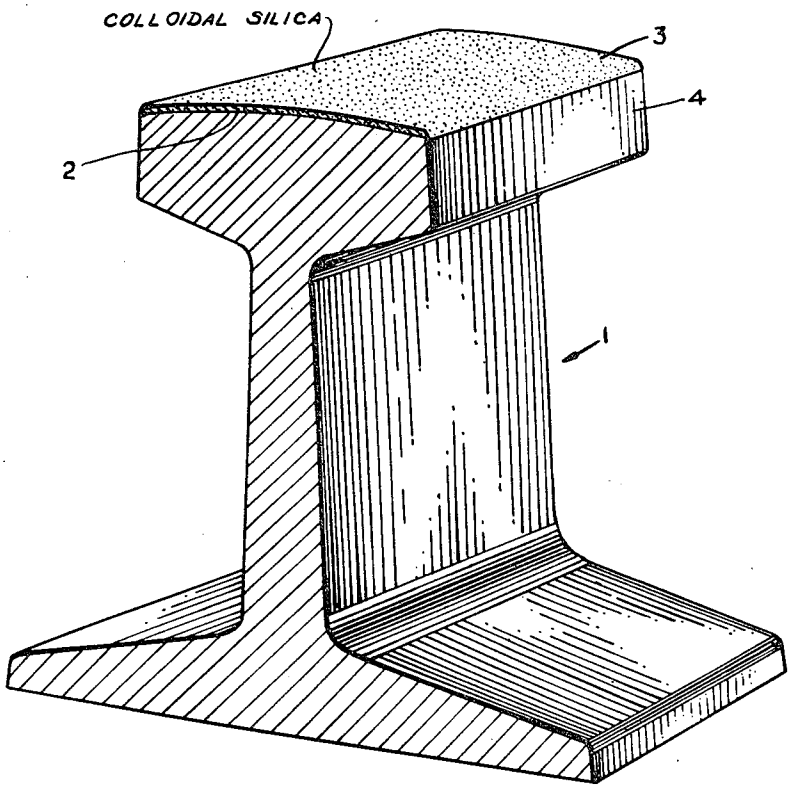
April 9, 1957 G. W. LUVISI 2,787,968

METHOD OF IMPROVING FRICTIONAL CONTACT BETWEEN METAL SURFACES NORMALLY IN ROLLING CONTACT AND RESULTANT STRUCTURE

Filed Sept. 8, 1955



INVENTOR:
GEORGE W. LUVISI
BY Darby, Johnston, Cooke & Rust
ATT'YS

United States Patent Office

2,787,968

Patented Apr. 9, 1957

2,787,968

METHOD OF IMPROVING FRICTIONAL CONTACT BETWEEN METAL SURFACES NORMALLY IN ROLLING CONTACT AND RESULTANT STRUCTURE

George W. Luvisi, Chicago, Ill., assignor to National Aluminate Corporation, Chicago, Ill., a corporation of Delaware

Application September 8, 1955, Serial No. 533,190

43 Claims. (Cl. 104—1)

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 strinkingly 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 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 liquid coating material which evaporates leaving a thin film or coating of 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 the contacting surfaces thereof a thin film of colloidal silica. The invention in its preferred embodiment is particularly applicable to improving the coefficient of friction between railway car wheels and tracks by applying to at least one of the contacting surfaces thereof a film of colloidal silica.

In the drawing a single figure shows a section of a railway rail containing a coating consisting essentially of colloidal silica applied to the bearing surface thereof.

As shown in the drawing the rail **1** has a bearing surface **2** to which the coating of colloidal silica **3** is applied. The coating of colloidal silica may also extend over the surface **4** which comes into contact with the wheel flange of the wheels of locomotives and railway cars.

An important feature of the present invention resides in the fact that silica in colloidal form adheres to steel rails. Furthermore, colloidal silica is a hydrous oxide and can be prepared in a liquid carrier medium, such as water, in the form of a silica sol. When a silica sol is applied to the bearing surface of a steel rail, the evaporation of the water or other liquid carrier medium leaves a thin strongly adherent film or coating which has pronounced anti-slip characteristics. In the simplest method of practicing the invention, therefore, an aqueous solution of colloidal silica, that is to say, a silica sol, is applied either to the steel rail or to the surface of a locomotive wheel or railway car wheel or to both the rail and the wheel. In most cases, however, the coating of colloidal silica will be applied to the rail by carrying or swabbing or by any other suitable mechanical or physical means. The colloidal silica can also be applied in paste or solid stick form, admixed with other substances such as, for example, silica flour, and finely divided kaolin.

If the colloidal silica dispersed in a liquid medium is applied to a metal surface such as a locomotive wheel, it is desirable that the product be dry or semi-dry by the

time the wheel contacts the rail. To this end the application of the liquid containing the colloidal silica is advantageously effected by a method involving blowing with air or other gas which assists in the evaporation of a volatile liquid in which the colloidal silica is dispersed. If the colloidal silica is in the form of a fine silica powder it can be applied to the metal surface separately, either simultaneously or contemporaneously, with a liquid which assists in forming a coating of the colloidal silica on the metal. The colloidal silica can also be converted to a semi-sol, gel, or paste and applied in such form by applicators suited for the application of gel-like or pasty materials.

