

PATENT SPECIFICATION

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- (72) Inventors: ROGER ODELL BJERK
WILLIAM DONALDSON BRANDON
FREDERICK SCOTT ENGELKING
JOHN PARKER JERO

(52) FLUOROELASTOMER BASED COMPOSITE MATERIAL

(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 composite material. More specifically, this invention relates to composite friction materials which exhibit high, stable, coefficients of friction over a wide temperature range and is an improvement in or modification of the invention claimed in Application No 24529/74 (Serial No. 1465755).

The elastomeric materials heretofore proposed for use as Friction materials have generally proven to be unsatisfactory when exposed to high ambient working temperatures such as encountered, for example, in clutch and brake applications in heavy duty service vehicles. Typically, such materials have been based on heat-hardenable resins such as phenol-aldehyde resins which tend to heat-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 these vehicles while operating. As a result of this decomposition, the physical properties of these materials typically deteriorate, and the consequent softening of the material and dispersal of the products of heat decomposition generally interfere with the functioning of the friction unit. Furthermore, many times after friction material comprising a

partially heat-decomposed heat-hardenable resin has cooled, the material will exhibit a lower coefficient of friction than did the original material.

These changes in the properties of the friction material as well as other problems associated with these and similar friction materials, result in a loss of efficiency in the friction unit and unreliability in the service vehicle, which is highly undesirable.

Many attempts have been made to obviate the problems associated with the elastomers in general use as friction material basis. Many different resins have been experimented with, in attempts to obtain a friction material which possesses a high, stable coefficient of friction over a wide temperature range. Modification of the heat-hardenable resins with other polymeric materials has been attempted.

Many of these friction material formulations have not performed well. Other formulations have required multi-step procedures which are costly in terms of labour and frequently in terms of the material used in these formulations.

Importantly, also, many of these known friction materials require a bonding agent to affix them to the backing plate or "core" portion of the friction element. This requirement severely restricts the scope of the moulding methods and mould configurations employable in forming these friction elements. In injection moulding, for example, the bonding agent is subject to scuffing during the moulding process, which deactivates or destroys the bond and renders this moulding process useless with these friction elements. In general, where bonding agents must be utilised, only compression mould-

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ing and relatively simple mould configurations can be employed in the process of moulding the friction element.

In order to obtain 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 of oil used in conjunction with such friction materials during use to ensure that the desired coefficient of friction is not impaired.

We have now developed a composition which has both a high and stable coefficient of friction over a wide range of operating conditions. Our composition may both be bonded to a metal core material, or compression moulded, particularly in conjunction with complex mould configurations. Such a composition is described in our application No 24529/74 (Serial No. 1465755), and comprises calcium oxide and particles of a vitreous or ceramic material dispersed throughout a fluoroelastomer matrix.

Since the fluoroelastomer is a costly material, it is desirable to use as little of it as is possible without reducing the effectiveness of the friction material and we have now found that satisfactory friction compositions may be formed using smaller amounts of fluoroelastomer than those described in our above-mentioned application.

Accordingly, we provide a composition comprising from 20 to 29% by weight of a copolymer of hexafluoropropylene and vinylidene fluoride, a minor amount of calcium oxide, and from 20 to 60% by weight of vitreous or ceramic particles of from .0001" in diameter dispersed throughout, the balance of the composition comprising one or more additives as herein defined. The fluoroelastomer 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.

Maximum energy absorption rates of from about 3 to 5 HP/in² of fluoroelastomer

friction material are typical. In comparison with high modulus materials, such a low modulus material significantly increases the load-carrying capabilities of the friction element of which it is a part, and further, possesses superior wear characteristics when compounded with high modulus asperities as herein disclosed.

The high modulus asperities, generally glassy or related substances, are compounded with the fluoroelastomer calcium oxide, and additive in sufficient quantities to produce a relatively high concentration of these asperities on the frictional surface of the fluoroelastomer matrix. In addition to acting as the friction-producing agent in the friction material, these asperities further serve to strengthen the support matrix and lessen compression set or permanent deformation under applied loads.

The compounded friction material may then be applied to the core of the friction element, for example by the method disclosed in our British Patent Application No 53398/73 (Serial No. 1450103).

The fluoroelastomers useful in this invention are exemplified by Viton E60C (Viton is a registered Trade Mark) which is a copolymer of hexafluoropropylene and vinylidene fluoride available from E.I. du Pont de Nemours and Company, Wilmington, Delaware, and a similar copolymer Fluorel FC2170 (the 3M Company, Minneapolis, Minnesota). Preferably, Viton E60C or Fluorel FC2170 is employed to form the matrix of the friction material.

To form the composite material of the invention, the fluoroelastomer is compounded with the additive, calcium oxide and particles of a relatively hard material, herein referred to as "asperities". These asperities are vitreous or ceramic materials in the form of very small beads, fibres or other shaped particles of suitable diameter. The preferred material is glass fibres.

Although the useful size of these asperities may vary somewhat according to the nature of the material and other factors, glass fibre particles of from 0.0001" to 0.005" in diameter, and preferably about 0.0005" in diameter, will yield the desired results. Such particles advantageously have a length to diameter ratio of from 3:1 to 10,000:1. The glass fibres or other asperities may be compounded in the form of chips, fibres, spheres or other convenient shapes, although fibres are generally preferably.

From 20 to 60% by weight of vitreous, preferably fibreglass, or ceramic particles to 20 to 29% by weight of fluoroelastomer are admixed, together with a minor amount of calcium oxide and the additive to provide a randomly irregular macroscopic surface finish on the friction material.

