

PATENT SPECIFICATION

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(54) FRICTON COUPLING

(71) We, CATERPILLAR TRACTOR CO., a corporation organised and existing under the laws of the State of California, United States of America, of 100 N.E. Adams Street, Peoria, State of Illinois 61602, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a friction coupling. More particularly, this invention relates to a friction coupling of the type which in use includes a layer of liquid between frictionally engaging plates to assist in absorption of energy.

Friction couplings, for example for use in clutch and brake applications in heavy duty service vehicles, have often proved unsatisfactory when exposed to the high ambient working temperatures that are frequently encountered. This is in part due to the fact that such couplings have often employed elastomeric materials as friction materials and these have been based on heat-hardenable resins such as phenol-aldehyde resins which tend to decompose under the high peak and bulk temperature conditions created by the sustained and/or heavy loading forces experienced in the clutch and brake systems of heavy duty vehicles while operating. As may be expected, this leads to a deterioration in performance.

In the search for a friction material with a usefully high coefficient of friction which is stable over a wide temperature range, the industry has most usually used non-resilient inorganic friction materials such as sintered bronze. Although the friction characteristics of this and similar metallic materials have been generally satisfactory under high temperature conditions, the high modulus or lack of resiliency of these materials and

their resultant inability during operation to conform to the friction element mating surface and absorb adequate energy result in relatively high wear rates and shortened life. Furthermore, great care must be taken in the type and viscosity of liquid, generally oil, used in conjunction with such friction materials during use to ensure that the desired coefficient of friction is not impaired.

According to the present invention, we provide a friction coupling comprising a rotatable friction plate formed of a rigid core having secured thereto a layer of elastomeric non-porous friction material providing a friction surface, and a reaction plate providing a mating surface for relative rotational frictional engagement with said friction surface.

said friction material on said friction surface providing a plurality of protuberances adapted in use to cooperate with a layer of liquid between the friction surface and the mating surface whereby a substantial amount of the energy of plate engagement is absorbed in shear of the liquid film during relative rotational engagement of the surfaces.

We have found that a bronze clutch material, when employed in a high load oil-cooled clutch environment of a transmission for a heavy duty earthmoving vehicle, exhibits a measurable difference in its frictional properties as a function of the viscosity of the liquid. We have further found that great advantage may be obtained by maintaining the oil film thickness as small as possible in order to permit more of the energy of engagement to be absorbed by shear in the oil film and it is likely that a further advantage would be gained by sustaining such thin film in the order of a few microinches during a longer portion of the engagement cycle. However, the oil film thickness between a rotary friction plate and a stationary substantially flat reaction plate depends on the



radius of curvature or size of the protuberances or asperities in the friction material under a given load, and so the smaller the asperities in the surface of the friction plate are, the thinner the oil film thickness can be. It is known that the thinner the oil film thickness, the greater rate of shear and, therefore, the greater shear force and energy that the oil film is capable of absorbing. Accordingly, a great plurality of such asperities in the surface of the friction plate produces greater fluid wedging effect of the oil film as it is squeezed between the multitude of asperities and the reaction plate to produce a substantial drag on the friction plate. Furthermore, the greater the amount of oil film in thin film shear, as discussed above, the greater the energy absorption. Accordingly, the substantially large number of asperities in the surface of the friction plate results in a greater amount of oil being retained over the entire surface area of the plate due to the trapping effect and cavitation of oil on the trailing sides of the asperities over the surface area between the friction material plate and its mating reaction plate. The greater the real viscosity or internal resistance to flow of fluid in contact between the friction surfaces, the greater is the energy absorption obtainable in the thin film shear. Such real or developed viscosity during the engagement cycle is, of course, enhanced by the substantial number of asperities through which the engagement pressure is transmitted to the oil film in shear. It is also known that the greater the relative motion between the friction plate and the reaction plate, the greater the shear and, again, the greater energy absorption obtained.

