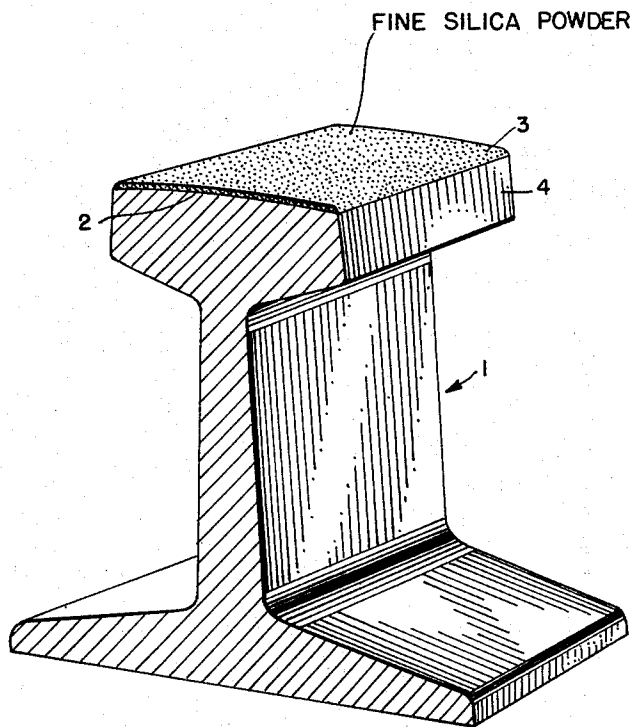


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TREATMENT OF METAL SURFACES TO INCREASE
THE COEFFICIENT OF FRICTION
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TREATMENT OF METAL SURFACES TO INCREASE THE COEFFICIENT OF FRICTION

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This invention relates to a new and improved adhesion treatment of metal surfaces and more particularly to a method and composition for increasing the coefficient of friction between metal surfaces capable of motion one with respect to the other. The invention is especially concerned with the provision of chemical means for preventing wheel slippage between locomotive wheels and rails. However, in its broader aspects the invention contemplates the improvement of frictional contact between metal surfaces which are susceptible of slippage one with respect to the other, as, for example, the slippage which occurs between a shaft and a sheave, gear or pinion frictionally mounted on said shaft.

The past several decades have produced railway locomotives possessing great power and weight, thus enabling long, heavily-laden trains to be pulled by single engines. With the advent of the extremely heavy locomotive it was felt that driving wheel slip would be eliminated. It was soon discovered, however, that the increased static weight carried on the driving wheels did not solve the problem to any great extent. Track sanding techniques were developed but this only partially alleviated the condition. Wheel slippage has proven to be an erratic condition which has not in all cases been satisfactorily explained.

In one explanation of the problem, rail slip is said to result from a tough invisible oil film on the wear band of the rail. Traffic and heat destroy this film and high adhesion results. When a light rain occurs or when the rails reach the dew point, as the result of the relatively high humidity, a water film forms across the wear band where it may contact oil deposits on the edge of a rail with the result that a film of oil creeps through and replaces the water film. The oil deposits on the rail sides act as reservoirs for the formation of new oil films and water acts as the transporting agent. The oil deposits on the rail come from journal box oil leakage by way of the outside face and outer portion of the tread of the car wheels. There are other sources of contamination such as road crossings, rail lubricators, and the like.

The importance of solving the problem is strikingly illustrated when it is realized that only 15% of the engine's weight can be utilized as tractive force when the rails are greasy and moist, and 30% when the rails are clean, dry and sanded. Even a small improvement in these figures, as expressed in the terms of increased coefficient of friction, would enable railway locomotives to operate more efficiently and economically as well as providing improved braking for railway locomotives and rolling stock.

Another instance where it is desirable to improve the frictional contact between two metal surfaces capable of motion one with respect to the other is where a gear or pinion is frictionally mounted on a shaft. Obviously, if slippage occurs between the gear or pinion and the shaft the efficiency of the particular operation in question is reduced or the device may even become inoperable.

It is therefore an object of this invention to provide a new and improved method for enhancing the frictional

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contact between two metal surfaces capable of motion one with respect to the other.

