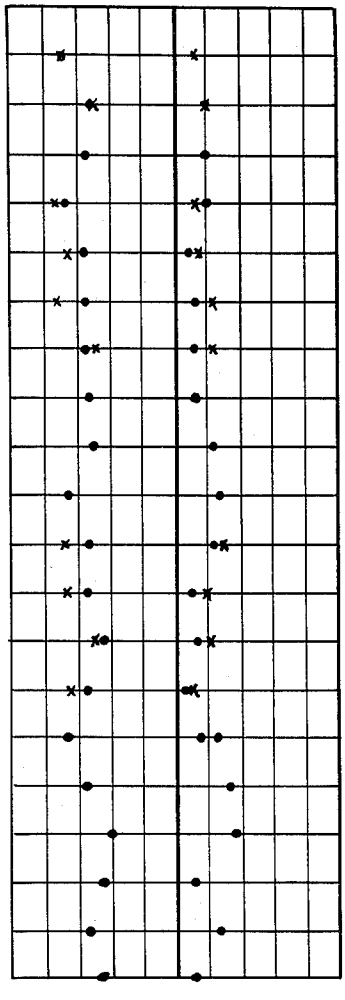
March 8, 1966 J. V. POLLARD 3,239,319

CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

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Fig. 1



EXAMPLE	HEAT NO.	MATERIAL PERCENTAGE BY VOLUME INSOLUBLE PARTICLES			MATRIX METAL	
1	2-286	GRAPHITE 25	SILICA SAND 25		CAST IRON 50	
2	2-339	GRAPHITE 25	SILICA SAND 25		CAST IRON 50	
3	2-318	GRAPHITE 25	SILICA SAND 25		CAST IRON 50	
4	2-405	GRAPHITE 25	SILICA SAND 25		CAST IRON 50	
5	2-415	GRAPHITE 12.5	SILICA SAND 25	STEEL SHOT 12.5	CAST IRON 50	
6	2-428		SILICA SAND 50		CAST IRON 50	
7	2-435	GRAPHITE 25		SILICON CARBIDE 25	CAST IRON 50	
8	2-464	GRAPHITE 15	SILICA SAND 35		CAST IRON 50	
9	2-469	GRAPHITE 35	SILICA SAND 15		CAST IRON 50	
10	2-482	GRAPHITE 12.5	SILICA SAND 25	SILICON CARBON 12.5	CAST IRON 50	
11	3-007-1	GRAPHITE 25	SILICA SAND 25		CAST IRON 50	
12	3-015-1	GRAPHITE 15		SILICON CARBIDE 35	CAST IRON 50	
13	3-015-2	GRAPHITE 35		SILICON CARBON 15	CAST IRON 50	
14	3-025-2	GRAPHITE 35	SILICA SAND 15		CAST STEEL 50	
15	3-025-3	GRAPHITE 15	SILICA SAND 35		CAST IRON 50	
16	3-029	GRAPHITE 25	SILICA SAND 12.5	IRON GRIT 12.5	AL. ALLOY 50	LEAD .01
17	3-031-2	GRAPHITE 45	SILICA SAND 5		CAST IRON 46	TIN 4
18	3-031-3	GRAPHITE 40	SILICA SAND 10		CAST IRON 46	TIN 4
19	3-040-3	GRAPHITE 25	SILICA SAND 15	AL OXIDE 10	CAST IRON 50	
20	3-046-2	GRAPHITE 35	SILICA SAND 15		CAST IRON 50	

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Fig. 1A

EXAMPLE HEAT No.	M.C.F.% 10 20 30 40 50	WEAR-IN^3/100 MIL FT.LB. 0 2 4 6 8 10	MATERIAL PERCENTAGE BY VOLUME INSOLUBLE PARTICLES			MATRIX METAL
21-3-057-3			GRAPHITE 35	SILICA SAND 15		CAST IRON 50
22-3-062-3			GRAPHITE 25	CHROMITE SAND 12.5%	SILICON CARBIDE 12.5	CAST IRON 50
23-3-075-2			GRAPHITE 35		SILICON CARBIDE 15	CAST STEEL 50
24-3-076-3			GRAPHITE 35	EMERY 15		CAST IRON 50
25-3-076-5			GRAPHITE 35	GARNET 15		CAST IRON 50
26-2-448-1			GRAPHITE 12.5	MULLITE 12.5	IRON GRIT 25	ALUMINUM 50
27-3-008-2				SILICA SAND 15	IRON GRIT 35	ALUMINUM 50
28-3-007-2			GRAPHITE 12.5	SILICA SAND 12.5	STEEL SHOT 25	CAST IRON 50
29-2-121			GRAPHITE 13.4	MULLITE 3.6	IRON GRIT 26.5	ALUMINUM 56.5
30-2-147			GRAPHITE 25	MULLITE 25		ALUMINUM 50
31-2-176			GRAPHITE 25	MULLITE 25		CAST IRON 50
32-2-032			GRAPHITE 34	MULLITE 6	IRON GRIT 25	CAST IRON 35
33-1-415			GRAPHITE 34	MULLITE 6	IRON GRIT 25	CAST IRON 35
34-1-353			GRAPHITE 50			CAST IRON 50
41-3-106-3			GRAPHITE 40		SILICON CARBIDE 10	CAST STEEL 50
42-3-114-4			GRAPHITE 35	SILICA SAND 15		DUCTIBLE IRON 50
43-3-138-4			GRAPHITE 5	SILICA SAND 45		CAST STEEL 50
44-3-143-3			GRAPHITE 30	ALUMINA 10	SILICON CARBIDE 10	CAST IRON 50
45-3-143-6			GRAPHITE 40		SILICON CARBIDE 10	CAST IRON 50

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CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

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Fig. 2

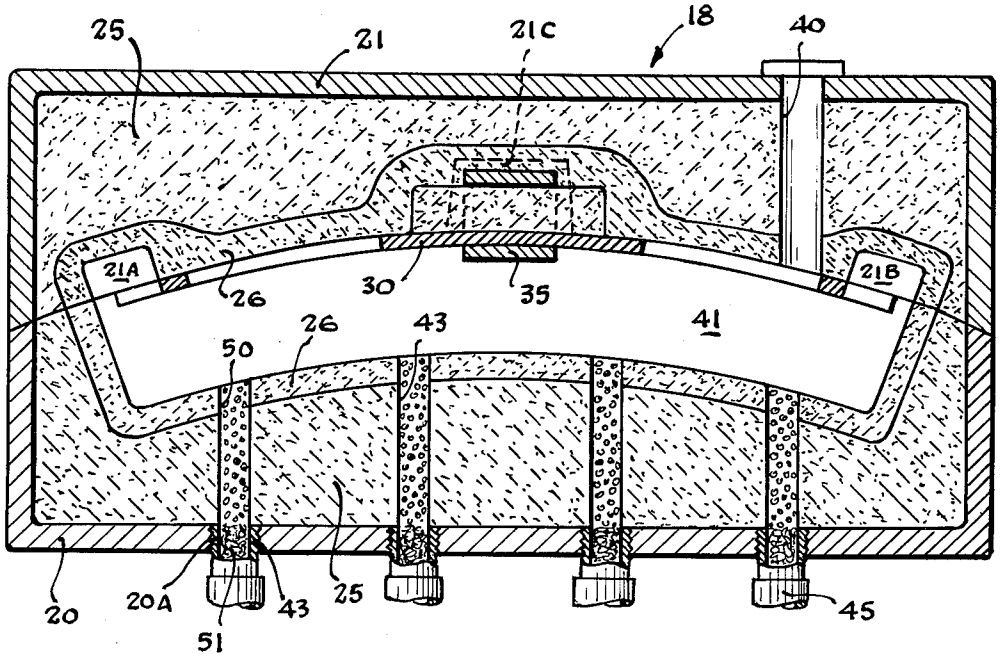


Fig. 3

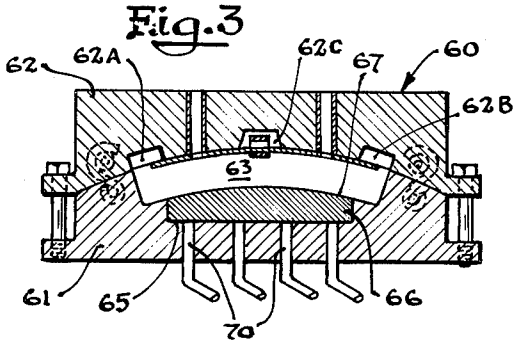


Fig. 2A

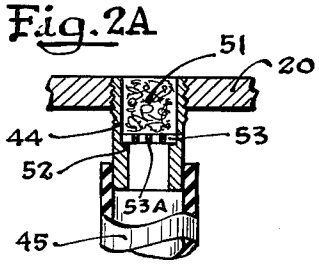
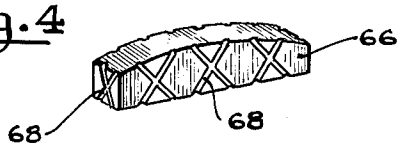


Fig. 4



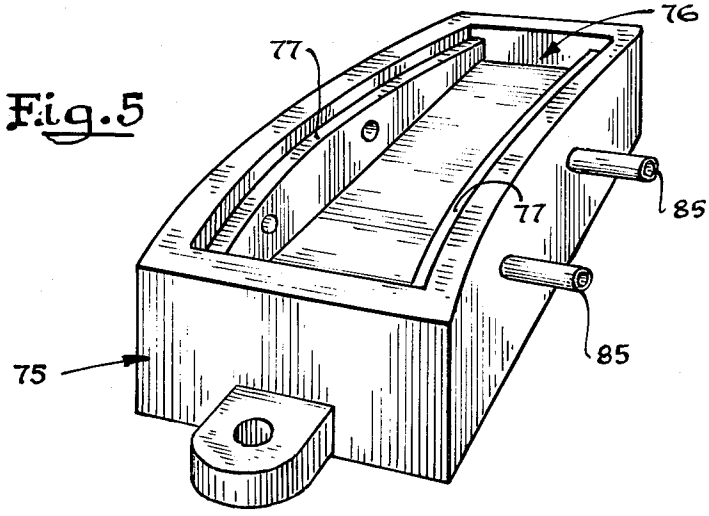
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CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

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Fig.5



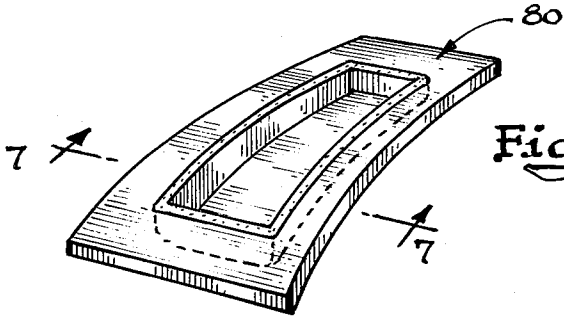


Fig.6

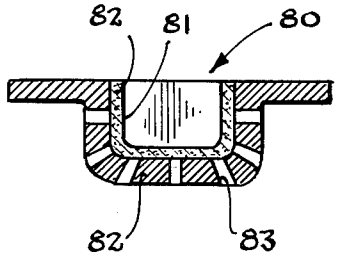


Fig.7

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CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