Colloidal silica occurs in various forms and it will be understood that all forms of colloidal silica do not give the same results in the practice of the invention. Some forms of colloidal silica, such as silica sols containing about 7% to about 48% by weight of SiO_2 are especially advantageous for the practice of the invention. The colloidal silica in these sols preferably has a particle size within the range of 1 millimicron to 150 millimicrons. The particle size can be varied, dependent upon the method of preparation as hereinafter described. These sols can also contain stabilizing agents as hereinafter described.

In general, the colloidal silicas, preferably employed in the practice of the invention fall into three classes:

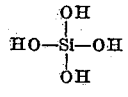
A. The silica sols.

B. The colloidal silicates, and

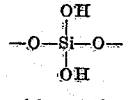
C. The hydrolyzed organic esters of silicic acid.

A. THE SILICA SOLS

Silicic acid sols are generally believed to be a polymeric derivative of monomeric silicic acid which arbitrarily may be assigned the formula



As this material is produced it is capable of polymerizing to form various sized polymers containing the mer unit



if the mechanism is considered linear. It is known, however, if the reaction carries to completion a gel is formed which evidences a three dimensional cross-linked network formed from the starting silicic acid molecule. The polymerization mechanism thus described may begin immediately upon the formation of monomeric silicic acid and proceeds to form particles or masses of colloidal size within a very short time. With the silica sols preferred for the practice of this invention when colloidal dimensions have been formed the cross-linking or gelation of the sol may be inhibited by adjusting the pH of the system with acid or alkali to between 2.5 to 4.8 and 8.5 to 10.0, respectively, or adding a small amount of alkali metal. Under these conditions, the sol will retain its colloidal dimensions for long periods of time. When the silicic acid reaches colloidal size and is stabilized, the particle size present is about 1 millimicron and possibly 2 to 3 millicrons in diameter. The exact size will depend on concentration, presence or absence of electrolytes, pH and temperature.

The silicic acid sols preferably employed in the present invention are those containing at least 3.0% SiO_2 and a pH sufficient to stabilize said sol against gelation. Silicic acid sols may be prepared by any number of well known methods, many of which are summarized in Bechtold, et al., U. S. Patent 2,574,902, and the present invention contemplates the use of any of such sols. Silica sols capable of use in the present invention may be conveniently prepared by the techniques described in Bird, U. S. Patent 2,244,325, although the well known method of hydrolyzing sodium silicate with strong mineral acids with the subsequent removal of excess salt is equally suitable.

The Bird patent shows that alkali metal silicate solutions may be contacted with a cation exchange resin in the hydrogen form to produce a silicic acid sol of relatively high purity. After the sol is produced it may be stabilized with a small amount of alkali metal to impart to the finished sol, a high degree of stability. Silica (SiO_2) to alkali metal (calculated as Na_2O) weight ratios of 50:1 to 100:1 are preferably employed to impart such stability.

The stabilized sols produced by Bird's method are capable of use in the practice of the present invention as produced or they may be concentrated to increase the silica content thereof, several folds. While the Bird patent shows generally the method of concentrating silica sols, there are now several methods available which produce sols having a relatively high silica concentration in the form of discrete non-agglomerated particles. Such methods are shown in Bechtold et al., U. S. Patent 2,574,902, Brage et al., U. S. Patent 2,680,721 and Parma et al., U. S. Patent 2,601,235.

In concentrating colloidal silicic acid sols, the usual methods increase the size of the discrete particles present in the sol. As the general rule the more concentrated the sol, the larger will be the particle size of the silica present. In a freshly prepared batch of stabilized 3.5% by weight SiO_2 sol prepared by the Bird method the particle size is believed to be about 1 to 3 millimicrons in size. If such a sol is concentrated to say about 30% SiO_2 by using the techniques of Bechtold et al., U. S. 2,574,902, the average particle size will vary from 15 to 130 millimicrons in diameter.

As can be seen from the previous discussion a wide variety of colloidal silica in the form of aqueous sols are readily capable of being prepared. The invention will be further illustrated by the following examples in which the proportions are given by weight unless otherwise indicated. All of the colloidal silica compositions described in these examples are suitable for the practice of the invention.

Example I

Commercial sodium silicate was diluted with Chicago tap water to produce a sodium silicate solution having present therein about 4.5% SiO_2. The weight ratio of Na_2O:SiO_2 was about 1:3.2, with a specific gravity of about 1.050. This diluted sodium silicate was passed through a column of a hydrogen form sulfonated polystyrene divinylbenzene copolymer cation exchanger of the type disclosed in U. S. Patent 2,366,007. The effluent contained about 3.5% SiO_2, had a pH of 3.5 and a conductivity of about 400 to 800 micromhos. To this silicic acid sol effluent was added an amount of 26° Baumé ammonium hydroxide sufficient to adjust the pH of the acid sol to about 9.0.

