71)

This invention relates to a torque transmitting and/or energy absorbing device and is specifically directed to brakes, clutches and the like.

More particularly, the invention is directed to the combination of a sintered ferrous brake lining or facing used in conjunction with a brake member including a braking surface formed from steel substantially free from ferrite.

An object of the invention is to produce a combination of elements for use in a torque transmitting and/or an energy absorbing device and particularly a brake wherein the uniformity of operation is improved.

In carrying out the above object it is a further object of the invention to reduce cold pedal effect normally present in automotive braking systems.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein preferred embodiments of the present invention are clearly shown.

In the drawings:

FIG. 1 is a photomicrograph of a cross section of a SAE 1010 steel drum showing the ferrite in the structure, and

FIG. 2 is a photomicrograph of a cross section of a SAE 1085 steel drum showing the absence of ferrite in the microstructure.

Recent trends in automotive design and improved road conditions have made possible higher speed travel in automotive vehicles. These trends have required improvement in brake design and construction so that the vehicles may be stopped within a safe distance even from the higher speeds. In order to make this condition possible, heavy duty brake lining materials have been developed which are metallic in nature and which will withstand the high temperature conditions which prevail in the brake during a stop or stops from high speeds. These temperature conditions are sufficient to, in many instances, cause charring of non-metallic type linings including organic type material. This new brake lining material which is specifically a sintered ferrous material including graphite, is disclosed in some detail in U.S. Patents 2,945,291 and 2,945,929, among others which are assigned to the assignee of this application. These metallic friction materials have the ability to provide reasonably constant coefficients of friction over a wide range of temperatures and specifically are capable of maintaining the reasonably high coefficient of friction at high temperatures whereby the vehicle may be brought to a stop without excessive pedal pressure and wherein the friction material remains unharmed due to the rise in temperature.

These same materials, however, do not provide the ultimate in cold pedal operation under normal conditions. Cold pedal may best be defined as a reduction in effectiveness of the brakes after a period of inactivity, that is, when the automotive vehicle has been standing idle for a period of time, for example, the first stop or first few stops made require greater pedal pressure to bring the car to a stop than do subsequent operations of the braking system. This condition, while not serious from a safety point of view, is nevertheless, annoying and has acted as a deterrent in some cases, toward the application of metallic brake linings in pleasure vehicles.

2

We have found that cold pedal conditions may be greatly lessened by utilizing a specific combination of elements in the braking system. Thus, when using a ferrous metal brake lining such as is disclosed, for example, in Patent 2,945,291, we have found that the cold pedal effects are greatly lessened if a brake drum surface formed from steel substantially free from ferrite is used in combination therewith. Most automotive vehicles made today utilize gray cast iron brake drums. The combination of the metallic lining with the aforementioned steel drum reduces the cold pedal effect in the order of 25% whereby much better and more uniform operation is obtained from the braking system.

A typical cold pedal test procedure is as follows: the linings and drums are conditioned by making ten stops at ½ mile intervals each from 40 miles per hour at a deceleration rate of 10 ft./sec.². The vehicle is then parked for a minimum of two hours. The cold pedal is then evaluated by making ten stops at ½ mile intervals from 40 miles per hour at a deceleration rate of 10 ft./sec.² wherein the initial and final line pressures required to maintain the specific deceleration is recorded through each stop.

Using brake linings as disclosed in the aforementioned patent with a standard cast iron drum conditioning, the tenth stop of the schedule required 270 p.s.i. to produce the desired deceleration. After the car was parked for the two hour rest period from a forward stop, the first check stop after the cooling off period required an initial line pressure of 320 p.s.i., which may be termed the cold forward effectiveness. If the car was parked for a cooling off period from a reverse stop, the first check stop required initial line pressure of 385 p.s.i. This may be termed cold reverse effectiveness.

If the car is parked with a forward stop before the cooling period and a controlled reverse stop is made before the first check stop, the first check stop requires an initial line pressure of 385 p.s.i. This is also called the cold reverse effectiveness.

It will be noted that the line pressure increase to effect a specific deceleration to stop is the same to effect a stop if the immediate previous stop was a reverse stop whether the reverse stop was before or after the cooling off period.

Thus the difference between warm brake effectiveness at 270 p.s.i. and cold reverse effectiveness at 385 p.s.i. is 115 p.s.i. This difference will be detected by the driver and is known as hardened pedal. It occurs in normal driving when a driver backs out of a parking space and then is required to make a forward stop. The change in brake output is noted regardless of the car speed.