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Fig.9

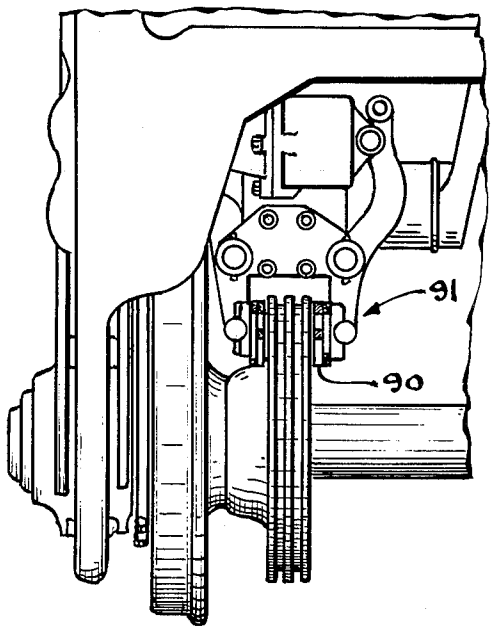
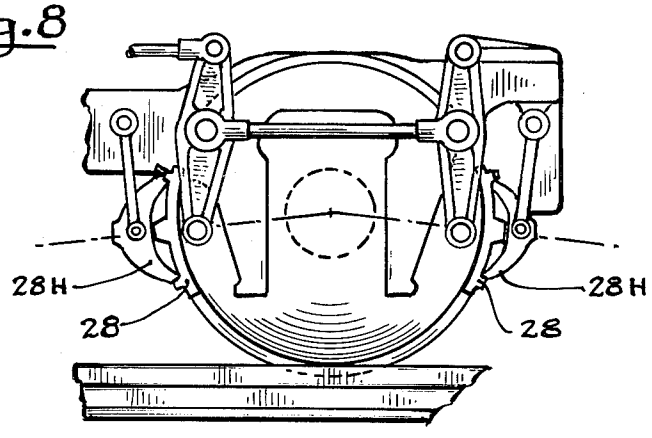


Fig.8



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CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

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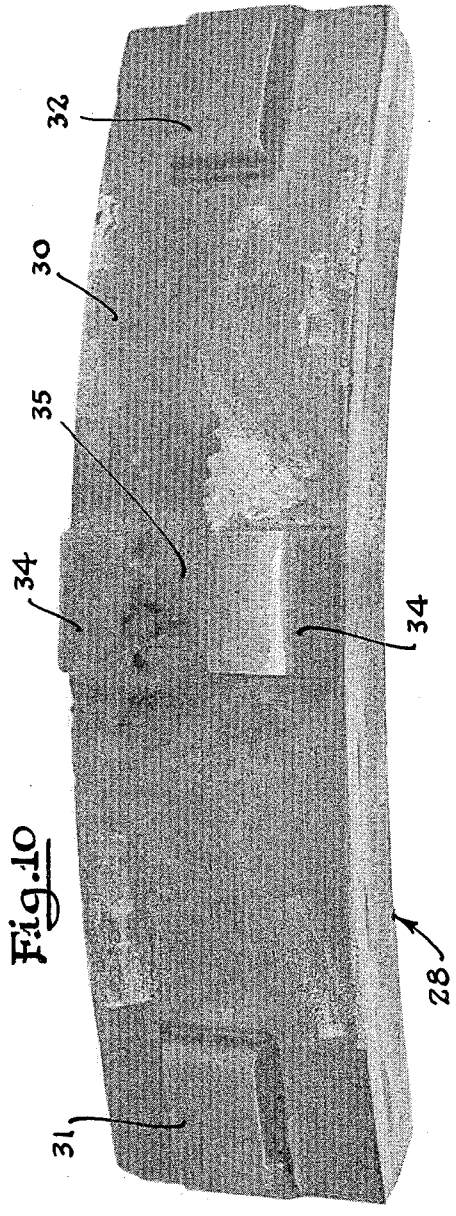


Fig. 10

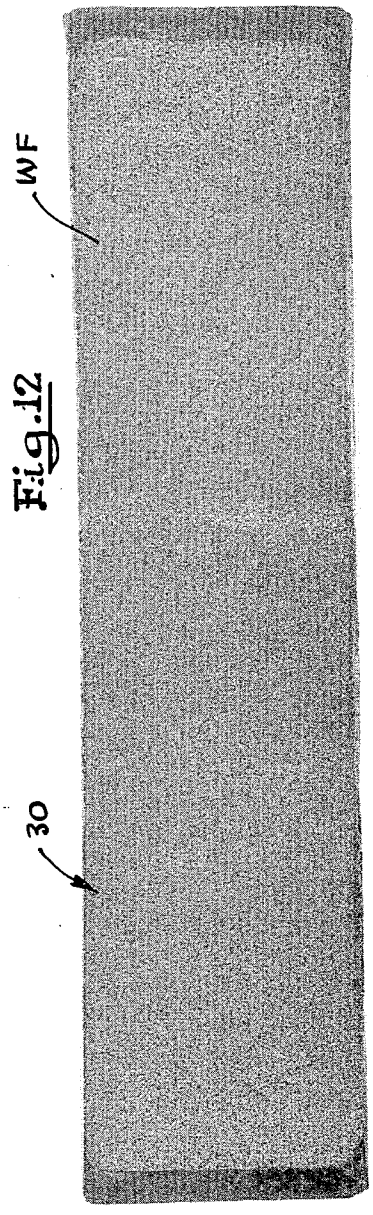


Fig. 12

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CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

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Fig.11

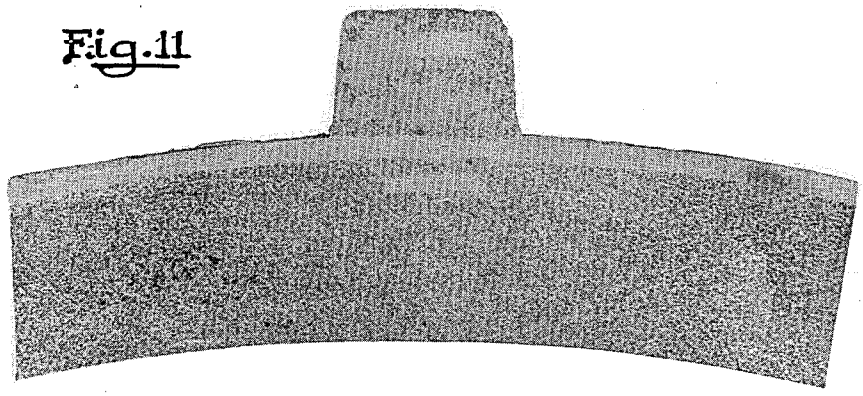


Fig.13

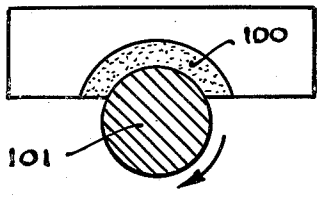


Fig.14

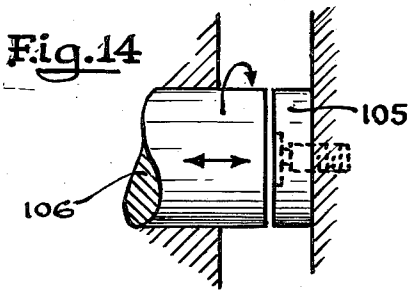
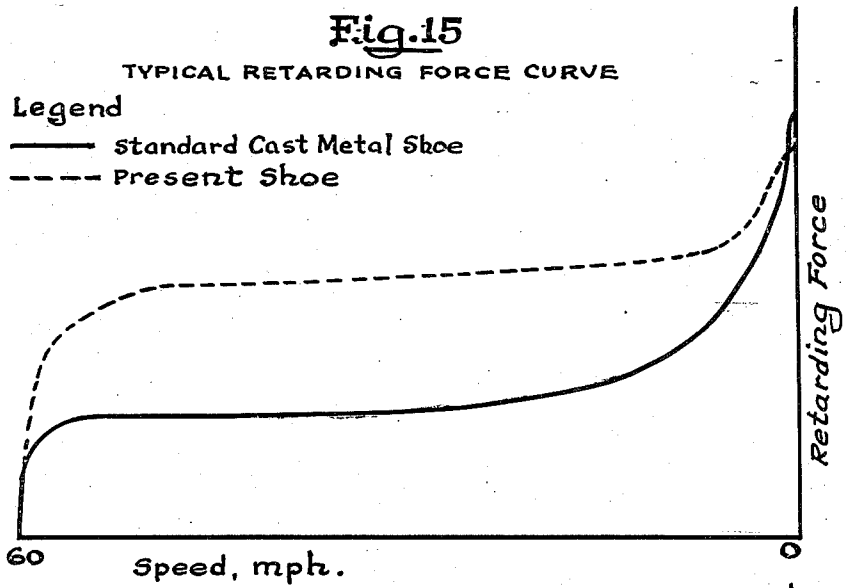


Fig.15

TYPICAL RETARDING FORCE CURVE



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United States Patent Office

3,239,319
Patented Mar. 8, 1966

3,239,319

CAST RAILROAD BRAKE SHOE AND METHOD OF MAKING SAME

Joseph V. Pollard, Ramsey, N.Y., assignor to American Brake Shoe Company, Wilmington, Del., a corporation of New York

Filed May 10, 1963, Ser. No. 279,456
13 Claims. (Cl. 29—183)

The invention relates to a composition of matter characterized by discrete particles that are uniformly distributed in a separated state throughout a cast metal matrix, and to a method of production thereof. This invention also relates to the production of articles of manufacture consisting of such a composition of matter and specifically those that may produce torque, as in a friction couple or similar mechanical arrangement wherein there are relatively movable elements of which one is adapted to engage the other.

There are numerous instances where it is desirable to have a cast metal body of definite geometrical shape, for an assigned application, that subscribes to predetermined wear and friction coefficient characteristics. Such a body is most expeditiously and inexpensively obtained by casting the same from molten metal, but if it is desired to selectively vary a given property such as the wear rate or friction coefficient, this is usually accomplished as a practical matter by varying the fundamental metallurgy of the molten material that is cast. In other words, a monolithic cast body is usually of homogeneous character throughout its useful thickness, and such homogeneity in fact is an essential requirement if a friction element, for example, or other body, is to display a uniform character throughout its useful thickness. On the other hand, it would be desirable to be able to selectively vary the character of a cast friction element, or other article for industrial application, as in torque or rotary motion couples, on the basis of components which have a selective effect on wear rate or friction or other essential property.

While the present problem has been set forth above on the basis of considerations specifically devoted to a friction element, it will be appreciated that there are other articles that are cast, or are fabricated from castings, wherein it would be advantageous to be able to vary certain properties selectively, without necessarily resorting to a change in metallurgy, and it is the primary object of the present invention to enable this to be accomplished, and specifically by making available a casting characterized by discrete, undissolved particles that are uniformly distributed throughout the useful thickness of the article and which have a potent, predictable effect on the fundamental character of the casting from the standpoint of wear rate, friction coefficient and like properties of fundamental or essential importance. Specifically, it is an object of the present invention to furnish a casting of definite geometrical shape, in which a selected molten metal, representing the matrix of the body, is cast in the mold uniformly about a loose particle content that is uniformly distributed throughout the volume of the mold cavity in an otherwise free or unsupported state, so that the resultant casting is one in which the particles remain insoluble in the matrix metal to impart to the overall

casting a selected property on the basis of wear rate, friction or the like.

Yet more specifically, it is an object of the present invention to be able to vary the friction or wear rate or similar property of a casting virtually at will by selecting particles to be uniformly distributed throughout the useful thickness of the casting.

In a railroad brake shoe or similar friction element, the wear rate and the coefficient of friction are of prime importance. Satisfactory values in this regard are achieved today by the AAR (Association of American Railroads) specified standard shoe. This shoe, the standard AAR shoe, by and large, has proven to be most satisfactory from its inception to date, and one of the primary reasons for this success is that such a cast iron railroad brake shoe displays a wet friction that is substantially equal to dry friction. In other words, inclement weather does not interfere with braking so far as concerns the friction coefficient of the shoe. Another object of the present invention is to be able to meet or better these standard AAR requirements in a shoe characterized by a selected metal matrix which contains undissolved, inorganic particles and which in fact results in a shoe having characteristics superior to the minimum AAR requirements.

Another object of the present invention in this regard is to develop a friction element or the like which controls peaking or so-called rooster-tailing that characterizes an increase in torque at the end of a braking operation.

The objects of the present invention above described are made possible by a cast metal matrix having distributed uniformly therethrough particles that are insoluble in the matrix, and another object of the present invention is to obtain a casting displaying this characteristic, and especially one wherein the particle distribution is uniform throughout the matrix body so that at any one plane in the useful thickness of the body, substantially the same density and material identification are found whereby the properties of the casting are uniform, which is to say that the unique effect of the particles is substantially uniform at any average area throughout the useful thickness of the cast body.