Example II

The procedure used in Example I was the same except that the solution of the starting sodium silicate contained about 10% SiO_2. The finished sol had an SiO_2 concentration of about 7% and a specific gravity of about 1.050. Ammonium hydroxide was added to the sol so that the final pH was about 10.5.

Example III

A portion of the sol of Example I was placed in an evaporating kettle and heated until ammonia and steam vapors began to come off. At this point a small amount of permanent alkali (KOH) was added and fresh ammonia stabilized sol was added to maintain the evaporating volume constant. Throughout the process the pH was never allowed to go below 8.5. This was accomplished by continually adding gaseous ammonia during the heating process. The constant evaporation was continued with constant checks being maintained to keep the pH always above 8.5, and was continued until specific

gravity of the sol had reached 1.20 at 68° F. When this specific gravity had been obtained an amount of potassium hydroxide was added to give the finished sol a pH of 9.0. This sol had an SiO_2 concentration of 30%.

Example IV

Another sol was produced by using the method shown in Example III. In this instance, however, the concentration process was continued until the sol had an SiO_2 concentration of about 48%.

In general, the silicic acid sols are preferably used in their more concentrated form. Sols containing about 30% SiO_2 have given superior results, yet sols having an SiO_2 content as low as 3% have shown effectiveness. Dosages in the amount of 1 to 5 gallons per two rail track mile are usually adequate.

TLese aqueous sols are sensitive to low temperatures but they may be treated by two methods whereby the effects of lower temperatures are avoided. The first method is to incorporate therewith an antifreeze such as methyl alcohol or ethylene glycol. This can be easily done by adjusting the pH of the sol to about 2.5. The second method is to treat the sol with an alkylamine so that if the sol is frozen it may be redispersed in a colloidal state. This later mode of treatment is shown in Horning, U. S. Patent 2,601,291.

In order to facilitate application of the sols to afford a more even distribution over the surfaces of the railway car wheels or rails, it is helpful to add thereto about 0.1% to 2% by weight of a compatible wetting agent. The only requirement of such agent is that it be compatible with the sol insofar as it is soluble and does not cause precipitation or gelation. Anionic synthetic detergents of the alkali metal alkyl (e. g., octyl or nonyl) benzene sulfonic acid type are admirably suited for the purpose of the invention. Any compatible anionic or non-ionic wetting agent can be employed, for example, those listed in the article "Synthetic detergents–to date, II, by John W. McCutcheon, appearing in Soap and Sanitary Chemicals, July, August, September and October issues, 1952. Cationic wetting agents tend to form gels or precipitates when added to these sols and should be avoided.

B. THE COLLOIDAL SILICATES

The colloidal alkali metal silicates or waterglasses are usually produced commercially by fusing soda ash and sand at a temperature of about 1300° C. The amount of alkali to silica may be varied by several well known methods thus enabling production of water soluble silicates of a wide variety of properties and characteristics. The colloidal waterglasses, however, usually have an alkali metal oxide ratio (expressed as Na_2O) to SiO_2 of not more than about 1:2, and generally less than 1:2.2. Sodium silicates having an Na_2O:SiO_2 ratio of 1:3.22 to 1:3.86 have improved the coefficient of friction between contacting metal surfaces as shown in the test methods hereinafter described. As the Na_2O to SiO_2 ratio decreases, the solubility in water decreases. For instance, a sodium silicate having an Na_2O to SiO_2 ratio of 1:2 can be concentrated to about 54% solids whereas a 1:3.2 material is only feasibly handled in concentrations below 40% solids. While the ratios shown above could theoretically be changed indefinitely, a ratio of about 1:4 sets the approximate lower limit since the materials become too difficult to manage and must be diluted before being capable of use.

Commercial forms of colloidal alkali metal silicates are usually liquids and are conveniently used in this invention as supplied. They have a Baumé gravity of from about 35.0° to 59.3° with the lower gravities being indicative of the high SiO_2 materials. While the liquid silicates are conveniently handled as furnished by the manufacturer, care must be taken to prevent water loss. Evaporation of as little as 1 to 2% of the water will cause these materials to become extremely viscous and incapable of an easy application to the contacting surfaces of railway car wheels and rails.

Other forms of alkali metal silicates that may be used are the soluble silicate hydrated powders. These are usually prepared by spray drying the various liquid silicates hereinbefore described. Here again, the Na_2O:SiO_2 ratios are preferably less than 1:2.5. Illustrations of the various liquid silicates that may be used in the practice of this invention are those shown below in Table I.