The elastomeric non-porous friction material utilized in the coupling of the invention preferably comprises a compounded elastomeric matrix in which are suspended minute particles of a friction-producing agent, or "high modulus asperities". A fluoro-elastomer matrix has excellent properties of thermal stability, and at the same time provides a relatively low modulus resilient matrix which permits the friction material to conform readily to inherently rapid changes between it and its mating surface, thereby distributing dynamic stresses and energy absorption over a much larger true friction surface area than is permitted with high modulus metallic or other non-resilient materials.

Suitable fluoroelastomeric materials for use in the present invention are described in our British Patent Specification No. 1,456,755, the disclosure of which is incorporated herein by reference.

When such a fluoroelastomeric friction material is utilized in a disc-type oil-cooled transmission clutch or brake environment for frictional engagement with a reaction plate of

relatively rigid noncompressible material, the asperities create a hydro-dynamic wedge in the oil passing between the friction material and the reaction plate with the microscopic size of the asperities producing a relatively thin oil film. This increases the viscosity of the oil film fully to support the load imposed between the friction plate and the reaction plate prior to their complete engagement. Both the viscous shear of the fluid and the pressure drag created by the hydro-dynamic wedging of oil ahead of the asperities and the cavitation behind the asperities contribute to the frictional force. This makes it possible to use the oil film to achieve dynamic frictional braking exclusive of the elastomeric material in the frictional surface during the major portion of the engagement cycle which produces greater wear resistance and improved temperature stability with a higher coefficient of friction than previously achieved with conventional friction materials.

An embodiment of the invention, which is by way of example only, will now be more particularly described in the following drawings in which:

Fig. 1 is a photomicrograph (at 500× magnification) of the surface of material used in the invention after this surface has been "worn in". The rod-like protuberances or asperities are clearly seen with the worn flat surfaces thereon apparent.

Fig. 2 is a photomicrograph (at 500× magnification) of another sample of friction material used in the invention. The protuberances or asperities are noted to have flattened upper surfaces produced upon "wearing in" of the material.

Fig. 3 is a photomicrograph (at 200× magnification) of a cross section through the friction material utilized in the present invention showing a plurality of particles of vitreous material dispersed throughout the relatively soft elastomeric matrix and forming protuberances of asperities protruding above the surface of the matrix.

Fig. 4 is a photomicrograph (at 500× magnification) of another cross sectional view through the friction material of the preceding Figs.

Fig. 5 is a force curve graph representing a conventional clutch or brake operation under simple conditions of engagement.

Fig. 6 is a graph showing the force curve under conditions of clutch or brake operation with the friction material utilized in the present invention operating under a microelastohydrodynamic condition in conformance with the principles of the present invention.

Fig. 7 is a greatly enlarged sectional view through the friction material disposed adjacent to a substantially flat reaction plate with a relatively thin energy absorbing oil film produced therebetween.

Fig. 8 is a central vertical cross section through a typical disc-type oil-cooled clutch or transmission brake employed on relatively heavy earthmoving vehicles with the friction material shown utilized in combination with a continuous flow of hydrodynamic liquid.

In Fig. 8, a representative transmission clutch or brake includes a fluid type housing 20 through which is journaled a rotatable shaft 22. The shaft has an integral annular flange 24 which supports a radially outwardly disposed annular splined ring 25. The ring has a plurality of axially oriented splines 26 and a plurality of oil directing openings 28 extended therethrough between the splines. An oil directing and piston receiving chamber 30 is formed between the ring 25, the flange 24 and the adjacent portion of the shaft 22. A centrally disposed axially extended bore 32 is formed in the shaft 22 and is connected to a source of cooling and hydrodynamic liquid, not shown. A port 34 is formed in the shaft 22 between the bore 32 and the chamber 30 for directing the supply of liquid toward the plurality of openings 28 in the ring 25.

A ring 35, stationary for a brake but rotatable for a clutch is mounted within the housing 20 is radially spaced circumscribing relation to the ring 25. The ring as a plurality of inner splines 37 between which are disposed a plurality of liquid exhaust openings 38. An annular actuating piston 40 is axially slidably mounted within the chamber 30 and has a radially outwardly extended annular actuating shoe 42 disposed between the inner and outer rings 25 and 35, respectively. A high pressure fluid passage 45 is formed within the shaft 22 in axially spaced relation to the bore 32 and is connected to a source of high pressure fluid, not shown. A radially outwardly extended passage 46 in the shaft 22 communicates such high pressure fluid to a piston actuating chamber 48 in the housing behind the actuating piston 40.

