Oct. 3, 1961 C. J. FITCH 3,002,596

ELECTROSTATIC CLUTCH

Filed Dec. 19, 1957

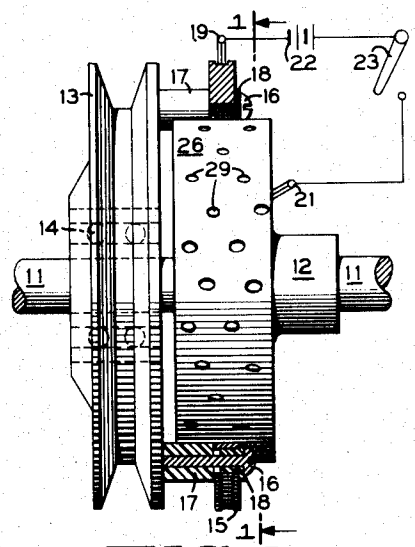


FIG_2

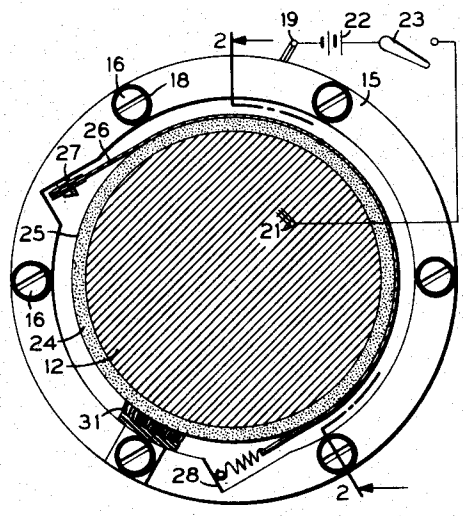


FIG_1

FIG_3

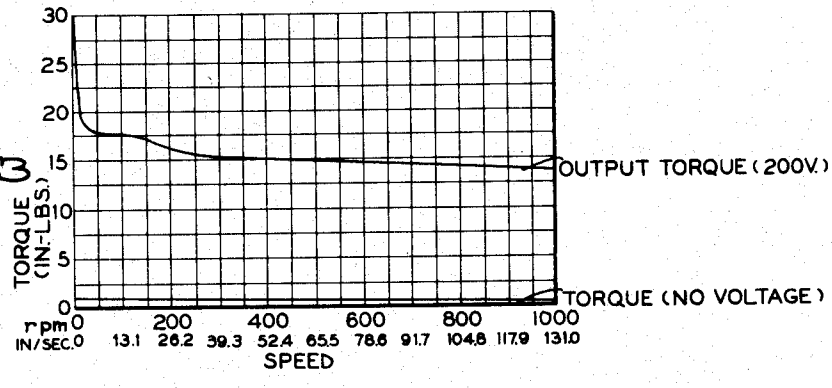
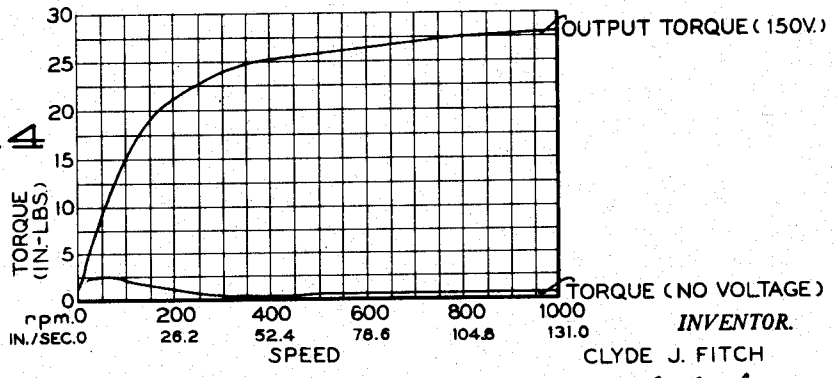


FIG_4



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United States Patent Office 3,002,596 Patented Oct. 3, 1961

3,002,596

ELECTROSTATIC CLUTCH

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Filed Dec. 19, 1957, Ser. No. 703,791
2 Claims. (Cl. 192—84)

This invention relates to electrostatic devices wherein the operation depends upon the electro-adhesive forces between a conductive member and a cooperating semi-conductive member. This application is a continuation-in-part of my application Serial No. 556,644 filed December 30, 1955, now abandoned.

More particularly, this invention is directed to electrostatic clutches wherein a driven member is clutched to a driving member by electro-adhesive forces.

The electro-adhesive effect between conductors and semi-conductors is well known in the art and there are hundreds of materials that will exhibit electro-adhesion under some conditions. In this art, a number of improvements and modifications have been made in efforts to obtain reliable devices. Early in these attempts to obtain a usable electrostatic or electro-adhesive device, an agate or similar stone cylinder was used as a clutch wheel. Moisture from an electrolyte within the porous cylinder rendered it what has been termed a "semi-conductor." As used hereinafter, a "semi-conductor" will be defined as a resistance material having a resistivity within the general range of 10^6 to 10^7 ohms per cubic centimeter. Among the defects in these early devices were the following: electrolysis (ionic conduction) and eventual erosion of the clutch surfaces, resulting from the use of an electrolyte; variations in resistance and torque caused by evaporation and nonuniform torque around the periphery because of the anistropic characteristics of natural stone. From this point, the use of alternating current was partially successful in avoiding electrochemical alterations in the device, and a synthetic stone, fabricated of materials such as powdered flint bonded together with conductive material such as water glass, was isotropic but remained hygroscopic. However, even with these improvements, only devices of erratic operation, particularly at high operating speeds, were possible. In further attempts to produce a reliable electro-adhesive device, semi-conductive materials of electronic conduction were fabricated from mixtures such as magnesium and titanium oxides. But these and all the prior attempts resulted in unstable electro-adhesive devices, particularly unreliable at high operating speeds.