TABLE I

Approx. Ratio, Na_2O:SiO_2	Baumé, Degrees	Viscosity, Poises
1:3.75	35.0	2.2
1:3.40	39.7	3.3
1:3.25	42.5	7.5
1:3.22	41.0	1.8
1:3.22	38.0	0.6
1:3.22	40.4	1.0
1:3.22	42.2	4.0
1:2.90	47.0	9.6
1:2.54	50.5	11.2
1:2.50	42.0	0.5
1:2.40	52.0	17.0
1:2.00	50.0	2.8
1:2.00	59.3	700

POTASSIUM SILICATES

Ratio, K_2O:SiO_2	Baumé, Degrees	Viscosity, Poises
1:3.9	28.0	0.4
1:3.3	40.75	17.5

SOLID SOLUBLE SODIUM SILICATES

Ratio, Na_2O:SiO_2	Percent SiO_2 Content	H_2O
1:3.22	62.5	17.5

In using these materials they are preferably applied in a concentrated form or may be diluted with water to about 15% SiO_2. Applications are made to one mile of two rail track using 1 to 5 gallons on the track surface. It is to be understood that the smaller the Na_2O:SiO_2 ratio, and the more concentrated the solution, the smaller will be the amount of colloidal alkali metal silicate required. In any event, it is to be understood that the amount used is dependent on various conditions and is predicated on the amount sufficient to improve the coefficient of friction for any given set of such conditions.

C. THE HYDROLYZED ORGANIC ESTERS OF SILICIC ACID

Another source of colloidal silica for use in the practice of the invention are the hydrolyzed organic esters of silicic acid. These esters are usually prepared by the reaction of an organic compound having a free hydroxyl group with $SiCl_4$. This reaction is shown by the following equation

$$SiCl_4 + 4ROH \rightarrow Si(OR)_4 + HCl$$

where R is a hydrocarbon group.

The organic hydroxyl containing compounds are usually low molecular weight acyclic aliphatic alcohols having not more than 6 carbon atoms and aromatic hydroxyl compounds such as phenol. If the condensation reaction above is carried to completion under substantially anhydrous conditions the tetra substituted alkoxy or aroxy silane will usually result. If, however, the esterification is incomplete or water is present, a condensed ester of the general formula $(RO_3)Si—O(Si—O)_n—Si(RO_3)$ will result where n is a small whole number and R is a hydrocarbon radical. Examples of several commercially available ethyl silicates are shown in Table II below.

TABLE II

	Tetraethyl Ortho Silicate	Condensed Ethyl Silicate	Ethyl (40% SiO_2) Silicate
Molecular Weight	208.30		
Specific Gravity at 20/20° C	0.9356	0.9323	1.0508.
Boiling Range, 760 mm. Hg	Below 160° C., 5% max. Below 170° C., 95% min.	Below 100° C., 5% max. Below 190° C., 92% min.	IBP, 80° C. min. Below 110° C., 5% max.
Available silica as SiO_2	28% min. [a]	28% min	40% min.
Freezing Point, °C	−77	−84	−90.0.
Average Weight per gallon at 20° C., Lb	7.78	7.78	8.82.
Viscosity at 20° C., cps	0.6	0.72	3.9.
Refractive Index at 20° C. n_D	1.3832	1.3838	1.3965.
Flash Point (Cleveland open cup) ° F	135	90	90.

[a] 98% tetraethyl silicate.

In addition to those silicates shown above, others that may be used are methyl silicate, butyl silicate, amyl silicate, phenyl silicate, benzoyl silicate, hexamethoxydisiloxane and hexaethoxydisiloxane.

All the silicic acid esters shown above have the property of hydrolyzing in water, or water alcohol mixtures at rather uniformly controllable rates. A small amount (0.03 to 0.1%) of a strong mineral acid such as hydrochloric will accelerate the hydrolysis reaction. When less than the equivalent amount of water is used in an alcohol solution of these silicates they can be stored for long periods of time without gelation. Examples of hydrolyzed ethyl silicate solutions are given in the publication "Ethyl Silicates," January 4, 1954, by Carbide and Carbon Chemicals Company. While some of the compounds shown above are esters of polymeric silicic acid they are herein considered to be simply esters of silicic acid.

EVALUATION OF THE INVENTION

In order to evaluate various colloidal silicas as agents for improving the coefficient of friction between railway car wheels and rails, 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 9/32" diameter hole was bored in the center of the base of the U. A 1⅛" 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 ¼" 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
Phosphorous	.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.

After a number of tests it was determined that tests on the oiled rail alone were sufficient for purposes of comparison.

Listed below are several compositions that were tested. The results, which are averages of two or more runs, are shown in Table III:

Composition A: Sodium salts of an alkylbenzene sulfonic acid, 20% solution. The alkyl groups in this composition contain about 8 to 12 carbon atoms

Composition B: Rubber paint

Composition C: Sodium metasilicate ($Na_2O:SiO_2$ of 1:1) 30% solution

Composition D: Sodium Lignosulfonate 10% solution

Composition E: Rust in situ on rail

Composition F: Silica sol shown in Example III

Composition G:
Silica sol shown in Example III ____percent__ 99.0
Composition A _____do____ 1.0
Composition H: Silica sol shown in Example II
Composition I: Cationic urea-formaldehyde wet strength resin
Composition J: Ethyl silicate (40% SiO_2) hydrolyzed in ethanol and water to 16% SiO_2 content
Composition K: Concentrated NH_4OH solution at 70±5° F.
Composition L:
Silica sol of Example III _____percent__ 99.9
25% solution of Composition A _____do____ 0.1
Composition M:
Silica sol of Example III _____ml__ 50
Methanol _____ml__ 50
Citric Acid _____gram__ 1
This gave a sol having a freezing point of —20° C.
Composition N:
Composition M _____percent__ 99.9
Composition A _____do____ 0.1
Composition O:
Silica sol of Example III _____ml__ 75
Methanol _____ml__ 25
Citric Acid _____grams__ 2
This gave a sol having a freezing point of —15° F.
Composition P: Silica sol of Example IV diluted to 7% SiO_2
Composition Q: Silica sol of Example III diluted to 7% SiO_2
Composition R: Sodium silicate (Na_2O:SiO_2 of 1:3.2) 37.5% SiO_2
Composition S: Composition R diluted to 19% SiO_2
Composition T: Sodium silicate (Na_2O:SiO_2 of 1:3.75) 27% SiO_2