A plurality of externally toothed reaction plates 50 are mounted in meshing engagement within the outer ring 35 on the splines 37 in predetermined axially spaced relation. The reaction plates present opposite substantially flat, smooth surfaces 52 with the plates being constructed of a substantially rigid noncompressive metallic material. A plurality of internally toothed friction plates 55 are mounted on the splines of the inner ring 25 in interleaved relation to the reaction plates and in slightly spaced relation thereto. Each of the friction plates has a metallic core 56 and on each of its opposite sides has bonded thereto the friction material 57 utilized in the present invention.

As best shown in Fig. 7, such improved friction material is constructed of a composition providing a fluoroelastomer matrix 58 having a plurality of particles 59 of a

vitreous material intermixed therewith and uniformly distributed throughout the matrix in nonbonded relation. Such particles form a great multitude of asperities 60 or protuberances in the surface of the friction plate for forming a hydrodynamic film of oil between each set of plates as will subsequently be more fully described.

During operation of the transmission, a continuous supply of cooling and hydrodynamic liquid is directed through the openings 28 in the inner rotary ring 25, between each of the interleaved friction plates 55 and reaction plates 50 and outwardly through the discharge openings 38 in the outer stationary ring 35. Upon the introduction of high pressure fluid into the actuating chamber 48, the piston 40 is positioned to the right as shown by the dashed lines in Fig. 8 which causes the shoe 42 to engage the stack of friction and reaction plates to initiate the plate engagement cycle and ultimately complete engagement with the rotary shaft 22. Prior to actual engagement of the asperities 60 in the surface of each of the friction plates with their mating reaction plate, each particle 59 acts as a tiny hydrodynamic bearing. The relatively soft matrix which serves as a carrier for the particles affords the dual function of allowing some deflection or partial recession of the more prominently extended particles into the matrix itself. In harder matrix materials, the hard particles would be destroyed as a result of excessive pressure and possibly torn from the matrix carrier. Secondly, the relatively soft matrix affords improved conformability with any irregularities in the mating surface of the reaction plate and permits a more uniform distribution of pressure over substantially the entire area of the friction plate.

As previously described, the great number of microscopic asperities 60 in the friction surface of the friction plate 55 produce a relatively thin film of fluid between them and the mating surface of the reaction plate through the hydrodynamic wedging of oil on the leading sides of the particles and the cavitation on their trailing sides as shown in Fig. 7. With the oil film thickness rapidly approaching that permitted by the microscopic particle size relatively early during the engagement cycle, the relatively high rotational speed between the friction plates and reaction plates produce a relatively high shear rate and torque absorption in such relatively thin oil film which is sufficient fully to support the load or pressure of engagement. This is indicated by the graph of Fig. 6 with the declining portion of the curve indicating no contact between the surface of the matrix and the surface of the reaction plate. In direct contrast, it will be noted that the force curve as shown in Fig. 5 with conventional friction materials

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indicates that the entire load is picked up primarily by the intimate contact of the surfaces of the plates which continues until substantially complete wring-in and expulsion of substantially all of the cooling liquid is achieved. However, with respect to Fig. 6, as the speed falls, oil shear rate reduces together with friction and torque until finally near the end of the engagement cycle the hydrodynamics can no longer be sustained by the particles due to the low speed and the unit goes into boundary lubrication, or substantial wring-in, completing the engagement cycle. It is further noted, however, from the graph of Fig. 6, that the relative speed is very low when such boundary lubrication or substantial wring-in occurs, delaying until the last possible moment any intimate contact of the matrix material with the mating reaction plate, nearly eliminating any load absorption by the matrix material alone. Accordingly, this produces a greater resistance to wear of the friction material and improved temperature stability with a higher coefficient of friction than heretofore achieved with conventional friction materials. In the embodiment described above, a fluoroelastomer matrix is used. It will, however, be apparent that other elastomers such as polyacrylate, silicone, fluorosilicone, chloroprene, acrylonitrile, or urethane or mixtures thereof may be used without departing from the scope of the present invention. Composite materials so formed exhibit tensile strengths comparable with the elastomers alone, but however exhibit better set and stress relaxation resistance than the fluoroelastomers alone.