Another object of this invention is to provide a method for raising the coefficient of friction between railway car wheels and rails.

Still another object is to raise the coefficient of friction between railway car wheels and rails having an oil film thereon.

A further object is to provide a method of decreasing slippage between railway wheels and rails.

Another object is to provide a chemical treatment to prevent locomotive slippage on dry, wet, or oily rails.

Still a further object is to enable railroad locomotives to utilize more of their tractive forces on wet oily rails than has heretofore been considered possible.

An additional object of the invention is to produce a railway rail containing an adherent coating of a material which substantially prevents slippage between the rail and a locomotive or railway car wheel.

Still a further object is to provide a method of substantially preventing slippage between the bearing surfaces of a railway rail and a locomotive or a railway car wheel by applying to the rail and/or wheel a solid of colloidal fineness which acts on a slip inhibiting substance.

A further and more specific object of the invention is to provide a new and improved method for improving the frictional contact between a metal shaft and a sheave, gear or pinion frictionally mounted thereon. Other objects will appear hereinafter.

In accordance with the invention it has been found that the coefficient of friction between metal surfaces capable of motion one with respect to the other can be increased by applying to at least one of the contacting surfaces a dried silica of colloidal fineness. The invention in its preferred embodiment is particularly applicable to increasing the coefficient of friction between railway car wheels and tracks by applying to at least one of the contacting surfaces thereof a dried silica of colloidal fineness.

The preferred type of dried silica employed in accordance with the invention is one when added to a liquid such as water or ethyl alcohol will form a silica sol.

The silica employed for the purpose of the invention is available commercially and includes dried silica sols (e. g., a silica sol containing 30% SiO_2 in water which has been dried but is still hydrated), fine silicas made by burning silicon tetrachloride, dried surface esterified silicas (e. g., du Pont Valron), and the so-called silica aerogols (e. g., Santocel C and Santocel 54). The colloidal silicates can also be employed in accordance with the invention but are less desirable, particularly if the ratio of Na_2O to SiO_2 is greater than 1:3.2. The colloidal silicas, both crystalline and amorphous, and the colloidal silicates, both crystalline and amorphous, have been described by Iler, "The Colloid Chemistry of Silica and Silicates," Cornell Press, 1955, and the present invention contemplates the use of any and all of such colloidal silicas and colloidal silicates, with the further proviso, however, that the colloidal silicas are preferred for the practice of the invention. In general, for the purpose of the invention the colloidal silicas and silicates, whether amorphous or crystalline, have a specific surface area greater than about 20 square meters per gram. The expressions "dried colloidal silica" and "dried colloidal silicates" are sometimes employed herein to describe colloidal silicas and silicates, respectively, in the form of finely divided solid particles.

The surface esterified silicas which are employed for the purpose of the present invention are sometimes called estersils and form a new class of hydrophobic gels and powders as disclosed, for example, in Iler, U. S. 2,657,149. These estersils are characterized by the chemi-

cal attachment of a monomolecular layer of primary or secondary alkoxy groups containing 2 to 18 carbon atoms to the silica surface. They can be produced by heating the silica with alcohol in the absence of any substantial amount of free water at a temperature of 190° C. for one hour in the case of the primary alcohols, or at a temperature up to 275° C. in the case of the secondary alcohols. As reported by Iler, the structure of the silica is unchanged by the esterification of the surface but the product is organophilic and where the coating is substantially complete, the product is hydrophobic.

Certain fine silicas fall in the class known as aerogels. An aerogel is a gel in which the liquid phase has been replaced by a gaseous phase in such a way as to avoid the shrinkage which would have occurred if the gel had been dried directly from a liquid. The method of manufacture on a commercial scale has been described by White, Chem. Indus. 51, 66-69 (1942); Trans. Am. Inst. Chem. Engrs. 38, 435-446 (1942). While the present invention contemplates the employment of the aerogels, the results obtained in practice indicate that these are less effective than the colloidal silicas derived by drying a silica sol or by burning silicon tetrachloride and also less effective than the estersils.