Specifically, it is an object of the present invention to accomplish the foregoing by freely distributing the particles that are to be insoluble in the matrix uniformly throughout the volume of the mold cavity in which the matrix metal is poured, preheating the particles to avoid premature solidification of the poured metal, and then driving or impelling the molten metal into the mold cavity containing the hot particles so that the molten metal flows quickly through the mold cavity and uniformly penetrates the voids between the particles whereby the casting is free of voids or like imperfections. Such driving or impelling of the molten metal in the present instance is specifically accomplished by creating a vacuum in the mold cavity which in effect allows atmospheric pressure to become the impelling or driving force, but it will be appreciated that other techniques are available such as injection, pressure pouring, a gravity head, centrifuging or the like for assuring a prompt and uniform running of the molten metal through the interstices between the insoluble particles without premature freezing of the molten metal. In this regard, it is another object of the pres-

ent invention to promote a rapid flow of the molten metal through the mold be heating the insoluble particles, where necessary, to an appropriate temperature. It will be understood that the temperture needed is that quantity of heat necessary to enable the force behind the molten metal to impel molten metal through the voids between the insoluble particles. In this regard, it will be understood that the rapidity of filling the voids by the molten metal is a function of the rate of speed at which the molten metal is forced into the voids between the insoluble particles and the temperature of the insoluble particles at that time.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what I now consider to be the best mode in which I have contemplated applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

FIGS. 1 and 1A are charts of friction and wear rate properties pertaining to certain examples that are characteristic of the present invention;

FIG. 2 is a sectional view of a mold for casting a typical article of manufacture under and in accordance with the present invention;

FIG. 2A is a detail view of an element associated with the mold of FIG. 2;

FIG. 3 is a sectional view of another kind of mold for casting an article of the character disclosed herein;

FIG. 4 is a detail perspective view of a vent plug used in the mold of FIG. 3;

FIG. 5 is a perspective view of the drag part of another mold, related to the mold of FIG. 3;

FIGS. 6 and 7 are views of an insert for the drag shown in FIG. 5 and which defines the mold cavity thereof;

FIG. 8 is a view illustrating a typical railroad brake of the clasp type in which friction elements of the present invention may be employed;

FIG. 9 is a plan view of a typical railroad disc brake illustrative of a friction couple in which friction blocks produced under and in accordance with the present invention can be used;

FIG. 10 is a perspective view of a railroad brake shoe that may be cast in the mold of FIG. 2;

FIGS. 11 and 12 are photographic reproductions of castings produced under the present invention;

FIGS. 13 and 14 illustrate typical shaft and bearing couples, of which the bearing is an element of the couple produced in accordance with the present invention; and

FIG. 15 is a graph showing torque reaction curves.

Introduction

In the past, it has been recognized that materials having a composite structure would be useful for many purposes. Indeed, a number of such materials have been manufactured and used, some for many years. For example, the addition of lead to certain metallic matrices in which the lead is insoluble, or virtually so, and in which the lead exists as a dispersion of small spheroidal particles is quite old and well known. These so-called "leaded" alloys have exhibited improved machinability and in some cases improved bearing properties when compared to the corresponding unleaded matrix metal properties. This class of materials depends upon certain factors or properties inherent in the nature of the matrix metal as well as in the nature of the dispersed metal. First, both metals must be in the liquid state together, both must be mutually immiscible, or virtually so, in both the liquid and solid states, the molten metal

to be dispersed must be broken up and distributed throughout the molten matrix metal, and the molten metals must be cast and the matrix solidified before the dispersed molten metal droplets can coalesce or segregate within the matrix. These factors obviously place severe limitations upon the geometry and size of articles which can be successfully made by this technique, as well as the kinds of metals which can be employed.

As another example of a different kind of composite structure, the group of materials known as "cermets" have evolved. Usually these materials have been produced by so-called powder metallurgy techniques involving mechanically mixing particles of metallic and non-metallic materials together, pressing the mixture into a shaped form and sintering together the particles having the lowest sintering temperature of the materials comprising the mixture. Usually such composite bodies have not exhibited very high mechanical properties and, in general, may be said to be weak when compared to the strength one would expect when the mechanical properties of the as-cast matrix metal are considered.

Another technique which has been proposed for the manufacture of cermet materials involves the manufacture of a shaped, highly porous, self-sustaining skeleton of sintered ceramic. The metal component in the molten state is then infiltrated into the interstices of the ceramic body. There are a number of serious difficulties inherent in this process, among which are limitations on the size and geometry of the body, the difficulty in getting the molten metal to "run" or penetrate into the interstices which involve such factors as the chilling effect or heat transfer properties of the ceramic, surface tension and viscosity of the metal, "blind" voids and many other problems.

Perhaps the most commonplace method of achieving a "composite" structure, broadly speaking, is the employment of the precipitation phenomenon commonly occurring in the practice of the metallurgical arts. In general, this practice requires the employment of a matrix metal and at least one element, metallic or non-metallic, which has at least a limited solubility in the matrix metal in the molten state and a lesser degree of solubility in the matrix metal in the solid state. Materials having unlimited solubility in the solid state are not suitable since they form a continuous series of solid solutions regardless of composition, and therefore are incapable of forming a precipitate.

In this latter group of materials, certainly the oldest, the most common and the best known are the so-called "gray" cast irons. These materials are alloys of iron and carbon and derive their name from the characteristic appearance of their fractured surfaces. This appearance of a freshly fractured surface of these materials is, as the name might suggest, gray rather than the bright silvery metallic appearance characteristic of other alloys. This difference in appearance is due to the presence of precipitated graphite as a dispersion throughout the body of these materials. The morphology of this composite structure is quite complex, but briefly may be stated as follows. Carbon has a limited solubility in liquid iron. Assuming a saturated solution of carbon and liquid iron to exist, as the temperature of the molten iron alloy approaches its freezing point, carbon as so-called primary graphite precipitates out of solution. As the temperature drops, graphite continues to precipitate, the liquid meanwhile becoming depleted in carbon until the eutectic composition is reached. Then the eutectic liquid-freezes to produce a matrix of iron containing flake graphite. Obviously, the total amount of graphite thus deposited depends upon the degree of saturation of dissolved carbon existing in the molten iron alloy prior to solidification over and above that which chemically combines with iron to form iron carbide. Therefore, the amount of graphic carbon particles which are producible in an iron-base matrix by precipitation is limited to a finite maxi-

mum which is governed by the solubility of carbon in molten iron.

Many attempts have been made during the past to increase the volumetric percentage of graphite in such cast irons beyond that achievable by precipitation, but prior to this invention, none has been successful. For example, for a great many years the vast majority of brake shoes used on railroad cars have been made of cast iron. Because of the limited amount of precipitable graphite possible to achieve in cast iron, as previously pointed out, no really significant improvement in the coefficient of friction between hard and soft iron shoes was attainable. It has long been known that if the shoes are made of a relatively soft cast iron, containing a relatively higher volumetric percentage of graphitic carbon in the usual flake form, that a relatively higher coefficient of friction can be achieved, but these shoes had a relatively poor resistance to wear. If the shoes were made of a harder cast iron containing little or no graphitic carbon, they exhibited a somewhat lower coefficient of friction, but their wear rate was improved.

As an attempt to make use of the better properties of each, that is, to produce a shoe having a higher coefficient of friction and a higher resistance to wear, a composite shoe was made in which a number of graphite block inserts were anchored in place in the brake shoe mold and a hard cast iron cast about them, as disclosed in United States Patent No. 2,162,770. These shoes displayed the somewhat improved friction and wear properties anticipated; however, it was recognized that if the added graphite could be put into the matrix as a dispersion of uniformly distributed smaller particles that these friction and wear properties could be maintained and a more satisfactory shoe from other viewpoints such as mechanical strength, could be made.

Many attempts were made to achieve this results, that is, to increase the volumetric percentage of graphite beyond that achievable by precipitation, including (1) attempting to stir graphite particles into the molten iron and then quickly pouring (2) attempting to pour graphite particles into the mold simultaneously with the molten iron, and many other variations but none has been successful. These prior attempts failed largely because of the relatively large differences in the specific gravities of molten iron and graphite. Because of this factor, it is practically impossible to prevent the graphite from floating to the top of the molten iron and therefore, any degree of uniformity of distribution in the rare cases where a few particles of graphite were carried down into the body of the casting was lacking. It should be pointed out at this point that similar problems were encountered when abrasive materials such as silica, for example, were attempted to be added. Various other attempts to solve these problems have been made but none has succeeded in significantly raising the coefficient of friction in metallic shoes. See, for example, United States Patent Nos. 995,067 and 1,184,137.

Until this invention, no entirely satisfactory solution for these problems was known. As will become apparent from the following detailed disclosure, not only have these problems been solved, but completely unexpected improvements in the coefficient of friction and wear rate are achieved.

The present invention is characterized by a composition of matter consisting of particles of relatively large size, up to one-quarter inch in diameter, substantially insoluble in and distributed uniformly through a matrix metal cast thereabout, such that the cast metal matrix represents the continuous phase and the discrete particles the discontinuous phase of the cast body. As a practical matter, the particles may dissolve to a slight extent at the surface thereof when the molten metal is poured in contact with the particles, particularly in the instance of pouring cast iron in contact with graphite particles, the iron being unsaturated with carbon. This is, however,

but a very slight degree of solubility. The particles are distributed uniformly throughout the useful thickness of the cast body so that the average density of the particles is uniform in any given average plane or area throughout the useful thickness of the casting, and a cross-section of the structure exhibits virtually no voids or similar imperfections as will be demonstrated.

As will be explained, the substantially insoluble particles may be mixed with metal particles, the latter being more soluble in the molten metal. Such mixing is resorted to in order to reduce the density or effective volume of the particles that are substantially insoluble, and to this extent the total effect of the insoluble particles can be controlled or modified.

Such cast structure is achieved under and in accordance with the present invention by first distributing the substantially insoluble particles in a mold cavity, such particles of the aforesaid character being selected on the basis of a property desired to be imparted to the structure uniquely by the particles. Thus, the mold cavity is filled with particles in a homogeneously mixed state, and in most instances the particles are pre-heated to a relatively high temperature, depending upon the nature of the molten metal to be poured, so that the particles in their heated state extract very little of the heat content of the molten metal subsequently poured, thereby avoiding chilling of the melt and assuring sustained fluidity of the molten metal moving through the interstices or voids in the particles. The particles can be pre-heated in the mold in some instances.

The present process is also characterized by forcefully impelling or pushing the liquid metal through the voids existing between the particulate or finely divided pre-heated material in the mold incidental to achieving a complete penetration of the molten metal through the particles. As a result of forcing the molten metal, the latter becomes a liquid under pressure in the mold cavity, and to some extent, therefore, moves the particles slightly and separates them sufficiently to enable the molten metal to wet and surround sach particle while investing each void in the mold before becoming chilled. Advantageously, such forcing action is accomplished by establishing a vacuum in the mold cavity immediately prior to introducing the molten metal. This appears to be the most efficacious and inexpensive mode of forcefully introducing the molten metal, but it will be appreciated that other techniques are possible, depending upon the scale of production and the nature of the article being produced.

By filling the mold cavity with the particles either entirely of the substantially insoluble kind or a mixture thereof with some metal particles that may be partially or completely dissolved in the metal matrix subsequently cast thereabout, it is assured that the particles are restrained against any substantial movement en masse. Hence, the particles will not float away in the heavier matrix metal or migrate to any marked degree in the course of pouring the molten matrix metal. This filling of the mold, to obtain uniform distribution of the substantially insoluble particles throughout the useful thickness of the cast body is one of the characteristic features of the present invention.

In the instance of thick castings such as railroad brake shoes, the particles added to the mold cavity are preheated to avoid chilling of the molten metal, and the mold may be heated sufficiently to avoid chilling the particles.

The following are typical practices under the invention using ferrous and non-ferrous matrices cast about a wide variety of particles that remain undissolved therein, including graphite (both synthetic and natural), silica, alumina, silicon carbide, sillimanite, mullite, garnet, metal particles (iron and steel) and organic particles (Teflon resin, that is, polytetrafluoroethylene).