Fluoroelastomers which are useful in this invention are exemplified by Viton E60C, ("Viton" is a Registered Trade Mark), a copolymer of hexafluoropropylene and vinylidene fluoride which is commercially available from E. I. duPont, Inc., Wilmington, Delaware, and Fluorel FC2170, commercially available from the 3M Company of Minneapolis, Minnesota. Preferably, Viton E60C or Fluorel FC2170 are employed to form the matrix of the friction material.

To form the preferred friction material used in the invention, the fluoroelastomer has admixed therewith particles of a relatively hard material, herein referred to as "asperities". These asperities are preferably vitreous or ceramic materials in very small beads, fibers or other irregular shapes.

Although the useful size of these asperities may vary somewhat according to the nature of the material and other factors, fiberglass particles of from .0001" to .005" in diameter, and preferably 0.0005" in diameter, will yield the desired results. Such particles advantageously have a length to diameter ratio of from 3 to 100. The fiberglass or other asperities may also be compounded in

the form of chips, fibers, spheres or other convenient shapes, although fibers are generally preferable.

The asperities are compounded with the fluoroelastomer at a rate sufficient to give and maintain a high surface concentration of asperities in the finished friction facing. Preferably, 20 to 50% by weight of fiberglass particles to 30 to 50% by weight of fluoroelastomer are admixed to provide a randomly irregular microscopic surface finish on the friction material. It may in some instances, however, be desirable to exceed these proportions, depending on the frictional characteristics desired in the finished material.

It is contemplated that carbon black will be incorporated into the fluoroelastomer, conveniently at the same time or prior to the time the asperities are incorporated. This additive is preferably added in amounts of 12 to 30% by weight of carbon black to 30 to 50% by weight of fluoroelastomer. Additionally, accelerators, stabilizers, and curing agents, inter alia, commonly used in fluoroelastomer products, will usually be compounded with the fluoroelastomer.

The asperities, carbon black, and other additives are incorporated into the fluoroelastomer by conventional mixing techniques, for example, in a Banbury mixer. Ideally, the asperities should be concentrated near the surface, or the frictionally active portion, of the fluoroelastomer matrix. However, in practicality this is difficult to achieve, and satisfactory results are obtained by intimately incorporating the asperities throughout the fluoroelastomer to obtain a random orientation of the asperities through the matrix.

The fluoroelastomer friction material may be bonded to a core of steel or other metal to form a friction element by a method as disclosed in our British Specification No. 1,450,103 noted above. Broadly, this process comprises incorporating CaO into the fluoroelastomer prior to curing, and then at high temperatures curing the fluoroelastomer in pressed contact with the core material. Conveniently, the CaO may be incorporated into the fluoroelastomer at the same time as are the asperities and other additives noted above.

Conventional molding techniques, such as compression, transfer or injection molding, are utilized for forming the fluoroelastomer/backing plate friction element. In applying the friction material to the backing plate of the friction element, it is usually desirable to apply the friction material to the plate in an amount sufficient to obtain a finished thickness of friction material of from 0.020 to 0.250 inches, especially in applications where the material is utilized in clutches.

The friction material used in this invention exhibits a high, stable, dynamic coefficient of friction through a wide range of sliding speeds and normal loads against a wide

variety of opposing faces and finishes. For example, dynamic friction coefficients (μ_D) of from 0.14 to 0.06 at from 2,000 to 11,000 ft/min sliding speed and from 50 to 680 psi of face pressure on gross area typically can be expected in friction elements comprised of the friction material of this invention.

Additionally, good static ("breakaway") coefficients of friction from 0.17 to 0.26 are characteristic of this fluoroelastomer friction material.