In the following table "Oiled Surface—Wet" means that the anti-slip composition was applied to the oiled surface as a liquid and the test was conducted before the coating was allowed to dry. The heading "Oiled Surface—Dry" means that the coated test piece was allowed to dry and then tested.

TABLE III

Test No.	Composition	Grams Force to Cause Slippage		
		Dry Surface	Oiled Surface	
			Wet	Dry
1	Blank	1,835	-------	620
2	A	-------	600	550
3	B	1,250	-------	-------
4	C	-------	-------	850
5	D	-------	575	650
6	E	1,150	-------	683
7	F	-------	-------	1,825
8	G	-------	1,625	2,118
9	H	-------	1,300	-------
10	I	-------	500	-------
11	J	-------	625	1,150
12	K	-------	525	-------
13	L[1]	-------	-------	2,300
14	L[2]	-------	-------	1,010
15	M	-------	-------	1,587
16	N	-------	-------	1,162
17	O	-------	-------	2,020
18	P	-------	1,210	1,850
19	Q	-------	-------	2,340
20	R	-------	1,108	2,283
21	S	-------	-------	1,200
22	T[3]	-------	-------	2,360

[1] Average of 11 consecutive runs.
[2] Continuation of 13 with fresh oil coat applied.
[3] Average of 10 consecutive runs.

From the results shown in Table III it can be seen that from the large variety of materials tested, Compositions F, G, H, J, L, M, N, O, P, Q, R, S and T were superior.

In order to further evaluate the compositions of the present invention field tests were run under actual railroad operating conditions.

Example V

The test engine used was an Alco diesel 1000 horsepower switcher type pulling thirteen freight cars. The test was run during the winter months and the temperature for the day of the test was about 40° F. with the sky being bright and clear. Six rail lengths of track were oiled with a mixture of diesel fuel and lube oils by wiping a rag saturated with the oil mixture along the top of the rail. One rail length was skipped and another six rail lengths were oiled in the same manner. To the second section of track a thin coating of Composition G was applied over the oil film by passing an applicator wet with the Composition G along the top of the rail. Composition G was allowed to dry and formed a barely visible film.

In order to increase the load on the switcher engine the brakes were set on the freight cars and the throttle opened wide on the engine. Operating under these conditions on the oiled but untreated rail, the engine was unable to move forward, the wheels spinning freely. To get the needed traction to move off the oiled rail the car brakes were released, the throttle reduced and sand was used. Even under these conditions forward motion was barely sustained.

When the engine, with full throttle and the brakes set on the freight cars started on the Composition G treated section of track, there was no wheel slip and the train readily picked up speed and moved forward. The contrast between the traction obtained on the untreated and treated oil track was very sharp. There was no visible wheel slip in the latter case.

Example VI

The same conditions shown in Example V prevailed except that Composition G was applied to the rail and the test run was run before the composition had dried. In this case Composition G appeared to reduce but not eliminate slippage. The train was able to sustain forward motion but there was some wheel slippage.

Example VII

The test conditions were similar to those shown in Examples V and VI above. The test equipment consisted of two 1000 horsepower Alco switcher diesel engines pulling twenty-seven loaded ore cars. Plain water was applied with an applicator to six rail lengths of track directly in front of the train. In starting, there was some wheel slip even on the dry rail, but when the switcher engines reached the wet track there was considerable slipping and the train proceeded with difficulty. The train was backed up and Composition F was applied to the wet rails with applicators. Immediately afterwards, while the rails were still wet, the train started over the treated section with no visible wheel slippage. There was no doubt that Composition F, while still liquid, had transformed a condition of wheel slip into that of no wheel slip.

Example VIII

The conditions were the same as Example VII, Composition F was applied to six rail lengths of track with an applicator and allowed to dry. The dried film was not as thin or as continuous as that in Example V.

The train started and proceeded on the treated section with no wheel slippage. In comparing Examples VII and VIII it was generally concluded that the dried Composition F gave better adhesion (i. e., less slippage) than the wet material.

Example IX

The composition tested consisted of a liquid made by adding orthophosphoric acid to a silica sol prepared by the ion exchange method containing 35% SiO_2 in water until the pH was 3.5 and then adding isopropanol until

the isopropanol content was 50% by volume of the total volume, hereafter referred to as Composition U.

The resultant composition was tested in actual railroad operation both by applying the composition to the wheels of the locomotive and by applying it to the rail.