EXAMPLE 1.—HEAT NO. 2–286

In this example, and in Examples 2 through 28 to follow where a railroad brake shoe is cast, a mold having a drag and cope of the character hereinafter described was used. Such a mold, as will be explained, may take different forms, but is characteristically a precision-faced mold, or a permanent mold, modified to enable a rather high vacuum to be established in the mold cavity. Consequently, the molten metal poured therein is forcefully driven through the particles which fill the mold cavity, usually to 50% of the total void volume thereof, that is exclusive of the inherent voids between the particles. The voids between the particles thus are occupied by the molten metal forcefully cast about the particles.

When making reference to the volume of the mold, the total occupiable volume is what is being considered. Thus, I fill the mold cavity at least level with particles before casting, so that the particles have no room to float or migrate to any great extent when the cope is positioned and the melt poured. Nevertheless, there are voids between the particles, and it is this space in the mold cavity of the drag, about fifty percent of the volume of the mold cavity, that is occupied by the molten metal cast therein.

There may of course be instances where it is desirable to locate a solid metal insert or so-called metal core in the drag cavity, the particles filling the mold cavity to the extent that it is not displaced by any insert that may be present. Moreover, and as part of the disclosure herein, a steel back reinforcement or other part supported by the cope may project a slight amount into the drag cavity to become part of the completed article, contacting the adjacent surface of the particles that fill the mold. Then, too, when vacuum is applied just before the molten metal is poured, the particles are slightly compacted, so it is advantageous to compensate this with a slight excess. Therefore, by a mold filled with particles before casting the molten metal in the voids between the particles, I mean, in the examples following, that the particles therein at least fill the entire unoccupied mold cavity, or equivalent mold part, that is, by the amount not occupied by a mold insert or cope-supported element that is or are to be embedded in the casting as an integral part thereof.

The particles include particles such as non-metallics that are substantially insoluble in the matrix metal, or these in combination with particles such as metallics which may actually dissolve to an appreciable extent. In any event, a characteristic feature of the present invention is that the particles which are substantially insoluble in the matrix metal are uniformly distributed throughout the entire volume of the mold cavity.

By thus filling the mold, the matrix-insoluble particles are blocked against any significant or undesired migration when the molten metal is poured and forced between the particles, and the cast body as a whole will display a uniform density in any given plane throughout its wearing or working thickness, characterized by a uniform distribution or concentration of the particles that remain undissolved in the matrix metal to impart their unique properties thereto. Attaching lugs, ears or projections that may be formed on the casting, by recesses in the cope into which the molten metal rises, for subsequently mounting or securing the casting in its intended environment, are not considered a part of said thickness of the casting, subject to wear or friction application, that need be usefully improved under the present invention.

It may finally be observed that for ferrous castings the particles in the mold are at a predetermined high temperature when the melt is poured, thereby to assure sustained fluidity of the latter in the course of its filling the voids between the particles and wetting each particle.

The particles are preferably heated to the needed temperature in a separate crucible, and then are added to the mold cavity until the mold cavity is filled. In order to prevent chilling of the particles, the mold walls should be hot enough, dull red for example, to prevent the mold from becoming a heat sink. The foregoing applies to ferrous metal matrices in particular, but such is by no means always necessary for aluminum, particularly a pre-heated mold.

In each of the examples herein, the matrix metal becomes a continuous network through the particles and surrounds and envelops each undissolved particle in the mold, or in other words, the particles are discrete and discontinuous and are isolated or separated from one another, and it is believed that this slight particle spreading phenomenon is encouraged or promoted by the forced action of driving the molten metal through the particles, thereby substantially disrupting such point-to-point contacts between the particles that might have been established in the course of filling the mold therewith preliminary to pouring the cast.

In Example 1, hard, synthetic graphite (+30 mesh), and silica sand (−16+20 mesh) each calculated as representing 25% of the mold cavity, were homogeneously mixed and added to a mold shaped to produce a predetermined railroad brake shoe structure of conventional geometry. The hard, synthetic grade of graphite was used in each example pertaining to a friction element of shoe or block form, serving as a friction modifier.

The silica sand in this instance, and in the examples following that pertain to friction elements of shoe or block form, served to enhance or promote friction and to impart long-wearing properties to the cast body. Silicon carbide, chromite sand, garnet, emery, mullite, sillimanite and alumina serve a similar purpose but to a different degree, and thus are representative.

The graphite and silica particles, in the homogeneously mixed state, were pre-heated to a temperature of 1860° F. and the hot mold cavity was filled therewith, these particles being substantially insoluble in cast iron. Thereafter, cast iron, having the analysis set forth below, was poured into the hot mold at a temperature of 2780° F. in contact with the hot particles and under pressure induced by a vacuum of 13 inches of mercury. Pouring of the molten metal completed the process such that the casting, when cooled, was removed from the mold in condition to be tested (after dressing fins and the like) for properties set forth in Table I and FIG. 1, as with all examples 1 to 34 hereof. Thus, the casting removed from the mold displayed a coefficient of friction and a wear rate plotted in FIG. 1 and tabulated in Table I.

The cast iron, to which was added a small amount of tellurium to enhance formation of hard white iron effect, namely, 2 grams per 100 pounds of iron at tap, analyzed as follows:

C	Mn	Si	S	P	Cr	Fe
3.0%	0.4%	0.80%	0.15%	1.0%	0.8%	Balance

EXAMPLE 2.—HEAT NO. 2–339

A hot mold for a railroad brake shoe was filled with a homogeneous mixture of graphite (−10+15 mesh) and silica sand (−10+16 mesh), each representing 25% of the total volume of the mold, similar to Example 1 above, and pre-heated to a temperature of 1800° F. Cast iron at a temperature of 2800° F. was poured into the mold containing the hot particles and impelled through the interstices between the particles under a vacuum of 28.5 inches of mercury. The cast iron was of the same analysis as that for Example 1, and occupied the remaining approximately 50% of the mold cavity, namely, the voids between the particles.

EXAMPLE 3.—HEAT NO. 2–318

A hot mold of the character for casting a railroad brake shoe was filled with a homogeneous mixture of graphite (+30 mesh) and silica sand (−16+30 mesh). The graphite particles represented 25% of the mold cavity volume, and the silica sand 25%, and the particles were pre-heated to a temperature of 1800° F. Cast iron of the Example 1 analysis at 2780° F. was forced into the mold, containing the hot particles, under a vacuum of 28.0 inches of mercury. The cast iron penetrated the voids between the particles representing about 50% of the mold cavity volume.

EXAMPLE 4.—HEAT NO. 2–405

A hot mold presenting a cavity shaped in conformance with a railroad brake shoe was filled with a homogeneous mixture of graphite (−10+16 mesh) and silica sand (−10+16 mesh). The graphite represented 25% of the mold cavity volume and the silica sand likewise 25%, and the particles in the hot mold were at a temperature of 2100° F. when molten cast iron (Example 1 analysis) was admitted to the mold at a temperature of 2800° F. and 28.5 inches of mercury, occupying the voids between the particles to the extent of the remaining mold cavity, namely, about 50%.

EXAMPLES 5.—HEAT NO. 2–415

A hot mold presenting a cavity defining the geometry of a railroad brake shoe was filled with a homogeneous mixture of graphite, silica sand and steel particles, the graphite representing 12.5% of the volume of the mold and having a mesh size of −10+20. The silica sand represented 25% of the volume of the mold cavity and had a mesh size of −16+20. The particles above specified were homogeneously mixed with metal particles in the form of steel grit of mesh size +16 which represented 12.5% of the volume of the mold cavity, whereby the graphite and silica particles were uniformly distributed among the steel particles in the mold cavity. All the particles were heated to a temperature of 1900° F. Cast iron (Example 1 analysis) at 2800° F. was poured into the mold containing the hot particles to occupy the remaining volume thereof between the particles, and was forced through the interstices of the particles under a vacuum of 28.5 inches of mercury.

In this example, the inorganic, non-metallic particles (graphite whether synthetic or natural is classified herein as inorganic and non-metallic) represented less than fifty percent of the occupiable mold cavity volume, namely, 37.5%. Nevertheless, these particles were uniformly distributed throughout the mold cavity by the steel grit particles which in effect attenuate and reduce the effective volume or density of the non-metallic, substantially insoluble particles. Such steel particles, of higher melting point than the iron, may be partially or even completely dissolved by the molten iron.

EXAMPLE 6.—HEAT NO. 2–428

A hot mold cavity for casting a railroad brake shoe was filled with pre-heated particles of silica sand (−16+20 mesh) representing 50% of the total volume of the mold cavity. These particles, insoluble in the matrix metal, were heated to a temperature of 2015° F. prior to being added to the mold cavity. Thereafter the matrix metal, cast iron of Example 1 analysis, was forced into the hot mold at 2800° F. under a vacuum of 29.0 inches of mercury to fill the remaining unoccupied volume thereof, namely, the interstices between the hot particles.

EXAMPLE 7.—HEAT NO. 2–435

A hot mold cavity for casting a railroad brake shoe was filled with a homogeneous mixture of graphite

(−16+20 mesh) and silicon carbide (approximately −40+60 mesh), heated to a temperature of 2000° F. The respective kinds of particles were calculated as representing about 25% of the mold cavity volume. Cast iron of the above analysis and in a molten state at 2800° F. was forced into the hot mold under a vacuum of 29.0 inches of mercury to fill the remaining unoccupied volume thereof.

EXAMPLE 8.—HEAT NO. 2–464

A hot mold of the shape of a railroad brake shoe was filled with a homogeneous mixture of graphite (+30 mesh) and silica sand (−16+20 mesh), pre-heated to a temperature of 2140° F. The graphite particles represented 15% of the mold cavity volume and the silica sand 35% of the mold cavity volume. Cast iron poured at a temperature of 2800° F. was forced into the mold under a vacuum of 29.0 inches of mercury to fill the unoccupied cavity content, 50%. The cast iron was of the Example 1 analysis.

EXAMPLE 9.—HEAT NO. 2–469

A hot mold for casting a railroad brake shoe was, in this instance, filled with 50% by volume of particles insoluble in the subsequently cast matrix metal. The particles included graphite (+30 mesh) calculated as 35% of the mold cavity volume and silica sand (−16+20 mesh) calculated as 15% of the mold cavity volume. These particles were homogeneously mixed to achieve a uniform distribution thereof, and were heated to a temperature of 2000° F. before addition to the hot mold, and thereafter the remaining unoccupied volume of the mold, about 50%, was filled with cast iron poured at a temperature of 2800° F. under a pressure head of 29.0 inches of mercury. The cast iron was of the analysis set forth above in connection with Example 1.

EXAMPLE 10.—HEAT NO. 2–482

A hot mold for a railroad brake shoe was filled with 50% by volume of particles insoluble in the subsequently poured matrix metal. These particles included graphite (+30 mesh) calculated as 12.5% of the mold volume, silica sand (−16+20 mesh) calculated as 25% of the mold volume, and silicon carbide (−40+60 mesh) calculated at 12.5% of the mold volume. These particles before addition to the mold cavity were heated to a temperature of 1900° F. and mixed to a homogeneous state. The remaining unoccupied volume of the hot mold (about 50%) was filled with cast iron of the Example 1 analysis poured about the hot particles at a temperature of 2800° F., and under a pressure head represented by 29.0 inches of mercury.

EXAMPLE 11.—HEAT NO. 3–007–1

A mold shaped to conform to a railroad brake shoe, as hereinafter described, was heated to a dull red state, as in the foregoing example, and filled with graphite (−6+10 mesh) and silica sand (¼" diameter) particles in a homogeneous state and heated to a temperature of 1900° F. The separate kinds of particles each represented 25% of the mold volume, that is, the cavity in the mold. Cast iron (Example 1 analysis) at a temperature of 2835° F. was immediately poured in the mold after addition of the hot particles to the hot mold, as in each previous example. The molten iron was forced through the particles to fill the unoccupied voids between the particles and envelop each of the particles, as in the foregoing embodiments. This was accomplished by establishing a vacuum of 29.0 inches of mercury in the mold in the manner explained hereinafter.