The same scheduled tests were made using drums formed from SAE 1080 steel with all other conditions identical. In this instance the warm effectiveness dropped to 215 p.s.i., the cold forward effectiveness to 230 p.s.i. and the cold reverse effectiveness to 250 p.s.i. Thus, the steel drum narrowed the difference between the warm stop and the cold reverse stop to 35 p.s.i. over the 115 p.s.i. required when using a gray cast iron drum.

In addition to the improved brake characteristics, steel has greatly improved tensile strength over the usual gray cast iron, as is well known. Further, when substantially free from ferrite, the steel has reduced scoring tendency. This is a very important consideration since free ferrite, such as is formed in SAE 1010 steel, produces marked scoring tendencies and is not useful in braking applications.

Steel offers another benefit that is commercially important, namely, due to the increased strength over gray cast iron the drums may be made considerably lighter with decreased wall thickness without sacrificing ruggedness. It should be understood that similar results can be obtained using cast iron drums lined with the desired steel surface. Thus, when the term drum is used herein the term is sufficiently broad to include any combination providing the braking surface is substantially free from ferrite.

In place of SAE 1080 or 1085 steel any other steel which has a structure substantially free from ferrite is useful, for example SAE #8660, #9260. Alloy steels of this character may also be used where specific physical characteristics are desired which may be obtained from the alloy.

In general, sintered ferrous linings and/or facings having a sintered ferrous base and including graphite in quantities above 10% with or without well-known friction fortifying and/or modifying materials, may be used effectively in the combination.

Any steel drum having a metallographic structure substantially free from ferrite when used in combination with a sintered, ferrous brake lining material will offer improved operational characteristics, particularly in the cold pedal range. Such improvements are easily noticeable by the operator of the vehicle and lessen the difference in pedal pressures required to bring a car to a stop under any given set of conditions.

It is to be understood that the principles involved are equally applicable to disc brakes, drum brakes, clutches and/or other torque transmitting and/or energy absorbing devices wherein sliding or rubbing engagement occurs between the several elements of the structure.

While the embodiments of the present invention as herein disclosed, constitute preferred forms, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. A torque transmitting and energy absorbing device, comprising in combination: a driving and a driven member wherein one of sad members comprises a sintered ferrous surface and wherein the other of said members consist of a steel surface substantially free from ferrite whereby the combination of the sintered ferrous surface and the said steel surface effect uniform torque transmission and/or energy absorption over a wide range of operating temperatures.

2. A torque transmitting device comprising a sintered ferrous facing and a mating surface consisting of steel substantially free from ferrite.

3. A brake for use in an automotive vehicle and the like, comprising in combination; a sintered ferrous brake lining and a braking surface cooperating with said lining, said braking surface consisting of steel substantially free from ferrite whereby the combination of the sintered ferrous lining and the said steel braking surface effect uniform braking conditions over a wide range of operating temperatures.

4. A brake for use in an automotive vehicle and the like, comprising in combination; a sintered ferrous brake lining and a brake drum for use as a rubbing surface against said lining, said drum having a contacting surface consisting of steel substantially free from ferrite whereby the combination of the sintered ferrous lining and the said steel braking surface effect uniform braking conditions over a wide range of operating temperatures.

5. A brake for use in an automotive vehicle and the like, comprising in combination, a sintered ferrous brake lining and a braking surface cooperating with said lining, said braking surface consisting of SAE 1080 steel substantially free from ferrite whereby the combination of said sintered brake lining and said SAE 1080 steel braking surface effect uniform braking conditions over a wide range of operating conditions.

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ARTHUR L. LA POINT, *Primary Examiner.*

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DESK

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BASED ON PAPER* BY

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THE varied properties required of a brake lining material calls for careful selection and blending of its ingredients.

Lining requirements are:

1. Correct coefficient of friction, which is influenced by temperature reaction, aging qualities, water reaction, and oil and grease reaction;
2. Durability;
3. Relative freedom from any tendency to score drums;
4. Quietness in operation; and
5. Nonoffensive odor.

Lining friction coefficients generally run between 0.20 and 0.40. Manufacturers usually describe linings as having high, medium, and low friction coefficients without specifying friction value numerically. It's not hard to compound a lining with an initial specific friction coefficient; but to produce a lining with uniform braking performance under various operating conditions takes much compounding study and laboratory and road testing.

The ideal lining would have a constant friction coefficient at high and low temperatures, under wet and dry conditions, throughout the lining's life. There is no such lining. All linings disintegrate under high braking temperatures. Chemical and physical changes either increase friction coefficient (build-up) or decrease it (fade).