The friction material used in this invention is capable of operating against mating surfaces of a variety of type, for example, hard or soft steel, cast iron, sintered metals, and ground, deburred or lapped surfaces. However, the mating surface finish may adversely affect the friction characteristics of the friction material if this surface is too roughly or too finely finished. Generally, a mating surface finish of 10 to about 45 μ will result in satisfactory performance of the friction material.

The fluoroelastomer friction material used in this invention is further characterized by low wear and dimensional stability during extended dynamic operation. Furthermore, with properly modulated engaging pressure, the material exhibits a relatively flat torque curve that "wrings in" 10–50% above the dynamic torque.

The friction material used in this invention will respond according to test results over a wide operating surface temperature range even up to 680°F. In general, the material can be expected to maintain optimum response levels at bulk temperatures below 475°F; i.e., where the average surface temperature of the friction material between operations of the friction element is below 475°F. Maximum peak temperatures, however, may be as high as from 560°F to 680°F before performance of the friction material is substantially affected.

In general, effective performance of the friction material contemplates operation of the friction element under oil cooled operating conditions. However, a much wider selection of oils may be effectively employed with the chemically inert fluoroelastomer friction material than with, for example, bronze.

In preparing friction elements utilizing the friction material described above it will generally be found that after demolding, few if any of the asperities will be present on the frictional surface of the material. The thin elastomer coating covering the asperities must therefore be worn off to expose the asperities and hence to obtain a stable coefficient of friction for the element. This may either be done in situ, allowing the rubber coating to be worn off during an initial break-in period of the friction element in the service vehicle, or by pre-grinding of the

friction material before installation of the element. The amount of matrix material which must be removed to obtain a desirably stable coefficient of friction for the material as a whole will of course vary according to the specific formulation. However, it is generally advantageous to sufficiently expose a major portion of the underlying asperities to a point where these asperities are in contact with the mating surface.

During early use, these asperities are ground to a point where they appear to be well-worn, as shown in Figs. 1 and 2 above, to obtain a stable coefficient of friction. The asperities are mechanically held in the matrix in nonbonded relation in order to enhance the noncompressive setting characteristic of the material.

The following Examples are provided only to further illustrate specific friction material compositions used in this invention and pertinent frictional characteristics thereof, without limiting the invention in any manner:

Example 1			Size
Ingredients	Amount (Parts by Weight)		
Viton E60	100 parts		
Type E Fiberglass	110 parts	0.0005"	diameter
Carbon Black	60 parts		
Accelerators	} Minor amounts		
Stabilizers			
Curing Agents			
CaO	5 parts		

The above ingredients were compounded by mixing in a Banbury mixer to achieve an even dispersion of the additives into the fluoroelastomer matrix, with random orientation of the glass particles. The mixture was applied to a steel backing plate and pressed to this plate into the desired pattern under about 2,500 psi. The mixture then was cured for 30 seconds at 390°F. Sufficient mixture material was applied to the plate to give a thickness of material, when cured, of .050 inches/face. The cured elastomer and backing plate, i.e., clutch disc, were then postcured at 450°F for 16 hours.

It was found that the friction material possessed a Shore A Hardness of 90–95, and an ultimate tensile strength of 1,900 to 2,100 psi. The clutch friction element made by the process of Example 1 was then subjected to a wear test in an earthmoving vehicle transmission comprising 220,000 cycles, from third speed reverse to third speed forward. 0.008 inches of wear was observed per friction material face element at the conclusion of this test. The friction material was found to have an excellent thermal stability up to 475°F (bulk), and 680°F (peak).

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Example 2

Full Scale Clutch Test Results

	Friction Material	As in Example 1
	Size O.D.—inches	12.25
5	Area/Face—inches	31
	Faces/Clutch	8
	Oil Temperature	210°F
	Cycle Time	30 seconds
10	Reaction Surfaces—Ground and Deburred Soft Steel	

Shift	3R—1F	3R—3F
Input RPM	2,000—1,800	1,800 2,000

Coefficient of Friction

	Maximum	0.110	0.110	0.116	0.112
15	Minimum	0.065	0.068	0.074	0.070
	Wring-In	0.073	0.075	0.083	0.083

Clutch Torque lb-ft/in²

	Max. Dynamic	11.2	11.7	13.3	12.6
	Wring-In	12.6	13.0	14.9	14.9
20	Peak HP/in ²	3.2	2.7	1.7	1.9
	Total BTU/in ²	0.65	0.51	0.58	0.73

Plate Temperature

	Max. °F	494	443	360	390
	Bulk °F	235	225	212	193

25 The above-described friction material is specifically intended for use in an oil-cooled disc-type friction coupling utilized in a power train such as a clutch or transmission brake as depicted in Fig. 8 above for relatively heavy earthmoving vehicles.