EXAMPLE 12.—HEAT NO. 3–015–1

The matrix insoluble particles in this instance were represented by 15%, by mold volume, graphite (+30 mesh) and 35% mold volume of silicon carbide

(—40+80 mesh). These particles, insoluble in the ultimate matrix, were heated to a temperature of 2000° F., added to a hot mold in a uniformly mixed state, whereupon the remaining 50% of the unoccupied mold volume was immediately filled with cast iron poured at a temperature of 2800° F. under an impelling force represented by 29.0 inches of mercury. The cast iron had the analysis of Eample 1.

EXAMPLE 13.—HEAT NO. 3–015–2

From the standpoint of volume percent of particles, this example is the reverse of that described immediately above in that 35% by volume of graphite (+30 mesh) and 15% volume of silicon carbide (—40+80 mesh) were mixed to a homogeneous state and used to fill the mold to 50% of the occupiable volume. The procedure, otherwise, was a duplicate of Example 12.

EXAMPLE 14.—HEAT NO. 3–025–2

A heated mold for a railroad brake shoe was filled with a homogeneous mixture of graphite (+30 mesh) and silica sand (—16+20 mesh) particles in amounts respectively calculated as 15% and 35% of the total occupiable volume of the mold cavity. The particles, prior to addition to the mold cavity, were heated to a temperature of 2200° F. The matrix metal in this instance was a 1.05% carbon steel poured into the mold at 3000° F. and under a vacuum of 29.0 inches of mercury.

As in each of the foregoing embodiments, the resultant casting was a sound, solid body in which the cast steel matrix was continuous, with the insoluble graphite and silica particles uniformly distributed therethrough. Each of the insoluble particles was enveloped in the matrix metal so as to be isolated from one another, and the casting on inspection displayed a uniform density, particle distribution and material identity throughout its useful life thickness, as in each example herein.

EXAMPLE 15.—HEAT NO. 3–025–3

This example, from the standpoint of volume of insoluble particles, is the reverse of Example 14 in that the mold was filled with a homogeneous mixture of graphite and silica sand particles, respectively 35% and 15% of the total occupiable volume. Otherwise the process and nature of the casting were identical to Example 14.

EXAMPLE 16.—HEAT NO. 3–029

A mold for a railroad brake shoe was filled with a homogeneous mixture of graphite (+30 mesh) and silica sand (—16+20 mesh). The graphite was calculated as representing 25% of the mold volume and the silica sand 12.5%. These particles were mixed with iron grit of +16 mesh size and calculated as representing 12.5% of the occupiable mold volume. The three kinds of particles were mixed to a homogeneous state, heated to a temperature of 1660° F., and used to fill the mold which, incidentally, was not heated. The iron grit, as in the instance of the steel grit of Example 5, accounted for dilution by distribution of the graphite and silica sand. The remaining unoccupied volume of the mold, 50%, was filled with an aluminum alloy of the following composition, modified with 0.01% lead:

Mg	Mn	Si	Ti	Cu	Fe	Al
0.30%	[1] 0.10%	7.0%	[1] 0.20%	[1] 0.10%	[1] 0.10%	Balance

[1] Max.

It should be noted in this instance that the insoluble particles are represented in part by iron, the latter being substantially insoluble in the molten aluminum. A vacuum of 29.0 inches of mercury was established in the mold.

EXAMPLE 17.—HEAT NO. 3–031–2

The mold in this instance was heated and filled with a homogeneous mixture of particles of graphite (—16+20 mesh) and silica sand (—20+60 mesh). The graphite represented 45%, and the silica sand 5%, of the mold volume. These particles, after being mixed to a homogeneous state, were heated to a temperature of 2000° F. and used to fill the mold, whereupon the mold was immediately filled with a matrix metal in a molten state at 2800° F. under the impulse of a vacuum of 29.0 inches of mercury in the mold. The matrix metal in this instance was composed of 46%, by mold volume, cast iron of Example 1 analysis modified with 4% tin, based on mold volume, and the mold was heated.

EXAMPLE 18.—HEAT NO. 3–031–3

The mold for the railroad brake shoe in this instance was heated and in the hot state filled with a homogeneous mixture of graphite (+30 mesh) and aluminum oxide (—40+60 mesh) respectively representing 40% and 10% of the mold cavity volume, the particles having been pre-heated to a temperature of 2000° F., whereupon cast iron of the Example 1 analysis, including 4% tin (mold volume percent) was poured rapidly into the mold under the impulse of 29.0 inches of mercury.

EXAMPLE 19.—HEAT NO. 3–040–3

The substantially insoluble particles in this example were represented by graphite and silica sand, each of —30+40 mesh size, and aluminum oxide of —40+80 mesh. The graphite was calculated as representing 25% of the mold cavity volume, the silica sand 15%, and the aluminum oxide 10%. The mold was heated to a dull red state. The particles were mixed to a homogeneous state and heated to a temperature of 2000° F. before the mold was filled therewith, whereupon molten cast iron (Example 1 analysis) at a temperature of 2800° F. was introduced into the mold under a vacuum of 29.0 inches of mercury to the extent that the remaining unoccupied volume of the mold, the interstices between the particles therein, was filled.

EXAMPLE 20.—HEAT NO. 3–046–2

A mold for a railroad brake shoe, pre-heated as in the foregoing examples, was filled in this instance with a homogeneous mixture of graphite (—20+60 mesh) and silica sand particles (—20+60 mesh). The graphite particles were calculated as representing 35% of the total mold cavity volume, and the silica sand particles 15%. These particles, in a uniformly mixed state, were heated to a temperature of 2200° F., added to the hot mold cavity until the latter was filled, and thereupon molten cast iron was poured into the hot mold cavity at a temperature of 2800° F. under a driving force represented by 29.0 inches of mercury. This impelled the molten matrix metal, as in each of the foregoing examples, rapidly through the interstices between the hot particles. The cast iron had the analysis of Example 1.

EXAMPLE 21.—HEAT NO. 3–057–3

The matrix metal in this instance, unlike the hard cast iron of Example 1, was a soft cast iron having the following analysis:

C	Mn	P	S	Si	Fe
3.30%	0.70%	0.25%	0.10%	2.10%	Balance

The particles, substantially insoluble in the cast iron matrix, consisted of graphite (+30 mesh) and silica sand (—16+20 mesh). The graphite was calculated as representing 35% of the mold volume and the silica sand 15%.

These particles, in a state of homogeneity, and pre-heated to a temperature of 2050° F., were used to fill the mold for casting the railroad brake shoe. The mold was hot, and the mold cavity was immediately filled with molten cast iron poured at a temperature of 2800° F., forced through the interstices through the particles by a vacuum of 29.0 inches of mercury.

EXAMPLE 22.—HEAT NO. 3–062–3

The mold for casting the railroad brake shoe in this instance was heated to a dull red state, and then was filled with a mixture of particles insoluble in the matrix, said particles consisting of chromite sand, silicon carbide and graphite. The graphite was of +30 mesh and represented twenty-five percent of the mold volume. The silicon carbide was a so-called "46B" size corresponding approximately to −40+80 mesh and was calculated as representing 12.5% of the mold volume. The chromite sand (−30+80 mesh) was calculated as representing 12.5% of the mold volume. The mold was filled with this mixture of insoluble particles in a homogeneous state, previously heated to a temperature of 2250° F., whereupon cast iron of the Example 1 analysis was poured into the mold under a pressure differential represented by 29.0 inches of mercury and at a temperature of 2800° F., completing the manufacture as in the foregoing examples and those following.

EXAMPLE 23.—HEAT NO. 3–075–2

A heated mold for casting a railroad brake shoe was filled with 35% graphite (+30 mesh) and 15% silicon carbide (size 46B), these percentages representing the percent of mold volume. The particles in the mold were in a homogeneous state, and prior to addition to the mold were heated to a temperature of 2200° F. A 1.05% carbon steel at 3000° F. was cast about the hot particles in the mold cavity, under a pressure differential represented by 29.0 inches of mercury.

EXAMPLE 24.—HEAT NO. 3–076–3

The mold in this instance was filled with a mixture of graphite and emery representing particles insoluble or substantially so in the subsequently cast matrix metal which was cast iron of the Example 1 analysis. Both the graphite and emery were of +30 mesh size. The graphite was calculated as representing 35% of the mold cavity and the emery 15%. These particles in a homogeneous state outside the mold were heated to a temperature of 2100° F. The mold was heated to prevent chilling of the hot particles, the hot particles were incorporated in the mold cavity, and immediately thereafter the molten cast iron was introduced into the mold at 2800° F. under a pressure differential of 29.0 inches of mercury, filling the remaining capacity of the mold, namely, about 50%.

EXAMPLE 25.—HEAT NO. 3–076–5

The insoluble particles in this instance were represented by graphite and garnet, respectively calculated as 35% and 15% of the mold capacity. Each was of +30 mesh size, and were heated outside the mold in a homogeneous state to a temperature of 2100° F. The hot particles were then added to the mold cavity, the mold being hot, whereupon molten cast iron of the analysis set forth in connection with Example 1 was introduced into the mold to fill the remaining 50% of the mold capacity represented by the interstices between the particles.

EXAMPLE 26.—HEAT NO. 2–484–1

A mold for casting a railroad brake shoe was filled with particles of graphite, silica sand and iron grit, the latter being a 2% carbon iron of so-called G–25 grade, approximately of +16 mesh size. The latter represented 25% of the mold volume, the silica sand 12.5% (−16+20 mesh) and the graphite 12.5% (+30 mesh). These particles were mixed homogeneously, heated to a temperature of 1625° F., and used to fill the mold without compacting, as in each example herein, whereupon the matrix metal in the form of the above-identified aluminum alloy (Example 16) was introduced into the mold at a temperature of 1450° F. under a pressure differential of 29.0 inches of mercury. As in a previous example, the iron particles diluted, by distribution, the non-metallic, inorganic particles, namely, the graphite and silica sand particles. It may further be noted that the iron grit, having a melting point well above that of aluminum, became particles insoluble in the aluminum metal matrix, and the latter, as in previous examples, represented 50% of the mold capacity.

EXAMPLE 27.—HEAT NO. 3–008–2

In this example, the insoluble particles did not include graphite, but rather consisted only of silica sand and iron grit of the character specified in connection with Example 26. The silica sand (−16+20 mesh) represented 15% of the fillable volume of the mold cavity, and the iron grit 35%. Again, the remainder of the mold was filled with molten aluminum having the analysis of Example 16, the latter being poured into the mold at a temperature of 1490° F. containing the particles preheated to a temperature of 1550° F.

EXAMPLE 28.—HEAT NO. 3–007–2

A lower friction value was achieved in this instance by utilizing a relatively low volume content of inorganic nonmetallics consisting of graphite and silica sand particles each of −10+16 mesh size and each representing 12.5% of the mold volume. These were mixed homogeneously with 1.5% carbon steel shot of 12 mesh size in an amount representing 25% of the mold volume. The aforesaid three kinds of particles were used to fill the mold cavity to its capacity, as in all examples. The particles had been heated to a temperature of 1900° F. and the voids between the particles, representing 50% of the mold capacity, were filled with molten cast iron poured at a temperature of 2835° F., assisted by a vacuum of 29.0 inches of mercury.

EXAMPLE 29.—HEAT NO. 2–121

In this instance, a friction block was cast in an ingot-type mold, as distinguished from a curved railroad brake shoe in each of the previous examples, such block being useful as the friction element of a disc brake, clutch, or the like as hereinafter described.

The insoluble particles in this example consisted of graphite and mullite each of approximately +30 mesh size. The graphite was calculated as representing 13.4% of the mold volume and the mullite 3.6%. These particles were supplemented with iron grit of about +16 mesh size, calculated as 26.5% of the mold volume. These particles were homogeneously mixed to a uniform state, heated to a temperature of 1200° F. and were used to fill the ingot mold, as in all examples following, whereupon the unoccupied portion of the mold cavity, the interstices between the particles, was filled with molten aluminum (at 28.5 inches mercury vacuum) representing 56.5% of the mold volume. The mold was not heated, and it was found that the aluminum alloy, of the analysis specified in connection with Example 16, easily penetrated the mold cavity.