With fade, if friction characteristics return to their initial condition, the lining is said to have good recovery properties. Satisfactory linings fade slightly with each brake application, but recover immediately after cooling. Linings producing build-up in friction coefficient are not satisfactory.

Friction coefficient may increase or decrease with age. When it decreases, it develops a hard pedal. Some linings harden and tend to score drums and be noisy.

Other linings are sensitive to water on the friction face, with effects as pronounced as those from temperature. Moisture also causes "morning sickness." Iron oxide forms on the drum and gives high friction reaction during the first two or three stops made after the car has been parked over night. Because of contact with oil and grease in service, linings should have some resistance to these materials.

Linings also should wear slowly and uniformly. This insures more consistent braking action by continually renewing the friction surface. Negligible wear may produce a glazed friction surface.

Certain ingredients tend to score drums. Steel drums score more readily than cast-iron ones. Brake system quietness is a function of the lining as well as other factors. Ingredients must not produce offensive odors at high braking temperatures. Good compounding ingredients may be discarded because of this limitation.

Brake lining materials derive their properties from fillers, binders, and wear-enhancing ingredients, such as those in Table 1. Selection and percentages of ingredients used varies with the type of lining.

Chief lining constituent is Chrysotile asbestos, used as the primary reinforcing material. Chemically, it is an hydrous magnesium silicate ($H_4Mg_3Si_2O_9$). The mineral fibers are 1/8 to 6 in. long. Under high magnification the fiber looks like many finer crystalline threads bundled together. Diam-

* Paper "Automotive Brake Lining Materials" was presented at SAE Annual Meeting, Detroit, Jan. [illegible], 19[illegible]. (This paper is available in full in multilithographed form from SAE Special Publications Department. Price: 25¢ to members, 50¢ to nonmembers.)

Table 1—Brake Lining Ingredients

Binders	Fillers: Reinforcing	Fillers: Nonreinforcing	Friction Modifying and Wear Enhancing Agents	Curing Agents and Accelerators
Elastomers	Chrysotile Asbestos	Barium sulphate	Cashew nut liquid products (powders)	Standard rubber and resin primary and secondary curing agents and accelerators
Rubber		Calcium sulphate	Rubber and synthetic rubber	
GR-S		White lead	Ground rubber tire scrap	
Buna N		Lead carbonate	Iron oxide	
Neoprene		Clay	Metals—lead, zinc, brass	
Phenolic resins		Asbestine	Lead salts	
Oil modified phenolic resins			Talc	
Cashew nut oil resins			Graphite	
Drying oils			Bituminous materials	
Sulfurized oils			Abrasives	

BRAKE LINING MATERIAL

Ingredients Hold Key To Service Behavior

eter of the smallest fiber which can be separated is about 0.00003 in.

Asbestos makes a good friction material because of its heat resistance, chemical resistance, flexibility, low thermal conductivity, and hardness. Its reaction to heat is particularly important.

The asbestos fibers start losing their water of crystallization at about 600 F. The loss rate increases with temperature and become rapid at 1000 F. When the water is driven off, asbestos looses its crystalline properties and becomes a powder. Asbestos fiber breakdown to powder with heat makes possible rejuvenation of the lining's friction surface. Today's brake linings would be impossible if heat generated in braking a car decomposed only organic materials and changed asbestos into a hard, organic fused layer of abrasive material.

Poor heat-conducting properties of asbestos help keep heat from penetrating deeply into the lining. This would produce chemical changes in binder materials and would harm lining friction characteristics.

Asbestos fabrics have a friction coefficient of about 0.35. This is within the 0.2 to 0.4 range around which satisfactory braking systems have been designed.

Brass, lead, or lead alloy wires used in woven materials strengthen the yarn. Some claim lead surpasses other metals because it stabilizes the friction coefficient, acts as a dry lubricant to prevent drum scoring, and inhibits formation of abrasive particles on the friction surface.

Metallic powders, such as zinc and lead, improve performance at high temperatures. Limitation with fine lead is that it oxidizes easily to litharge, which promotes oxidation in unsaturated organic compounds. Some believe these powders help break the continuity of the friction surface film during braking action. Large amounts of metal (40%), such as brass chips, are added to linings for very high temperature requirements.

Brake lining compounders also add lead to compositions in the form of organic salt. High temperature liberates it as finely divided lead in a reducing or inert atmosphere. This prevents oxidation of the metal to an oxide and permits it to function as a friction stabilizer.