The test equipment installed on the locomotive units consisted of one single and one dual recording meter and a transition indicator. The single instrument, an ammeter, was mounted in the cab of the leading locomotive unit and connected to record the current in the first traction motor. The dual instrument was installed in the cab of the trailing unit. The voltmeter and ammeter elements were connected across the main generator so that the main generator voltage was recorded. The ammeter was connected to a shunt which was inserted in the main generator lead to the traction motor.

An indexing needle on both tapes of the dual meter was fitted with a push button which recorded mile posts for identification. A second indexing needle on the ammeter was connected in a wheel slip relay circuit to record wheel slips. A second indexing needle on the voltmeter was connected across the sander circuit to record sanding operations. In addition, a transition indicator light was installed in the cab of the trailing unit. Observers in this cab kept a minute-by-minute log of motor current, speed and other pertinent data.

Traction motor torque was calculated from meter readings and the motor characteristic curve by the formula:

(1) $T=k\phi I_a \times \text{Efficiency}$

Where

T=motor torque in foot pounds
k=factor to convert electrical to mechanical units
I_a=motor armature current
ϕ=magnetic flux (from motor characteristic curve)

The corresponding tractive effort was:

(2) $$T.\ E.=\frac{T\times G.\ R.}{0.5\ W.\ D.}$$

Where

$T.\ E.$=tractive effort in pounds
T=motor torque per axle, (1) above
$W.\ D.$=wheel diameter in feet
$G.\ R.$=motor gear ratio

Adhesion then was:

(3) $$F=\frac{T.\ E.}{W}\times 100$$

Where

F=adhesion factor in percent
W=weight per driving axle in pounds

Thus, it was possible to obtain a continuous record of adhesion being developed by the locomotive and limiting adhesion at the time of a wheel slip.

The rails were sprayed with the previously described rail conditioning composition from a motorcar operating at about six miles per hour. The composition was sprayed from a knapsack sprayer at 30 pounds per square inch at a rate of about 0.1 gallon per minute. In some tests the engine wheels were also sprayed and allowed to dry before starting. Control tests were also made in which no treatment was applied to the rails or to the wheels.

In a control test on a clear day with a train consisting of two diesel units and 77 cars (60 loaded and 17 empty) having an adjusted gross tonnage of 4992 starting at an elevation of about 250 feet and going to an elevation of around 400 feet over a distance of about 3 miles, 21 wheel slips were counted. Intermittent sanding was used to increase traction but slipping was prevalent on the entire grade.

On a subsequent clear day, after treating the rails with a rail conditioning composition of the type previously described, a train consisting of 2 diesel units, 93 cars (53 loaded and 40 empty), having an adjusted tonnage of 5758, ascended the same grade with no rail slips and without using any sand. It will be noted that this train was 16 cars longer than the train used in the control test. The maximum adhesion developed was about 24% on the lead unit.

In a subsequent test on a clear day with a train consisting of 2 diesel units and 80 cars (70 loaded and 10 empty) having an adjusted tonnage of 6160, the train ascended the grade with no slips and without the use of sand. The maximum adhesion developed was 26.7% on the lead unit. In general, it was noted that the control adhesion with no sanding did not exceed about 11% and with sanding not more than about 18.5% adhesion was obtained. Thus, the practice of the present invention greatly increased the efficiency of the operation even without sanding.

Example X

The rail conditioning composition was prepared by adding isopropanol to a silica sol prepared by concentrating a silica sol made by the Bird ion exchange method and consisting of 35% SiO_2 in water having a pH of about 8. The isopropanol was added until it constituted 50% by volume of the composition. The resultant composition hereafter referred to as Composition V was a paste which was applied to the tread of the locomotive wheel through a 1/16" diameter copper tubing with the assistance of an air nozzle using 6 cubic feet of air per minute. The lead wheels of the two trucks on the front unit were treated with this composition at the rate of 20 ounces applied to each of the left No. 1 and No. 3 wheels, 4 ounces applied to the right No. 1 wheel and 10 ounces applied to the right No. 3 wheel, on a train pulling 80 cars and having an adjusted tonnage of 5002 over a distance of about three miles on a 1.1% ascending grade. No slips were encountered and no sanding was required.

As previously indicated, the colloidal silica can be used in the practice of the invention in conjunction with auxiliary materials. For example, compositions have been prepared for the purpose of the invention as follows:

Example XI

A composition was prepared by mixing together 75 parts of kaolin and 25 parts of a silica sol prepared by concentrating a silica sol made by the Bird ion exchange method and containing 30% SiO_2. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XII

A composition was prepared by mixing together 50 parts of a silica sol made by the Bird ion exchange method and containing 30% SiO_2 and 50 parts of kaolin. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XIII

A composition was prepared by mixing together 50 parts of waterglass having an $Na_2O:SiO_2$ ratio of 1:3.2 and 50 parts of kaolin. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XIV

A composition was prepared by mixing together 50 parts of waterglass of Example XIII and 50 parts of finely divided 87% silica-13% alumina catalyst fines with a fineness such that the average particle diameter was 1 micron or less. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XV

A composition was prepared by mixing together 50 parts of a silica sol prepared by concentrating a silica sol made by the Bird ion exchange method and containing 30% SiO_2 and 50 parts of fine silicon dioxide having a particle size of 5 to 10 millimicrons. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XVI

A composition was prepared by mixing together 50 parts of a 30% silica sol and 50 parts of waterglass having an $Na_2O:SiO_2$ ratio of 1:3.2. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XVII

A composition was prepared by mixing together 50 parts of waterglass having an $Na_2O:SiO_2$ ratio of 1:3.2 and 50 parts of jeweler's rouge. The bearing surface of a steel rail coated with this composition showed improved anti-slip characteristics.