The friction block was machined from the ingot casting, fitted to a steel back for test, and displayed the properties tabulated in Table I and plotted in FIG. 1.

EXAMPLE 30.—HEAT NO. 2–47

This example was similar to Example 29 in that the insoluble particles consisted of graphite and mullite, but iron grit particles were not used. Thus, an ingot-type mold for casting a friction block for a disc brake, clutch or the like was filled with a homogeneous mixture of graphite (+30 mesh size) and mullite (+30 mesh), each

calculated as representing 25% of the mold cavity, in this instance an ingot mold. These particles were pre-heated to a temperature of 1200° F., and used to fill the mold. The mold itself was not heated, but the voids in the ingot mold between particles were easily penetrated by molten aluminum, of the kind specified in Example 16, representing 50% of the mold volume, poured into the mold cavity at a temperature of 1250° F. under a pressure differential represented by 28.5 inches of mercury. A friction block was obtained from the ingot casting, fitted to a steel back, and this cast body displayed a flexural strength of 17,650 p.s.i. and had the properties tabulated in Table I and plotted in FIG. 1.

EXAMPLE 31.—HEAT NO. 2–176

An ingot-type mold for obtaining friction blocks was filled wyith a homogeneous mixture of graphite and mullite, each of particle size +30 mesh and each calculated as representing 25% of the mold volume. These particles in the mold were pre-heated to a temperature of 1400° F., the mold was filled with the hot particles, and then the cast iron of Example 1 analysis, poured at a temperature of 2700° F. and under a vacuum of 28.5 inches of mercury, was introduced into the mold. A friction block, cut from the ingot casting, displayed a flexural strength of 18,800 p.s.i., and had the properties tabulated in Table I and plotted in FIG. 1.

EXAMPLE 32.—HEAT NO. 2–032

In ingot-type mold was filled with a homogeneous mixture consisting of graphite, mullite and a 2% carbon iron grit of approximately +16 mesh size. The iron grit was calculated as 25% of the mold volume and served to distribute, by dilution, the non-metallic particles consisting of mullite and graphite each of −20+30 mesh size. The mullite represented 6% of the mold volume and the graphite 34% of the mold volume.

The graphite, mullite and iron grit particles were mixed to a homogeneous state, heated to a temperature of 1800° F. and the mold was filled therewith. The remaining 35% of the mold volume was represented by cast iron of Example 1 analysis, poured into the mold at a temperature of 2770° under a vacuum in the mold of 27.5 inches of mercury. A friction block was cut from the ingot casting and had the properties tabulated in Table I and plotted in FIG. 1.

EXAMPLE 33.—HEAT NO. 1–415

The materials and process were substantially identical to Example 32 described above with the following exceptions. The cast iron was of softer grade in comparison to the analysis of Example 1 in that the tellurium addition was omitted. Otherwise the iron was of the Example 1 analysis and was poured at a temperature of 2800° F. The resultant casting in the form of a friction block had a flexural strength of 12,048 p.s.i., and the properties tabulated in Table I and plotted in FIG. 1.

EXAMPLE 34.—HEAT NO. 1–353

A friction block was obtained from a casting in an ingot-type mold, using the cast iron of Example 33 as the matrix metal and graphite particles as the insoluble particles for modifying the character of the metal.

Thus, an unheated ingot mold was filled with graphite particles of the hard, synthetic type, as in each of the foregoing examples, the graphite being of −12+20 mesh size and occupying 50% of the occupiable mold volume. The particles were pre-heated in a graphite crucible to a temperature of 1900° F., and poured into the room temperature mold until the latter was full, whereupon the cast iron was poured into the unheated mold cavity at a temperature of 2800 F. and under the influence of 24.0 inches of mercury in the mold. A section cut from the casting was used as a friction block and had the properties tabulated in Table I and plotted in FIG. 1.

EXAMPLE 35.—HEAT NO. 60L–1

The article produced in this instance was a friction element in the form of a clutch disc for a so-called dry clutch, and was obtained from an ingot casting produced under and in accordance with the present invention.

Thus, the mold cavity of an ingot mold, prior to pouring the molten metal, was filled with a homogeneous mixture of graphite and silica particles each of −40+50 mesh size and each calculated as representing 25% of the occupiable mold cavity. These particles, in a homogeneous state in the mold, were heated by electrical resistance elements to a temperature of 1800° F., whereupon the unoccupied portion of the mold cavity, the voids between the particles, was filled with a copper-tin alloy (90% copper, 10% tin) poured into the mold at a temperature of 2275° F. and forced through the particles under the influence of a vacuum of 29.0 inches of mercury.

A disc was cut from the ingot casting and used as a dry clutch disc against an opposing steel member in a test apparatus.

EXAMPLE 36.—HEAT NO. 84–91

This is another example of the manufacture of a friction disc, obtained in the manner of Example 35. In this instance, however, the insoluble particles consisted of graphite and sillimanite each of −10+16 mesh size. The volume of graphite was based on 34% of the mold volume and sillimanite 6%. These particles were distributed in the ingot mold in a homogeneous state to fill the same, and because of the relatively large particle size it was calculated that the insoluble particles occupied but 40% of the fillable mold volume. These particles in the mold were heated to a temperature of 1800° F., as by electrical resistance elements, whereupon soft cast iron of Example 21 was poured into the mold at a temperature of 2800° F. under a vacuum of 28.0 inches of mercury. The resultant cast article, when removed from the mold, is useful as a friction disc for a dry clutch as in the instance of Example 35 above.

EXAMPLE 37.—HEAT NO. 84–92

This is another example pertaining to the manufacture of a friction disc for a clutch, in this instance a so-called wet clutch. Ingot production was again relied upon as the source for obtaining the disc. The mold cavity was filled with a homogeneous mixture of graphite and silica sand each of −30+40 mesh size, and each kind of particle representing 25% of the mold volume. The particles in the mold were heated to a temperature of 560° F., whereupon a lead-tin alloy (50% lead, 50% tin) was poured into a mold at a temperature of 600° F. under a vacuum of 27.0 inches of mercury.

EXAMPLE 38.—HEAT NO. CP–3

A journal-type bearing was prepared in this instance by casting in a suitably shaped mold. The mold cavity was filled with graphite calculated as occupying 50% of the volume thereof, the graphite being of −40+50 mesh size, and it may be noted that in order to impart desirable low friction properties to the bearing, the graphite was of the natural, so-called flaky type commonly employed for low friction applications.

The graphite that was used to fill the mold cavity was heated to a temperature of 600° F., whereupon a lead-tin alloy was poured into the mold filling the voids between the graphite particles, under a temperature of 700° F. and an impelling force represented by 27.0 inches of mercury. The lead-tin alloy was 50% lead, 50% tin.

EXAMPLE 39.—HEAT NO. CP–4

A thrust-type bearing was cast in this instance, and consisted of graphite in an aluminum matrix. The graphite in an aluminum matrix. The graphite was of −12+20 mesh size, and it was calculated that the graphite particles, filling the mold, occupied 50% of the total

volume thereof. The graphite particles in the mold were heated to a temperature of 450° F. whereupon aluminum of 99+ percent purity was poured into the mold at a temperature of 1500° F. under an impelling force represented by a vacuum of 20.0 inches of mercury.

EXAMPLE 40.—HEAT NO. CP–5

A low friction element was cast in this instance in the form of a thrust-type bearing, and the bearing body consisted of Teflon resin particles (polytetrafluoroethylene) surrounded by a cast matrix in the form of a lead-tin alloy. Thus, a suitable mold was filled with Teflon particles of —30+40 mesh size, calculated as occupying 50% of the total mold volume when the mold was filled therewith. The Teflon resin particles in the mold were heated to a temperature of 650° F., and after the particles had obtained this temperature, a vacuum of 27.0 inches of mercury was established in the mold, whereupon a 50% lead, 50% tin alloy was introduced into the mold at a temperature of 600° F. to the extent, as in all examples herein, that the molten metal filled the interstices between the particles in the mold.

The Teflon resin in the above examples is a material well known for its exceptionally low coefficient of friction and hence is eminently well suited for imparting low friction properties to a bearing or like element that need be of low friction character. This attribute is also possessed by natural graphite of Examples 38 and 39, but to a lesser degree, and of course the lead-tin matrix is a metal which displays some lubricating features, that is, low friction qualities.

EXAMPLE 49.—HEAT NO. 3–106–3

A mold for casting a railroad brake shoe was filled with particles of graphite (+30 mesh size) and silicon carbide (—40+60 mesh size), the graphite particles representing 40% of the mold volume and the silicon carbide 10%. These particles were mixed to a homogeneous state and preheated to a temperature of 2125° F., whereupon they were added to the mold, itself preheated to a temperature of 800–1000° F. Thereafter, a 1.05% carbon steel was poured into the mold to fill the interstices between the hot particles therein, the steel being poured at a temperature of 3000° F. A vacuum of 28 inches of mercury was maintained in the mold during the course of pouring the cast steel. Friction and wear data are set forth in FIG. 1 and in Table I, as with the remaining examples immediately following.

EXAMPLE 42.—HEAT NO. 3–114–4

A mold heated to a temperature of 800–1000° F., and presenting the geometry of a railroad brake shoe, was filled with hot particles consisting of a homogeneous mixture of graphite and silica sand. The graphite was of the mesh size of Example 41 and the silica was of the mesh size of the silicon carbide of Example 41, both preheated to a temperature of 2100° F. before addition to the hot mold cavity. After the mold cavity had been filled with the particles, substantially insoluble in the matrix metal, the unoccupied portion of the mold cavity, approximately 50%, was filled with ferritic ductile iron poured at a temperature of 2800° F. and under the impelling influence of a vacuum of 28 inches of mercury in the mold cavity.

The graphite particles represented 35% of the occupiable mold volume, and the silica particles 15%.

The ductile iron had the following analysis:

Carbon	3.18
Manganese	0.20
Phosphorus	0.007
Sulphur	0.019
Silicon	2.43
Magnesium	0.058

EXAMPLE 43.—HEAT NO. 3–138–4

A hot mold, heated to a temperature of 800–1000° F. for casting a railroad brake shoe, was filled with a homogeneous mixture of graphite and silica sand particles, respectively representing 5% and 45% of the volume of the mold cavity, these particles having the mesh size set forth above in connection with Example 42. The particles were preheated to a temperature of 2200° F., and after the mold had been filled therewith, the interstices between the particles were filled with molten steel (1.05% carbon) poured at a temperature of 2800° F. and impelled through the interstices by a vacuum represented by 28 inches of mercury.

EXAMPLE 44.—HEAT NO. 3–143–3

A hot mold, heated to a temperature of 800–1000° F. for casting a railroad brake shoe was filled with a homogeneous mixture of the following particles preheated to a temperature of 2125° F., the percentage amounts indicating mold volume percent:

	Percent
Graphite (+30 mesh size)	30
Silicon carbide (—40+60 mesh size)	10
Alumina (—40+80 mesh size)	10

The interstices between the hot particles and the mold were filled with molten cast iron having the analysis of Example 1, poured at a temperature of 2800° F. in the presence of a vacuum represented by 28 inches of mercury in the mold cavity.

EXAMPLE 45.—HEAT NO. 3–143–6

A hot mold, heated to a temperature of 800–1000° F., for casting a railroad brake shoe, was filled with a homogeneous mixture of the following particles preheated to a temperature of 2125° F., the percentage amounts indicating mold volume percent:

	Percent
Graphite (+30 mesh size)	40
Silicon carbide (—40+60 mesh size)	10

After the mold was filled, cast iron was poured into the mold under the conditions of Example 44.

Molds and casting techniques

In the examples above pertaining to the production of railroad brake shoes, these were cast in molds of the character illustrated in FIGS. 2 through 7. Typically, a brake shoe having a ferrous metal matrix is cast in a precision sand-backed mold of the kind illustrated in FIG. 2, and those brake shoes having an aluminum-type matrix were cast in permanent molds of the character illustrated in FIGS. 3 through 7. In each instance, the mold cavity is filled with the insoluble particles that are to remain undissolved in the matrix metal, the particles being in a predetermined state of pre-heat. Vacuum is applied, and the molten metal is instantly poured until the mold is filled at least to the extent that the voids between the particles are occupied by the matrix metal.