Graphite in lining compounds imparts a lubricating effect for smoother stopping. It can be incorporated in the hard rubber or added separately. Some compounders see two advantages for graphite encased in rubber. First, it does not interfere with flow of the resin binder during curing. Second, graphite is released for its lubricating action only after the rubber is softened by high braking temperature.

Iron oxide in small amounts sometimes is used as a friction-controlling element. It tends to have a self-polishing action which partly controls surface frictional properties.

The compound usually requires large amounts of inorganic fillers to produce frictional effects. This necessitates an improved friction stabilizer that functions over a wide temperature range. Organic modifiers—such as rubber, ground rubber scrap, pitches, and gilsonite—function best over narrow temperature ranges.

A powdered product made from cashew nut liquid is one of the better friction-stabilizing and wear-enhancing agents used today. This material works satisfactorily up to temperatures of 600 to 650 F. Tire scrap particles function up to about only 500 F. About 6 to 8% of dust is needed to improve wearing qualities.

Ground-rubber tire scrap has been, and will continue to be, widely used because it is a cheap raw material. Other friction modifiers—such as pitches, gilsonite, coal, and petroleum coke—can be used in limited quantities only because of their low temperature resistance. Braking temperatures destructively distill these materials to form tarry or pitchy residues at the friction surface. These increase the friction coefficient at low temperatures. But at high temperatures, volatile materials may be driven off too rapidly before formation of tarry products, losing their effectiveness.

Research today is aimed at getting binding materials with high heat resistance. Currently the

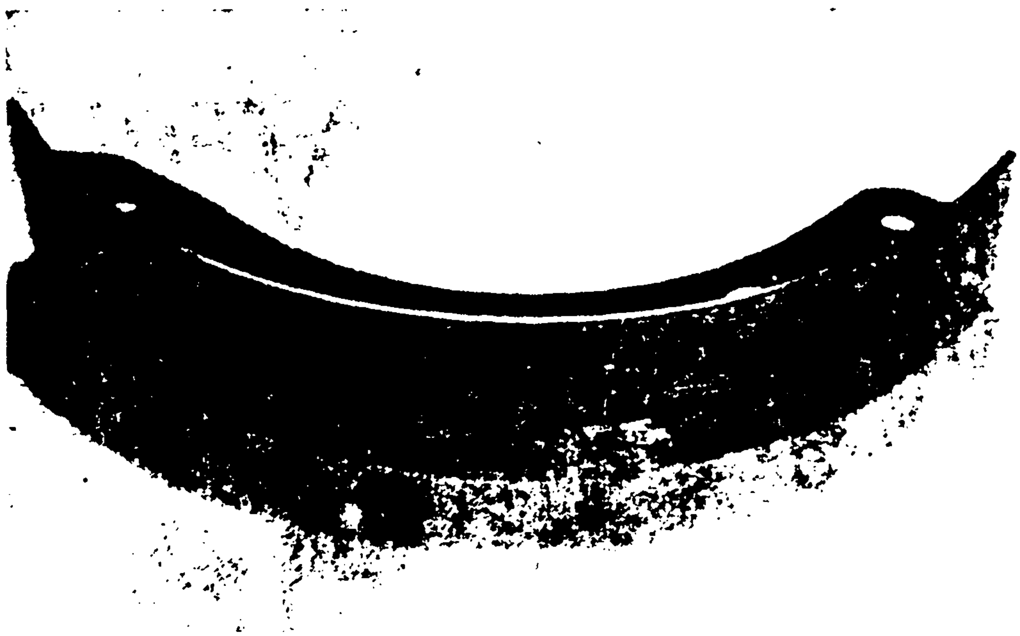

Fig 1—As this brake shoe shows, bonded lining makes available twice the usual lining and virtually eliminates drum score

Lists New Need With Bonding Lining

Add bondability as a sixth lining requirement, advises S. G. Tilden, The Permafuse Co. The advent of bonded brake linings makes this a must.

Tilden's organization has set up an arbitrary minimum bond strength requirement of 600 psi in shear. This gives a total shear strength of 11,500 lb on a 1¾, 11-in. segment. That is about five times the maximum shear force exerted on linings by a simulated emergency stop with a 1 g deceleration.

All lining factors producing good bondability have not been established. But tests have been made to find the effect of porosity. Strangely enough, denser and less absorbent linings bond better.