In practicing the invention it has been noted that where the fine powder employed contains Na₂O in substantial amounts, there is a tendency toward the formation of a film when the powdered material is wet with water which is less effective for the purpose of the invention than a dry coating of the same material. It is therefore preferable in the practice of the invention that the ratio of SiO₂ to Na₂O in the composition to be at least 3.2:1. In general, the specific surface area can vary within a relatively wide range, for example, within the range of 20 to 800 square meters per gram. The ultimate particle size can also vary within a relatively wide range, for example, within the range of 8 to 1000 millimicrons in diameter. The silica or silicate particles can be either hydrophilic or hydrophobic.

To illustrate the effectiveness of the various colloidal silica and silicate powders as agents for improving the coefficient of friction, the following test apparatus was employed:

A steel rail was used as the base surface upon which the test was run. A U-shaped member made of heavy strap steel was formed having two perpendicular pieces attached to the tips of the U. A $\frac{3}{32}$ " diameter hole was bored in the center of the base of the U. A $1\frac{1}{8}$ " diameter steel ball having a Brinell hardness of 500 was welded to a threaded steel rod. The threaded steel rod was placed in the hole formed in the U-shaped steel member and fastened with a nut so that the steel ball was within the cradle of the U. The perpendicular arms were fitted with small steel boxes capable of holding lead shot or other weighted material. The U-shaped member was placed on the rail so the steel ball rested on the surface of the rail. To either side of the inverted U, wires were attached at a point slightly above the rail surface. Fixed to the other ends of the wire was a short piece of string that passed over a fixed pulley, the top of which was approximately coplanar with the surface of the rail. At the opposite end of the string was a suspended container which could be filled with weights.

In operation, the boxes were filled with lead shot in an amount which, when included with the weight of the cradle and fixtures, exerted a pressure at point of contact on the rail of 73,900 pounds per square inch. The weight of the U-shaped member and ball was 3,065 grams, which, for the purposes of experiment, may be considered as the operative downward pressure. The suspended container was filled gradually with lead shot until the steel ball just started to slide. This amount of weight is considered as the force necessary to overcome the friction existing between the ball and the rail. Using

these two factors, the coefficient of friction may readily be evolved from the following simple equation:

$$\text{Coefficient of friction} = \frac{F}{P}$$

where P equals 3,065 grams and F is the weight necessary to move the 3,065 grams.

During the course of testing various materials, it was necessary to make several modifications of the test apparatus. After using the rail for numerous experiments it was ground flat to remove surface abrasion and to facilitate cleaning operations. This was later substituted by a 4-inch long piece of polished heat treated steel which was rigidly held in a small wooden frame. The steel piece was 1" wide and $\frac{1}{4}$ " thick. It had a tensile strength of 164,200 pounds per square inch, a yield point of 159,200 pounds per square inch, a percent elongation of 17.3% and a decarburization to a depth of 0.008". An analysis of this steel showed it to contain the following:

	Percent by weight
Carbon	.31
Manganese	.58
Phosphorus	.016
Sulfur	.016
Silicon	.29
Chromium	1.000
Molybdenum	.22

In using each of these surfaces the blank tests did not vary within experimental error and hence the test method was concluded to be standardized throughout.

At the start of each series of tests the rail and ball were cleaned with scouring powder, rinsed with distilled water and dried with cellulose tissues. Periodic inspections were made of the contacting surfaces and when scratches occurred the ball and rail were polished with emery paper to renew the surface finish.

To simplify the experimental results the forces necessary to overcome the friction of the steel ball on the rail were recorded in grams. Three types of blank tests were run, the first being conducted with clean dry surfaces. The average of 10 such tests showed a force of 1835 grams necessary to move the ball. When a visible film of journal box oil was applied to the rail the average was 620 grams. When water was applied to the oil film the average was found to be 720 grams.

In the test, the results of which are shown in the following table, all of the fine silicas and silicates were applied in dry form to a test rail containing a visible film of journal box oil and the test was conducted as previously described.

Table I

Test No.	Composition	Number of test runs	Average force in grams to cause slippage
1.	Blank	10	620
2.	30% silica sol dried	6	2,200
3.	Estersil (Du Pont Valron)	15	1,700
4.	Dow Corning fine silica	8	1,418
5.	Santocel 54	4	987
6.	Santocel C	5	840
7.	Dry sodium silicate having an Na ₂ O to SiO ₂ ratio of 1:3.2	4	1,075
8.	Hi Sil 233	5	920
9.	Hi Sil X303	4	637
10.	Silene	2	700

In the foregoing test results it will be observed that the dried sodium silicate was much less effective than the dried silica sol or the estersil or the Dow Corning fine silica. All of the most effective colloidal silica powders were characterized by the fact that upon redispersion in water or ethyl alcohol they would form a sol.