Referring to FIG. 2, a flask precision mold or mold housing **18** for casting a railroad brake shoe includes a drag **20** and a cope **21** each containing a foundry Calamo backing **25** faced with a precision ceramic investment **26**, the surfaces of the latter defining the geometry of the shoe to be cast, of which the shoe **28** illustrated in FIG. 10 is typical. Such a shoe may include a steel back reinforcement **30** having openings through which project the so-called toe guides **31** and **32**, center-attaching lugs **34** and a separate steel strap **35** having ends embedded in the lugs **34**. These parts represent standard attaching and securing elements that relate the shoes as **28** to the brake heads **28H** of standard construction, FIG. 8, that characterizes railroad brakes of the class type.

The cope includes the usual sprue **40** for directing the molten matrix metal into the drag mold cavity **41**. In

order to establish a vacuum within the drag cavity 41 at the time the cast is poured, vent passages 43 are formed in the drag backing 25 and extend through the precision facing 26 to communicate at their upper ends with the drag cavity 41.

The shell of the drag is provided with threaded apertures 20A that communicate with the lower ends of the vent passages 43, and a nipple 44 is threaded into each opening. Each nipple includes a stub portion to which a hose 45 is connected, and the hoses at their opposite ends are connected to a manifold (not shown) in turn connected to a vacuum pump for establishing the desired vacuum within the mold cavity.

In order to inhibit the particles in the matrix metal from flowing into the vent passages 43 in the course of casting under vacuum, the vent passages 43 are filled with steel shot 50, and steel wool 51, as shown in FIG. 2A, is stuffed against an annular ledge 52 formed within each nipple 43. A stainless steel washer 53 is set on the ledge 52, the washer having apertures 53A drilled therethrough for communicating the vacuum in the hose 45 to the portion of the nipple filled with steel wool.

With the cope 21 separated from the drag 20, and after heating the drag to avoid chilling the hot particles, the insoluble particles that are to become a part of the casting after being heated, are poured into the mold in a homogeneous state, filling the drag cavity 41 to the brim, and preferably slightly above in order to afford some compensation for compaction of the particles when the force of the vacuum is exerted within the mold cavity. Preferably, the top surface of the particles in the drag cavity 41 is pressed slightly by a template that conforms to the geometry of the steel back 30 of the shoe 28 that is supported by the cope 21. The degree of pre-heat in the mold assures that when the molten metal is poured, the latter is maintained in a fluid state in the course of being impelled through the particles by the force of the vacuum.

The cope having the steel back 30 and the lug 35 related thereto is juxtaposed on the drag and secured tightly, whereupon vacuum is established within the drag cavity through the connections above described, and the molten metal thereupon poured down the sprue 40. The molten metal remains fluid as it flows through the hot particles. When it reaches the vent passages 43, the steel shot in the vent passages has some chilling effect thereon.

It will be noted in connection with FIG. 2 that the cope includes mold recesses 21A and 21B into which the molten metal rises, when cast, to form the toe guides 31 and 32 identified above in connection with FIG. 10. Also, molten metal rises into the mold recesses 21C in the cope for forming the lugs 34 of the shoe. In this connection, it may be noted that a few of the insoluble particles at the top of the drag cavity may float upward into the recesses 21A, 21B and 21C, but this occurs only to a very minor extent, and moreover, these projections on the casting are not part of the thickness of the cast body that is to be improved by the presence of the insoluble particles. Such movement of the particles is minimized by the end vent passages 43 that exert their influence in the proximity of the recesses 21A and 21B.

Referring to FIGS. 11 and 12, there are reproductions from photographs respectively showing a cross-section of the actual shoe of Example 17, Heat No. 3–031–2, and the wear face WF thereof, FIG. 12. The dark portions are graphite, and the light portions are the matrix metal in FIG. 11. The silica particles are visible in FIG. 12 as the white particles; the graphite particles are dark; and the matrix metal is gray.

Particularly in the instance of casting an aluminum shoe under and in accordance with the present invention, it is possible to resort to a permanent mold 60, FIG. 3, inclusive of a drag 61 and a cope 62. The drag 61 is formed with a mold cavity 63 that is representative of the main body of the shoe to be cast therein, and the cope is recessed at 62A, 62B and 62C for the purposes described above in connection with FIG. 2.

In making provision for the establishment of vacuum in the drag cavity 63, the drag is formed with a relatively large recess 65 in which is positioned a precision, ceramic plug 66 having an upper surface 67 which represents the arcuate wear face of the shoe that is cast in the mold cavity 63. The ceramic plug 66, FIG. 4, is formed at the end, bottom and vertical side faces thereof with interconnecting half-round passages 68 that are continuous between the upper and lower surfaces thereof. The drag is provided with a plurality of vent passages 70, FIG. 3, adapted to be connected to a source of vacuum, and the upper ends of these communicate with passages 68 at the underside of the core 68, to thereby establish vacuum communication between the passages 70 and the mold cavity 63.

Another form of permanent mold for casting aluminum shoes is illustrated in FIGS. 5 to 7 inclusive of a drag 75 that is usable with a cope of the character described in connection with FIG. 3. The drag in this instance is formed with a cavity 76 bordered by a pair of spaced ledges 77 that extend along the inner faces of the side walls of the drag. These ledges serve to support a mold tray 80, FIGS. 6 and 7, configured, as illustrated in FIGS. 6 and 7, to present a mold cavity 81 faced with a porous ceramic lining 82 that defines the mold cavity in which the particles and martix metal are to be cast. The tray 80 is a metallic member, composed of a heat-resistant alloy, and the upper portion 82 thereof that is shaped to afford the lined mold cavity is formed with a plurality of vent openings 83.

The drag 75 is equipped with a pair of conduits 85, the outer ends of which are to be connected to a source of vacuum, communicated to the interior of the drag by the conduits 85, and in turn to the vents 83 when the tray 80 is located in the drag recess 76.

It may be noted in connection with what has been described above in connection with FIGS. 5 and 7 that such an arrangement is also typical of an ingot mold, with the exception of configuration, capable of casting ingot from which can be obtained the friction blocks of Examples 29 to 34, serving as the friction blocks 90 of a railroad disc brake 91 illustrated in FIG. 9. Such an ingot mold is also typical of that used for producing the castings from which are obtained the clutch discs of Examples 35, 36 and 37.

In connection with Examples 38, 39 and 40, attention is directed to FIGS. 13 and 14 which schematically illustrate shaft and bearing couples, of which the bearing is an element produced in accordance with Examples 38, 39 and 40. Thus, in FIG. 13, the bearing 100 is a journal-type bearing, cast in accordance with Example 38, and supports the shaft 101. In FIG. 14, the bearing 105 is a thrust bearing engageable by the end of the shaft 106 when thrust thereagainst, the bearing 105 being of the character and composition set forth above in connection with Example 40.

AAR tests

In view of the ability to cast composite materials of the foregoing kind with various kinds of metal matrices and inclusions therein of insoluble particles which contribute unique results uniformly throughout the useful thickness of the cast body, these materials become useful as friction elements, and in particular shoes or blocks to be part of a friction couple as, for example, a shoe attached to a railroad brake head or a block as part of a brake disc.

There are many conditions which a satisfactory railroad brake shoe, in particular, must satisfy, and in fact, the Association of American Railroads (AAR) specifies minimum requirements for a railroad brake shoe from the standpoint of friction and wear rate. Specifically, the

AAR requirement is a minimum coefficient of friction of 0.15 and a maximum rate of wear of one pound (3.85 cubic inches) per 100 million foot pounds of work done in braking.

The AAR test specifies the following conditions:

Equivalent wheel load	lbs.	7190
Brake shoe load	lbs.	7190
Speed	m.p.h.	60
Single brake shoe wheel diameter	inches	36

Under the conditions set forth above, the standard AAR cast iron brake shoe should have a minimum mean coefficient of friction of 0.15 and a maximum wear per 100 million foot pounds of work done of one pound, equivalent to 3.85 cubic inches of material lost. A brake shoe meeting these conditions will produce a dynamometer stop distance of 800 feet or less from 60 miles per hour. A dynamometer screening test was initiated on the basis of the AAR specifications. However, because of the relatively different friction values of the materials of the present invention, the dynamometer screening test was one in which the brake shoe load was determined for each distinct shoe or block as that which would produce a stop in approximately 800 feet. The results of this dynamometer test are plotted in FIG. 1 and are tabulated in Table I.

Having determined on the basis of the screening test that many of the examples, apparent from Table I and FIG. 1, met the severe, minimum AAR requirements for a railroad brake shoe, selected of the materials were then chosen for a more comprehensive and exacting speed load test on the dynamometer, the results of which are tabulated in Table II. The test duplicated a clasp brake arrangement of the kind illustrated in FIG. 8. This test series additionally was enlarged to determine friction and wear from the standpoint of wet and dry conditions, and separate tests were conducted using a wheel tread on the dynamometer that had been dressed (plot as "X" in FIG. 1) to somewhat roughen the same.

It will be noted in Table II that the test series consisted of five stops each from 100, 80, 60, 40 and 20 m.p.h. with an equivalent wheel load of 18,176 pounds in a clasp brake arrangement on the dynamometer with three different brake shoe loads, a more severe test which goes beyond the AAR specifications referred to above. The

total energy dissipated in each such test was approximately 100 million foot pounds per shoe. Referring further to Table II, it will be observed that one significant characteristic of the materials tested, aside from high friction, was substantial uniformity in wet and dry friction, which is of extreme importance to friction elements that are subjected to inclement weather conditions.

TABLE I.—SCREENING TEST

Example	Friction Coefficient Percent		Wear Rate [1]	
	Unconditioned Wheel Tread	Conditioned Wheel Tread	Unconditioned Wheel Tread	Conditioned Wheel Tread [2]
1	28	28	1.6	1.6
2	35	36	2	2
3	32		2	
4	27	25	2	1.4
5	32	29	1.1	1.7
6	32	24	1.2	2.3
7	33	35	1.2	2.4
8	33		1.3	
9	35		2.1	
10	28		2.7	
11	32	27	2.5	3
12	31	27	0.9	2
13	36	35	1.5	2.1
14	31	29	0.4	2.1
15	29		2.6	
16	31		3.2	
17	40		3.8	
18	38		1.6	
19	33		2.4	
20	36		1.6	
21	29		1.5	
22	28		1.4	
23	31		.65	
24	34		1.0	
25	31		3.5	
26	31	29	7.2	7.4
27	26	27.5	6.5	1.7
28	14	12	1.8	2.3
29	29		4	
30	34		8.4	
31	32	30	1.8	2.5
32		22		3.3
33		25		7.5
34		33		8.3
41	33		1	
42	31		1.1	
43	22		0.8	
44	36		1.8	
45	41		1.5	

[1] Cubic inches per 100 million ft.-lb. work.
[2] Wheel tread roughened with 40 grit belt "X" in Fig. 1.

TABLE II.—FRICTION DATA—SPEED TESTS

Brake Shoe Load (Pounds)	Material	Condition	Coefficient of Friction (percent) Initial Speed, m.p.h.					Avg.	Grand Avg.
			20	40	60	80	100		
1,400	2-464	Dry	27	28	25	21	20	24	
	2-318		28	28	29	26	23	27	
	2-469		34	31	30	30	27	30	
	2-482		27	26	24	22	20	24	
2,800	2-464		25	26	24	20	19	23	
	2-318		26	27	25	23	22	25	
	2-469		31	31	24	25	24	22	
4,830	2-464		22	25	22	20	22	22	23
	2-318		24	25	24	23	23	24	25
	2-469		29	28	24	25	26	26	28
	2-482		23	23	19	18	19	20	22
1,400	2-464	Wet	32	29	27	24	21	27	
	2-318		29	27	23	21	20	24	
	2-469		34	34	29	25	22	29	
	2-482		35	33	35	27	24	31	
2,800	2-464		31	26	23	20	18	24	
	2-318		33	26	21	19	17	23	
	2-469		33	27	21	20	20	24	
4,830	2-464		27	27	22	22	24	24	25
	2-318		28	23	20	17	18	21	23
	2-469		30	27	19	19	19	23	25
	2-482		31	26	21	19	20	23	27
1,400	2-464	Dry [1]	35	33	29	25	22	28	
2,800	2-464		33	30	27	24	24	28	
4,830	2-464		28	27	24	22	24	25	27

[1] Wheel tread ground with 40 grit belt after each brake shoe load.