Bonding suitability also calls for availability of the entire lining thickness for use. That's why wire-back linings are not suited for bonding. They can be used only down to the wire backing; after that they score the drums. With wire backing, the promised double wear from bonded linings cannot be realized.

Typical of the extra wear available with bonded linings is the lining in Fig. 1. This brake shoe with bonded lining was used until the segment had worn completely through to the shoe at the central tangential area. Note the lack of drum score. Except for the lower edge portion, this came from actual metal-to-metal contact between brake shoe and drum.

Tilden points out that bonded linings also improve the path for conduction of heat into the brake shoes, backing plate, and axles. It provides a binder without the insulating air layer usually present in riveted linings.

main binding agents are synthetic resins, drying oils, rubber, and bituminous materials. Most important group is the synthetic resins. Oil modified phenolics are mostly used. Synthetic resins hold much promise because they can be synthetized in the laboratory to meet desired binding material requirements.

Available resins vary in their properties. Some can be used alone, others must be used together with natural, synthetic, or reclaimed rubber. Oil modified types also are commonly used with these rubbers.

Used as a binder, rubber or GR-S must be vulcanized to function properly. In lining compositions they usually are cured to a hard rubber with 25 to 40% sulfur as the vulcanizing agent. Their relatively low softening and decomposition temperatures limit rubbers alone as binding agents. In the future it may be possible to synthesize rubber polymers that will make satisfactory brake lining binding materials. Some day special rubbers may be expressly made for this use.

Drying oils, used for many years in brake lining formulations, are limited because of control of polymerization (hardening). They are used in air-curing type and woven linings. Wide use also is made of them as a binding component in modifying phenolic resins.

(The paper also tells how fabric and molded linings are made.)

automotive engineering

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Designers can affect frictional coefficients of brake ana clutch linings by blending ingredients in their binders.

Friction modifiers tailor brake a

New requirements for friction lining materials exist because of the elimination of asbestos in brake and clutch compositions and the use of small pads for downsized and compact cars. Semi-metallic compositions generally need some friction modifiers to reduce squeal and wear and produce friction characteristics that are less temperature-dependent. Research on solid friction control additivies at Dow Corning has produced new technology by which friction and wear properties can be tailored to specific requirements.

Friction modifiers

Friction modifier additives are synergistic blends of temperature-stable materials which can be incorporated into various compositions to provide specific friction, wear, and load-carrying properties. Concentrations of one to six weight percent can reduce noise levels and dependence of friction on speed and temperature.

Additives, such as cashew resin or graphite, have been used for many years to control friction properties in brake and clutch compositions. Friction composites are composed of a balanced mixture of resin plus additives and generally contain over a dozen ingredients to achieve desired characteristics. In Europe MoS_2 (molybdenum disulfide) has been utilized as a friction modifier for harder brake pad compositions. Comparisons were made between MoS_2 and a composition termed by Dow Corning "Friction Modifier A".

Phenolic resin compositions

Phenolic resins are the most common organic binders used in friction composites. Compositions of phenolics with high loading of MoS_2 powder and Friction Modifier "A" were tested using an Alpha LFW-1 friction and wear testing machine.

Phenolic resin by itself does not have the best lubricating properties. Addition of MoS_2 or Friction Modififer "A" provided a reduction in wear and friction. Generally, the phenolic resin with Friction Modifier "A" gave lower initial coefficients of friction and wear values as compared to an equivalent weight concentration of MoS_2. Coefficient of friction for the Friction Modifier "A" formulation changed less with time than the base resin or MoS_2 composition.

Additional tests at a lower load of 13.6 kg and higher speeds revealed that formulations with Friction Modifier "A" gave a more constant coefficient of friction with changes in speed, load, and time. At higher speeds and lower loads, no difference in wear was apparent between MoS_2 and Friction Modifier "A", but wear was significantly lower than the base resin.

Compositions

Three different brake compositions were categorized as follows:

- *Class A*—High in asbestos and organic components
- *Class B*—Less asbestos and organic components plus some inorganic components
- *Class C*—Semi-metallic non-asbestos composite
- *Class C prototype*—Semi-metallic nonasbestos composite with 10% Friction Modifier "A".

Table 1 lists the different characteristics of the three classes. The brake compositions were tested on the LFW-1 test machine.

The results of the testing are listed in Table 2. Good correlation between the LFW-1 tests and the general characteristics provided for each of the classes was obtained. Complete correlation existed for the wear of the brake composite and the metal mate, and very close correlation existed with noise and friction properties at low and high temperatures.

Class C, which produced the