The Hi Sil products contained approximately 86.5% SiO₂ and 3% CaO but apparently, due to their method

of manufacture or their particle size, some of these products had a much greater tendency to form a silica sol than others. Thus, the Hi Sil 233 had a greater tendency to form a silica sol than the Hi Sil X303 and the latter was not much better than the blank. It will also be noted that the aerogels, namely, the Santocel products, were less effective than the dried silica sols or the dried estersil.

The fine silica, either in the form of SiO_2 as such or mixed with a minor proportion of Na_2O or other oxides, such as CaO , can be applied to the metal surface as a powder but this is sometimes difficult under conditions where the surface is being subjected to motion either by movement of the surface or by movement of air or other medium, around the surface. Accordingly, one preferred method of application is to mold the fine silica into a solid stick by the use of a binder, such as dextrin, a plastic or a resin, and then apply the stick to the metal surface. Any of the dried colloidal silicas can be prepared in this manner. The particle size of the preferred dried colloidal silicas is preferably one micron or less but the aggregate form may be larger due to the drying methods employed.

The term "fine silica" as used herein is intended to include the dried silica sols, dried silica gels, fine silicas derived by dehydrating silicic acid, silicas derived by burning silicon tetrachloride, and also the dried colloidal alkali metal silicates. The dried colloidal silicates as previously pointed out are generally less effective than the dried colloidal silica sols. Their effectiveness can be increased when they are used in conjunction with other substances containing finely divided discrete particles, such as fine clay (kaolin) and other finely divided water insoluble materials (e. g., oxides and/or carbonates). These same materials can also be mixed with the dried colloidal sols.

While the invention is believed to be especially important in improving the frictional contact between wheels and rails, it is contemplated that it can be applied generally to improving the frictional contact between two metal surfaces capable of motion one with respect to the other. In the case of locomotive wheels and rails, the improvement of frictional contact involves contacting parts which are normally in motion (or dynamic) during the period when optimum frictional contact is desired. However, the invention is also applicable to improving the frictional contact between a metal shaft and a sheave or between a gear and a metal shaft or

between a pinion and a metal shaft where the sheave, gear or pinion is frictionally mounted on the shaft. In this case, a coating of the fine silica powder is applied to the shaft and the frictionally mounted member is forced on the shaft so that the colloidal silica is between said member and the shaft. Similarly, the invention can be applied to form a layer or coating of colloidal silica between bolts and lock nuts, and between other parts which are normally desired to remain static.

The present application is a continuation-in-part of my application Serial No. 533,190 filed September 8, 1955, now Patent No. 2,787,968 which in turn is a continuation-in-part of my application Serial No. 484,171 filed January 26, 1955, and the disclosures of said applications are incorporated herein as fully as if they had been set forth in their entireties.

The invention is hereby claimed as follows:

1. The method of improving the frictional contact between two metal surfaces capable of motion one with respect to the other which comprises applying to at least one of said surfaces a fine silica in powder form having a specific surface area of at least 20 square meters per gram, and bringing said surfaces into contact with one another with said fine silica therebetween.

2. The method as claimed in claim 1 in which the fine silica is a dried silica sol.

3. A method as claimed in claim 1 in which the fine silica is a dried estersil.

4. A method as claimed in claim 1 in which the fine silica also contains Na_2O in a ratio of SiO_2 to Na_2O less than 3.2:1.

5. A method as claimed in claim 1 in which the fine silica also contains CaO .

6. A method as claimed in claim 1 in which the metal surfaces capable of motion one with respect to the other are respectively a locomotive wheel and rail.

7. A structure having two metal surfaces capable of motion one with respect to the other and adapted to engage each other by frictional contact, at least one of said surfaces being coated with a thin coating of fine silica in powder form having a specific surface area of at least 20 square meters per gram.

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