WHAT WE CLAIM IS:—

35 1. A friction coupling comprising a rotatable friction plate formed of a rigid core having secured thereto a layer of elastomeric non-porous friction material providing a friction surface, and a reaction plate providing a mating surface for relative rotational frictional engagement with said frictional surface, said friction material on said friction surface providing a plurality of protuberances adapted in use to cooperate with a layer of liquid between the friction surface and the mating surface whereby a substantial amount of energy of plate engagement is absorbed in shear of the liquid film during relative rotational engagement of the surfaces.

50 2. A friction coupling as claimed in claim 1 wherein the protuberances comprise a plurality of discrete particles of a ceramic or vitreous material intermixed with and dispersed throughout the friction material in non-bonded relationship therewith, said material being reboundably deflecting so as to permit at least partial recession of prominently extended protuberances into the material so as to assist maximum conformity of the friction surface with the mating surface.

3. A friction coupling as claimed in claim 1 or claim 2 wherein the friction material comprises a copolymer of hexafluoropropylene and vinylidene fluoride.

65 4. A friction coupling as claimed in claim 1 or claim 2 wherein the friction material comprises an elastomeric material selected from polyacrylate, silicone, fluorosilicone, chloroprene, acrylonitrile, urethane or mixtures thereof.

70 5. A friction coupling as claimed in any of claims 1—4 wherein the protuberances comprise glass fibres of from 0.0001 to 0.005 inches in diameter and having a length to diameter ratio of from 3 to 100.

75 6. A friction coupling as claimed in any of claims 1—5 wherein the protuberances are of a size effective to produce microscopic voids on their trailing sides with respect to plate rotation whereby in use to cause cavitation of the liquid in the trailing sides so as to provide increased viscous drag on the friction plate.

80 7. A friction coupling as claimed in any of claims 1—6 wherein a supply of liquid is provided between the plates which hydrodynamically wedges between the protuberances and the mating surface of the reaction plate during relative rotational frictional engagement of the plates for developing and sustaining a film of separating liquid over the protuberances, said film producing a viscous drag upon the friction plate so as to cause a substantial amount of the energy of plate engagement to be absorbed in shear of the liquid film until just prior to complete engagement of the plates.

85 8. A friction coupling as claimed in any of claims 1—7 wherein the liquid is an oil.

90 9. A friction coupling for an energy-transmitting power train having a fluid tight housing; comprising

95 at least one friction plate journaled for rotation in said housing with the plate formed of a rigid core having secured thereto a layer of an elastomeric non-porous friction material providing at least one friction surface having a plurality of protuberances extended therefrom;

100 at least one reaction plate mounted within the housing in closely spaced substantially parallel relation to said reaction plate with the plates being rotatable relative to each other;

105 actuating means within the housing selectively to force said plates axially into frictional engagement; and

110 means for continuously supplying in use a cooling and hydrodynamic liquid between said plates wherein the liquid wedges between the protuberances on the friction plate and the mating surface of the reaction plate during relative rotation and axial movement of the plates toward each other so as to develop and sustain a film of separating fluid

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Example 2

Full Scale Clutch Test Results

Friction Material As in Example 1
Size O.D.—inches 12.25
Area/Face—inches 31
Faces/Clutch 8
Oil Temperature 210°F
Cycle Time 30 seconds
Reaction Surfaces—Ground and Deburred
Soft Steel

Shift 3R—1F 3R—3F
Input RPM 2,000—1,800 1,800 2,000

Coefficient of Friction

Maximum 0.110 0.110 0.116 0.112
Minimum 0.065 0.068 0.074 0.070
Wring-In 0.073 0.075 0.083 0.083