Example XVIII

Compositions were prepared by incorporating with each of the compositions described in Examples I to IV and XI to XVII about 0.1 to 2% by weight of a finely divided electrical conductor such as carbon and finely divided powdered metals, e. g., iron and copper. These materials were incorporated in order to increase the electrical conductance of the coating. The bearing surface of a steel rail coated with these compositions showed an improved anti-slip characteristic and also had better electrical conductance than the coated rail having no electrically conducting material added to the coating composition.

In a similar manner, pasty to solid adhesion producing coating compositions can be prepared with other auxiliary materials, including, for example, the esterified silicas disclosed in U. S. 2,657,149 by mixing such materials with colloidal silica. The best results have been obtained by using as auxiliary materials predominantly siliceous materials capable of forming particles in liquid suspension having an average diameter of 1 micron or less. The resultant compositions can be molded to a solid stick form and applied to a wheel or rail by rubbing or other suitable means similar to those now employed in applying stick lubricants to wheel flanges. Suitable resins, plastics and other binders can be incorporated to produce and maintain the desired physical form.

Other materials which are capable of use in the invention are the solid silicas which are derived from silicic acid and silica sols. These solid silicas are extremely fine in particle size and are more accurately described as dehydrated colloidal silicas. The particle size of the preferred dehydrated colloidal silicas is preferably one micron or less but the aggregate form may be larger due to the drying techniques employed. Examples of such materials are the solid surface esterified silicas, dried silica sols, silica gels and fine silica derived by dehydrating silicic acid.

It will be seen from the foregoing discussion that the colloidal silica may be used in various physical forms including sols, semi-sols, gels, pastes and powders. It is also desirable to use a carrier which will assist in distributing or dispersing the silica on the metal surface, the frictional contact of which it is desired to improve. The carrier is preferably water, a low molecular weight alcohol or other non-lubricating liquid. By "non-lubricating" is meant that the liquid should have no substantially lubricating effect. It is possible, of course, for a liquid to have a slight lubricating effect which is more than counteracted by the adhesion-producing properties of the colloidal silica particles. In the practice of the invention, however, the liquids preferably employed as a carrier medium for the colloidal silica are sufficiently volatile at the temperatures used to permit the formation of a semi-dry to dry coating which contains only minor proportions or substantially no residual carrier liquid.

In general, superior results are obtained by using compositions containing a silica sol as described under the heading "A. Silica Sols." Good results are also obtained by employing the compositions described under the heading "C. The Hydrolyzed Organic Esters of Silicic Acid." The colloidal alkali metal silicates described under heading "B" hereof are generally less effective than the other materials mentioned when employed alone but their effectiveness is increased when they are used in conjunction with substances containing finely divided discrete particles, such as fine clay (kaolin) and other finely divided water insoluble materials (e. g., inorganic silicates, oxides, and/or carbonates) as described in Examples XIV, XV, XVII, and XVIII.

While the invention has been illustrated with respect to 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, gear or pinion frictionally mounted thereon. In this case, the colloidal silica, e. g., any of the compositions of Examples I to XVIII, is applied as a thin coating 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 may be applied to form a layer, coating or film between bolts and locknuts, and also between other parts which are normally desired to remain static. In both dynamic and static applications the optimum effect is obtained when the colloidal silica is present on the metal surfaces in a semi-dry to dry state.

The present application is a continuation-in-part of my copending application Serial No. 484,171 filed January 26, 1955, and the disclosure of said application is incorporated herein as fully as if it had been set forth in its entirety.

The invention is hereby claimed as follows:

1. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

2. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in a substantially non-lubricating carrier liquid, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

3. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a silica sol, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

4. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a silica sol containing at least 3.0% SiO_2, and bringing said surfaces into contact with one another with said colloidal silica therebetweeen.

5. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a silica sol containing from 7% to 48% SiO_2, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

6. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of colloidal silica dispersed in a non-lubricating liquid comprising a lower aliphatic monohydric alcohol and water, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

7. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of colloidal silica dispersed in a non-lubricating liquid comprising isopropanol and water, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

8. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of colloidal silica dispersed in a non-lubricating liquid comprising methanol and water, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

9. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a coating of a silica sol containing a finely divided silicate, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

10. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a coating of a silica sol containing a finely divided kaolin, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

11. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a hydrolyzed organic ester of silicic acid, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

12. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of a hydrolyzed ethyl silicate, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

13. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of an aqueous sodium silicate solution having an $Na_2O:SiO_2$ ratio within the range from about 1:3.2 to about 1:3.75 and containing a finely divided predominantly siliceous material capable of forming particles in liquid suspension having an average diameter not exceeding one micron, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

14. The method of improving the frictional contact between two metal surfaces normally in rolling contact one with respect to the other which comprises applying to at least one of said surfaces a thin coating of colloidal silica in the form of an aqueous sodium silicate solution having an $Na_2O:SiO_2$ ratio within the range from about 1:3.2 to about 1:3.75 and containing a finely divided kaolin capable of forming particles in liquid suspension having an average diameter not exceeding one micron, and bringing said surfaces into contact with one another with said colloidal silica therebetween.