An additive, which is preferably carbon

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black, will be incorporated into the compounded fluoroelastomer, conveniently at the same time as the asperities and calcium oxide are incorporated. By the term 'additive' is meant a material commonly used in conjunction with fluoroelastomer products. Examples of such materials include, inter alia, carbon black, accelerators, stabilisers and curing agents. It is greatly preferred that carbon black be present. This is preferably added in amounts such as to constitute from 12 to 40% by weight of the fluoroelastomer composition.

The asperities, calcium oxide and 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 of 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 distribution of the asperities through the matrix.

The fluoroelastomer material may be bonded to a core of steel or other metal by the process described in our Application No 53398/73 (Serial No. 1450103) noted above. This process comprises curing the fluoroelastomer at high temperatures in pressed contact with the core material. Conveniently, the amount of CaO will be from 3-15 parts per hundred parts of copolymer by weight and this elastomer copolymer at the same time as are the asperities and other additives noted above. About 5 parts by weight of calcium oxide per hundred parts of copolymer are preferred.

Conventional moulding techniques, such as compression transfer or injection moulding, are utilised for forming the fluoroelastomer friction material back 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 utilised in clutches.

The friction material of 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 finished. For example, dynamic friction coefficient (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 of this invention is capable of operating against mating surfaces of a variety of types, 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 20 to 65 μ will result in satisfactory performance of the friction material.

The fluoroelastomer friction material of this invention is further characterised by low wear and dimensional stability can be expected during extended dynamic operation. Furthermore, the material exhibits a relatively flat torque curve that "wrings in" about 10-25% above the dynamic torque.

The friction material of this invention will respond according to test results over a wide operating surface temperature range even up to about 680°F. In general, the material can be expected to maintain optimum response levels at bulk temperatures below about 475°F; i.e. where the average surface temperature of the friction material between operations of the friction element is below about 475°F to about 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 fluoroelastomer friction material than with, for example, bronze.

In preparing friction elements utilising the friction material of this invention, it will generally be found that, after demoulding, 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 elastomer coating to be worn off during an initial break-in period of the friction element in the service vehicle, or by pregrinding of the friction material before installation of the element. The amount of friction 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 grinding or mating surface.

During early use, these asperities are

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ground to a point where they appear to be well-worn, to obtain a stable coefficient of friction. The asperities appear to be mechanically bonded in the matrix.

5 An acceptable material having only about 20% by weight, (actually 20.5%) of the fluoroelastomer matrix with slightly increased amounts of glass fibre particles and carbon black has been formulated by analogy with the formulations of Application No 24529/74 (Serial No. 1465755).

10 The use of lower fluoroelastomer content together with somewhat increased glass fibre and/or additive content compared with the compositions of the aforesaid application, is desirable since the fluoroelastomer is generally the most expensive ingredient in the friction material.

20 WHAT WE CLAIM IS:-

1. A composition comprising from 20 to 29% by weight of a copolymer of hexafluoropropylene and vinylidene fluoride, a minor amount of calcium oxide, and from 20 to 60% by weight of vitreous or ceramic particles of from .0001" to .005" in diameter dispersed therethrough, the balance of the composition comprising one or more additives as hereinbefore defined.

2. A composition as claimed in claim 1 wherein said vitreous or ceramic particles are glass fibres.

3. A composition as claimed in claim 2 wherein said vitreous or ceramic particles have a length to diameter ratio of from 3:1 to 10,000:1.

4. A composition as claimed in any of claims 1-3 wherein carbon black as additive constitutes from 12 to 40% by weight of the composition.

5. A composition as claimed in any of claims 1-4 wherein the vitreous or ceramic particles have a diameter of 0.005 inches.

6. A composition as claimed in any of the preceding claims wherein the particles are in the form of chips, fibres or spheres.

7. A composition as claimed in any of the preceding claims wherein the calcium oxide is present in an amount of about five parts by weight per hundred parts of the copolymer.

8. A composition as claimed in claim 1 substantially as hereinbefore described.

9. A friction element for clutch plates which comprises a layer of friction material bonded to a backing plate, the friction

material comprising a composition as claimed in any of claims 1-8.

10. A friction element as claimed in claim 9 substantially as hereinbefore described. 70

For the Applicants:
FRANK B. DEHN & CO
Chartered Patent Agents
Imperial House
15-19 Kingsway
London WC2B 6UZ 75

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- 35 3. A composition as claimed in claim 2 wherein said vitreous or ceramic particles have a length to diameter ratio of from 3:1 to 10,000:1.

- 40 4. A composition as claimed in any of claims 1-3 wherein carbon black as additive constitutes from 12 to 40% by weight of the composition.

- 45 5. A composition as claimed in any of claims 1-4 wherein the vitreous or ceramic particles have a diameter of 0.005 inches.

- 50 6. A composition as claimed in any of the preceding claims wherein the particles are in the form of chips, fibres or spheres.

- 55 7. A composition as claimed in any of the preceding claims wherein the calcium oxide is present in an amount of about five parts by weight per hundred parts of the copolymer.

- 60 8. A composition as claimed in claim 1 substantially as hereinbefore described.

- 65 9. A friction element for clutch plates which comprises a layer of friction material bonded to a backing plate, the friction

material comprising a composition as claimed in any of claims 1-8.

10. A friction element as claimed in claim 9 substantially as hereinbefore described. 70

For the Applicants:
FRANK B. DEHN & CO
Chartered Patent Agents
Imperial House
15-19 Kingsway
London WC2B 6UZ 75

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