TABLE III.—WEAR DATA

[For each speed Series of Table II]

Brake Shoe Load	Material	Condition	Wear		Total Wear	
			Lbs.	In.[3] [1]	Lbs.	In.[3]
1,400	2-464	Dry	.319	2.06		
	2-318		.382	2.30		
	2-469		.464	2.99		
2,800	2-464		.573	3.70		
	2-318		.685	4.12		
	2-469		.912	5.88		
4,830	2-464		.733	4.73	1.625	10.49
	2-318		.920	5.54	1.987	11.96
	2-469		1.248	8.05	2.624	16.9
1,400	2-464	Dry [2]	.461	2.97		
2,800	2-464		.731	4.71		
4,830	2-464		.853	5.50	2.045	13.18

[1] Per 100 million ft.-lb. of energy absorbed.
[2] Wheel tread ground after each brake shoe load.

TABLE IV

[Typical mean coefficient of friction values for conventional cast metal brake shoes]

Brake Shoe Load (Pounds)*	Dry					Avg.	Grand Avg.
	20	40	60	80	100		
3,500	24	15	13	13	11	15	
8,000	16	11	9	7	6	10	
12,000	17	11	8	6	5	9	11
	Wet						
3,500	23	17	14	12	10	15	
8,000	20	12	9	8	6	11	
12,000	18	11	8	7	6	10	12

*Brake shoe loads are different from Table II because mean coefficient of friction values are significantly different.

It may finally be observed in connection with the tests conducted on the shoe castings as typically representing the achievements possible under the present invention that one unique advantage of the present compositions from the standpoint of conventional cast friction elements is that the increase in retarding force (so-called "torque peaking or rooster-tailing") toward the end of a brake stop can be controlled. This comparative advantage is illustrated in FIG. 15 where the solid line is typical of the torque or retarding force of a known kind of commercial railroad brake shoe, and the curve in dotted lines compares the like property of a randomly selected shoe of the present invention.

Conclusion

It will be appreciated from the tables set forth above that significant and unique properties can be achieved with castings produced under the present invention, especially when it is realized, for example, that the standard cast iron railroad brake shoe has a friction of not less than about 0.15 and a wear rate well in excess of the compositions as tabulated above when compared under AAR test conditions. Moreover, the present compositions do not display a rapid increase in torque near the end of a friction stop, see FIG. 15, characteristic of some friction elements.

The foregoing is exemplary of what can be achieved with articles produced in accordance with the principles of the present invention, manifest in a cast body having undissolved particles, up to and inclusive of about ¼" in diameter, and which, as so far determined, can range down to 150 mesh, distributed uniformly in the matrix throughout the useful thickness of the casting. I have found that if the particles are larger than about ¼" in a railroad brake shoe, the wear rate becomes excessive.

The particles are discontinuous in the continuous phase matrix metal, and may take any form so long as the

particles remain insoluble in the matrix metal to contribute their unique effect thereto, although for wear parts that are to display predetermined friction toward an opposing member in a mechanical couple that includes engageable members, the presence of graphite may be advantageous, together with hard long-wearing particles of the above examples. The matrix metal can be either ferrous or non-ferrous, and many examples are set forth. Therefore, the specific materials specified herein are representative of their classes and are chosen on the basis of cost, availability and potency of effect.

The particles must fill the portion of the mold not occupied by any insert that is to be part of the casting, and this is so in order to obtain the essential homogeneity of density and material identity throughout the useful thickness of the casting. In other words, the particles must fill the useful volume of the casting, and it would appear that most advantageously the particles should represent about fifty percent of the casting volume. The useful thickness of the casting can be, and in many of the examples herein is, appreciable, and complete investment by the cast metal is made possible by having the particles hot and impelling the molten metal. The force behind the molten metal assures sufficiently rapid filling of the voids between the particles as to prevent that much heat transfer from the metal to the particles as might cause the molten metal to be disadvantageously chilled. A distinct and useful result of forcing the metal is that there is achieved just that slight dispersion of the particles that assures the discontinuous particle phase and the continuous metal phase necessary to maximum strength.

Hence, while I have illustrated and described preferred embodiments of my invention, it is to be understood that these are capable of variation and modification, and I therefore do not wish to be limited to the precise details set forth, but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. A process of casting dense bodies characterized by a continuous metal matrix containing a uniform dispersion of non-metallic particles therethrough and with substantially each particle enveloped by the matrix metal comprising, affording a mold housing including a part presenting a mold cavity, filling the unoccupied volume of said mold cavity, that will not be occupied by an insert, with particles substantially insoluble in the metal to be subsequently cast in the mold and said particles being separately pre-heated as such and apart from the molten metal to be cast thereby to assure rapid filling of the voids between the particles by the molten metal and to avoid disadvantageous chilling of the molten metal subsequently introduced into the mold cavity, closing the mold to complete said housing around the cavity containing the pre-heated particles while restraining said hot particles on all sides against substantial movement en masse in the mold cavity when the metal is cast in contact therewith to prevent migration of the particles in and assure uniform density of the particles throughout the matrix metal subsequently introduced into the mold cavity, establishing an atmospheric pressure differential in the mold cavity filled with said hot particles and immediately allowing molten metal from a source outside any housing confining the mold cavity to pour into the mold cavity and into direct contact with the restrained hot particles through an opening in the mold housing while said pressure differential is communicated directly to the moten metal entering the mold cavity to forcefully impel the molten metal rapidly into and through the voids between the hot particles to the extent that the voids between the particle content of the mold are filled by the molten metal and substantially each particle is enveloped entirely by the matrix metal.

2. A process according to claim 1 wherein the matrix metal is a ferrous metal selected from the group consisting of steel and cast iron and wherein the particles include at least one selected from the group consisting of graphite, silica and mixtures of graphite and silica, which particles do not exceed about one-quarter inch average diameter.

3. A process according to claim 2 in which the mold includes a drag and a cope, in which the mold cavity is in the shape of a railroad brake shoe, and in which the cast shoe displays a dynamometer mean friction coefficient in excess of 0.15 and a wear rate of not more than about 3.85 cubic inches per 100 million foot pounds of energy exerted thereon during dynamometer braking under the following conditions:

Wheel load	lbs	7190
Brake shoe load	lbs	7190
Speed	m.p.h	60
Single brake shoe wheel diameter	inches	36

4. A process according to claim 3 in which the mold cavity contains an insert in the form of a steel back for the shoe.

5. A railroad brake shoe cast to shape and comprising a reinforcing metal back, an attaching lug at the back and a shoe body having a wear face located below the back and cast integral with the back and the lug, said shoe body having a metal matrix selected from the group consisting of aluminum-silicon alloy, steel and cast iron cast as a continuous phase through and cast about a substantially uniform dispersion of solid particles including at least two kinds of particles selected from the group consisting of chromite, silicon carbide, iron grit, alumina, emery, garnet, steel shot, mullite, graphite and silica which remain substantially undissolved in said matrix as a discontinuous phase, said particles in the portion of the shoe body lying between the wear face and said back being of substantially uniform distribution, said particles being not larger than about one-quarter inch average diameter and cooperating with the metal matrix to afford a dynamometer mean friction coefficient of not less than about 0.15 and a wear rate not more than about 3.85 cubic inches per 100 million foot pounds of energy exerted thereon during dynamometer braking under the following dynamometer conditions:

Wheel load	lbs	7190
Brake shoe load	lbs	7190
Speed	m.p.h	60
Single brake shoe wheel diameter	inches	36

and substantially all of the particles each being individually enveloped by the metal affording said matrix.

6. A process of casting dense bodies characterized by a substantially continuous metal matrix containing a dispersion of particles therein and with substantially each such particle enveloped by the matrix metal comprising: affording a mold housing including a part presenting a mold cavity, incorporating in the unoccupied volume of said mold cavity particles substantially insoluble in the metal to be subsequently cast in the mold and said particles being separately pre-heated as such and apart from the molten metal to be cast thereby to assure rapid filling of the voids between the particles by the molten metal and to avoid disadvantageous chilling of the molten metal subsequently introduced into the mold cavity, closing the mold to complete said housing around the cavity containing the pre-heated particles while restraining said hot particles against substantial movement en masse in the mold cavity when the metal is cast in contact therewith substantially to prevent migration of the particles in the matrix metal subsequently introduced into the mold cavity, establishing a pressure differential in the mold cavity containing said hot particles and allowing molten metal from a source outside any housing confining the mold

cavity to pour into the mold cavity and into direct contact with the restrained hot particles through an opening in the mold housing while the molten metal entering the mold cavity is subjected to said pressure differential to forcefully impel the molten metal rapidly into and through the voids between the hot particles to the extent that the voids between the particle content of the mold are substantially filled by the molten metal and substantially each particle is enveloped entirely by the matrix metal.

7. A process according to claim 6 wherein the matrix metal is a ferrous metal selected from the group consisting of steel and cast iron and wherein the particles include at least one selected from the group consisting of graphite, silica and mixtures of graphite and silica, which particles do not exceed about one-quarter inch average diameter.

8. A process according to claim 7 in which the mold includes a drag and a cope, in which the mold cavity is in the shape of a railroad brake shoe, and in which the cast shoe displays a dynamometer mean friction coefficient in excess of 0.15 and a wear rate of not more than about 3.85 cubic inches per 100 million foot pounds of energy exerted thereon during dynamometer braking under the following conditions:

Wheel load	lbs	7190
Brake shoe load	lbs	7190
Speed	m.p.h	60
Single brake shoe wheel diameter	inches	36

9. A process according to claim 8 in which the mold cavity contains an insert in the form of a steel back for the shoe.

10. A process of casting dense bodies characterized by a substantially continuous metal matrix containing a dispersion of particles and with substantially each such particle enveloped by the matrix metal comprising: affording a mold housing including a part presenting a mold cavity, incorporating in the unoccupied volume of said mold cavity particles restrained against movement en masse, said particles being substantially insoluble in the metal to be subsequently cast in the mold, said particles being separately pre-heated as such and apart from the molten metal to be cast thereby to assure rapid filling of the voids between the particles by the molten metal and to avoid disadvantageous chilling of the molten metal subsequently introduced into the mold cavity, closing the mold to complete said housing around the cavity containing the pre-heated particles, establishing a pressure differential in the mold cavity containing said hot restrained particles and allowing molten metal from a source outside any housing confining the mold cavity to pour into the mold cavity and into contact with the restrained hot particles through an opening in the mold housing while said molten metal entering the mold cavity is subjected to said pressure differential so as to forcefully impel the molten metal rapidly into and through the voids between the hot particles to the extent that the voids between the particle content of the mold are filled by the molten metal and substantially each particle is enveloped entirely by the matrix metal.

11. A process according to claim 10 wherein the matrix metal is a ferrous metal selected from the group consisting of steel and cast iron and wherein the particles include at least one selected from the group consisting of graphite, silica and mixtures of graphite and silica, which particles do not exceed about one-quarter inch average diameter.

12. A process according to claim 11 in which the mold includes a drag and a cope, in which the mold cavity is in the shape of a railroad brake shoe, and in which the cast shoe displays a dynamometer mean friction coefficient in excess of 0.15 and a wear rate of not more than about 3.85 cubic inches per 100 million foot pounds of

energy exerted thereon during dynamometer braking under the following conditions:

Wheel load	lbs.	7190
Brake shoe load	lbs.	7190
Speed	m.p.h.	60
Single brake shoe wheel diameter	inches	36

13. A process according to claim 12 in which the mold cavity contains an insert in the form of a steel back for the shoe.

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