15. A structure having two metal surfaces normally in rolling contact 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 a colloidal silica.

16. A structure having two metal surfaces normally in rolling contact 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 a semi-dry to dry coating of colloidal silica.

17. A structure having two metal surfaces normally in rolling contact 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 a semi-dry to dry coating of colloidal silica having an average particle size within the range from 1 to 150 millimicrons.

18. A structure having two metal surfaces normally in rolling contact 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 a semi-dry to dry coating composition consisting predominantly of a siliceous material having an average diameter of not more than 1 micron and containing colloidal silica having an average particle size within the range from 1 to 150 millimicrons.

19. A structure having two metal surfaces normally in rolling contact 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 resulting from allowing to dry thereon a coating of silica sol containing 3% to 48% SiO_2.

20. A structure having two metal surfaces normally in rolling contact 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 resulting from allowing to dry thereon a vaporizable liquid containing a hydrolyzed organic silicic acid ester.

21. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica.

22. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in a substantially non-lubricating carrier liquid.

23. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a silica sol.

24. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a silica sol containing at least 3.0% SiO_2.

25. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a silica sol containing from 7% to 48% SiO_2.

26. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of colloidal

silica dispersed in a non-lubricating liquid comprising a lower aliphatic monohydric alcohol and water.

27. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of colloidal silica dispersed in a non-lubricating liquid comprising isopropanol and water.

28. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of colloidal silica dispersed in a non-lubricating liquid comprising methanol and water.

29. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a coating of a silica sol containing a finely divided silicate.

30. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a coating of a silica sol containing a finely divided kaolin.

31. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a hydrolyzed organic ester of silicic acid.

32. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of a hydrolyzed ethyl silicate.

33. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of an aqueous sodium silicate solution having an $Na_2O:SiO_2$ ratio within the range from about 1:3.2 to about 1:3.75 and containing a finely divided predominantly siliceous material capable of forming particles in liquid suspension having an average diameter not exceeding one micron.

34. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin coating of colloidal silica in the form of an aqueout sodium silicate solution having an $Na_2O:SiO_2$ ratio within the range from about 1:3.2 to about 1:3.75 and containing a finely divided kaolin capable of forming particles in liquid suspension having an average diameter not exceeding one micron.

35. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin liquid coating of colloidal silica in the form of a silica sol, at least partially drying said coating and bringing said surfaces into contact with one another with said coating of colloidal silica therebetween.

36. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin liquid coating of colloidal silica in the form of a silica sol resulting from acidifying an aqueous silica sol containing 7% to 48% by weight SiO_2 in a colloidal state and adding a lower aliphatic monohydric alcohol thereto, at least partially drying said coating and bringing said surfaces into contact with one another with said coating of colloidal silica therebetween.

37. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin liquid coating of colloidal silica in the form of a silica sol resulting from acidifying an aqueous silica sol containing 7% to 48% by weight SiO_2 in a colloidal state with phosphoric acid and adding a lower aliphatic monohydric alcohol, at least partially drying said coating and bringing said surfaces into contact with one another with said coating of colloidal silica therebetween.

38. The method of improving the frictional contact between railway wheels and tracks which comprises applying to at least one of the contacting surfaces thereof a thin liquid coating of colloidal silica in the form of a silica sol resulting from acidifying an aqueous silica sol containing 7% to 48% by weight SiO_2 in a colloidal state with phosphoric acid to a pH of about 3.5 and adding isopropanol thereto until the isopropanol content is approximately 50% of the total volume, at least partially drying said coating and bringing said surfaces into contact with one another with said coating of colloidal silica therebetween.

39. A railway rail having its wheel bearing surface coated with a thin coating of a colloidal silica.

40. A railway rail having its wheel bearing surface coated with a thin coating of a semi-dry to dry coating of colloidal silica having an average particle size from 1 to 150 millimicrons.

41. A railway rail having its wheel bearing surface coated with a thin coating resulting from allowing to dry thereon a coating of silica sol containing 3% to 48% SiO_2.

42. A railway rail having its wheel bearing surface coated with a thin coating resulting from allowing to dry thereon a coating of acidified silica sol containing a lower aliphatic monohydric alcohol.

43. A railway rail having its wheel bearing surface coated with a thin coating resulting from allowing to dry thereon a coating of acidified silica sol containing phosphoric acid and isopropanol.

References Cited in the file of this patent

UNITED STATES PATENTS

1,666,167	Connolly	Apr. 17, 1928
2,408,656	Kirk	Oct. 1, 1946