Clutch Torque lb-ft/in²

Max. Dynamic 11.2 11.7 13.3 12.6
Wring-In 12.6 13.0 14.9 14.9
Peak HP/in² 3.2 2.7 1.7 1.9
Total BTU/in² 0.65 0.51 0.58 0.73

Plate Temperature

Max. °F 494 443 360 390
Bulk °F 235 225 212 193

The above-described friction material is specifically intended for use in an oil-cooled disc-type friction coupling utilized in a power train such as a clutch or transmission brake as depicted in Fig. 8 above for relatively heavy earthmoving vehicles.

WHAT WE CLAIM IS:—

1. A friction coupling comprising a rotatable friction plate formed of a rigid core having secured thereto a layer of elastomeric non-porous friction material providing a friction surface, and a reaction plate providing a mating surface for relative rotational frictional engagement with said frictional surface, said friction material on said friction surface providing a plurality of protuberances adapted in use to cooperate with a layer of liquid between the friction surface and the mating surface whereby a substantial amount of energy of plate engagement is absorbed in shear of the liquid film during relative rotational engagement of the surfaces.

2. A friction coupling as claimed in claim 1 wherein the protuberances comprise a plurality of discrete particles of a ceramic or vitreous material intermixed with and dispersed throughout the friction material in non-bonded relationship therewith, said material being reboundably deflecting so as to permit at least partial recession of prominently extended protuberances into the material so as to assist maximum conformability of the friction surface with the mating surface.

3. A friction coupling as claimed in claim 1 or claim 2 wherein the friction material comprises a copolymer of hexafluoropropylene and vinylidene fluoride.

4. A friction coupling as claimed in claim 1 or claim 2 wherein the friction material comprises an elastomeric material selected from polyacrylate, silicone, fluorosilicone, chloroprene, acrylonitrile, urethane or mixtures thereof.

5. A friction coupling as claimed in any of claims 1—4 wherein the protuberances comprise glass fibres of from 0.0001 to 0.005 inches in diameter and having a length to diameter ratio of from 3 to 100.

6. A friction coupling as claimed in any of claims 1—5 wherein the protuberances are of a size effective to produce microscopic voids on their trailing sides with respect to plate rotation whereby in use to cause cavitation of the liquid in the trailing sides so as to provide increased viscous drag on the friction plate.

7. A friction coupling as claimed in any of claims 1—6 wherein a supply of liquid is provided between the plates which hydrodynamically wedges between the protuberances and the mating surface of the reaction plate during relative rotational frictional engagement of the plates for developing and sustaining a film of separating liquid over the protuberances, said film producing a viscous drag upon the friction plate so as to cause a substantial amount of the energy of plate engagement to be absorbed in shear of the liquid film until just prior to complete engagement of the plates.

8. A friction coupling as claimed in any of claims 1—7 wherein the liquid is an oil.

9. A friction coupling for an energy-transmitting power train having a fluid tight housing; comprising

at least one friction plate journaled for rotation in said housing with the plate formed of a rigid core having secured thereto a layer of an elastomeric non-porous friction material providing at least one friction surface having a plurality of protuberances extended therefrom;

at least one reaction plate mounted within the housing in closely spaced substantially parallel relation to said reaction plate with the plates being rotatable relative to each other;

actuating means within the housing selectively to force said plates axially into frictional engagement; and

means for continuously supplying in use a cooling and hydrodynamic liquid between said plates wherein the liquid wedges between the protuberances on the friction plate and the mating surface of the reaction plate during relative rotation and axial movement of the plates toward each other so as to develop and sustain a film of separating fluid



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5 over the protuberances that produces a viscous drag upon the friction plate thus causing a substantial amount of the energy of plate engagement to be absorbed in shear of said fluid film during the complete engagement cycle of the plates.

10. A friction coupling as claimed in claim 1 substantially as hereinbefore described.

11. A friction coupling as claimed in claim

1 substantially as hereinbefore described with reference to Figures 1—4 and 6—8 of the accompanying drawings. 10

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