In addition to the above defects, amplified wear of the clutching surfaces was caused by dust particles acting as an abrasive between the surfaces. These dust particles were produced by wear, due to surface friction, and erosion, due to making and breaking electrical current passing through the surface contact. This amplified wear resulted in alterations of the quality of the clutching surfaces, i.e., smoothness and shape, and produced unstable and unreliable operation. In attempts to prevent this amplified wear, brushes were used as wipers to remove the abrasive particles. However, the brushes became saturated with the abrasive dust particles and ceased to function.

Even though a primary advantage of an electro-adhesive clutch over other similar devices is rapid electrical response time (of the order of microseconds), this advantage has not, in practice, been available for most applications because of erratic operation and unreliability. In addition to rapid response time, an electro-adhesive clutch has many other potential advantages not found in similar devices. Low operating current (of the order of milliampere at 200 volts), non-inductive circuit operation, low manufacturing cost, and small size in relation to torque output are examples of these advantages.

The copending application, Serial No. 556,676 of the present inventor, filed December 30, 1955, now Patent No. 2,923,390, granted February 2, 1960, and assigned to the present assignee, discloses and claims an improved electro-adhesive clutch wherein reliability and stability are obtained with a novel semi-conductive material, comprised of conductive particles bound in an insulating binder, and a scavenger agent, such as tetrafluorethylene resin, acting as a lubricant and to maintain the sliding clutching surfaces free from abrasive particles of wear.

The present invention is directed to an electro-adhesive clutch comprised of a semi-conductive member and a conductive member, with a lubricating dielectric disposed therebetween.

A primary object of this invention is to provide an improved electro-adhesive clutch.

Another object is to provide an electro-adhesive clutch with extremely high wear resistance.

Still another object is to provide an electro-adhesive clutch with the clutching characteristics of a "fluid drive."

Another object is to provide a stable electro-adhesive clutch with improved torque output.

A further object is to provide a reliable electro-adhesive clutch of improved power rating.

Another object is to provide an improved and simplified electro-adhesive device.

Another object is to provide an electro-adhesive device of improved current requirements.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of examples, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

FIG. 1 is a transverse vertical sectional view, partly diagrammatic, of an electro-adhesive clutch constructed in accordance with the present invention and taken along the line 1—1 of FIG. 2.

FIG. 2 is a partial sectional view taken along line 2—2 of FIG. 1.

FIGS. 3 and 4 are torque-versus-speed charts, on the same scale, for two types of electro-adhesive clutches.

Referring to the drawings, a shaft 11 has a conductive hub 12, preferably of brass, secured thereto and has a pulley 13 mounted, by a bearing 14, to rotate freely thereon. The pulley 13 has a metal ring 15 secured thereto by bolts 16, insulating sleeves 17 and insulating plugs 18. Thus the ring 15 may be electrically isolated from the hub 12. The ring 15 has a contact brush 19 riding thereon and the hub 12 has a contact brush 21 riding thereon. The brush 19 is connected to the negative terminal of a source of potential shown as a battery 22, and the brush 21 is connected through a switch 23 to the positive terminal of the source. A semi-conductive material 24, which may be of conductive particles bound in an insulating binder, as described in the above-mentioned copending application, is bonded to the hub 12 and forms a surface 25. A conductive band 26, preferably of stainless steel, has perforations 29 therein and is secured at one end to the ring 15 by a member 27, so as to make electrical contact with the ring 15. The other end of the band 26 is connected to the ring 15 through a spring 28 so that the spring 28 urges the band 26 toward the surface 25. The surface 25 has deposited thereon a thin film of a dielectric lubricant, such as a silicone oil, which may, with operation over a period of time, be squeezed off the surface 25. A mohair wiper 31, or the like, containing a small quantity of the dielectric, may serve to replenish the film on the surface 25.

In operation, either the shaft **11** or the pulley **13** may be externally driven as desired by a motor, or the like, not shown. With the switch **23** open, the surface **25** and the band **26** move relative to one another. When the switch **23** is closed, the potential of the battery **22** is applied between the band **26** and the material **24**, and the resulting electro-adhesive force between the surface **25** and the band **26** will clutch the pulley **13** to the shaft **11**. It should be pointed out that the clutch operates at either polarity; however, it is preferable that the conductive band be the negative electrode and the semi-conductive material be the positive electrode. The clutch also operates satisfactorily with an alternating current source. Thus, if the shaft **11** is externally driven, the hub **12**, with the material **24** bonded thereon, acts as the driving member of the clutch, and the band **26** acts as the driven member. If the pulley **13** is externally driven, the opposite functions prevail as to driving and driven members.

According to the present invention, a dielectric lubricant is provided between the sliding surfaces of an electro-adhesive device. A member of the family of silicone oils is a preferred dielectric. At higher temperatures, melted methyl methacrylate is another suitable dielectric. It is believed that the necessary property of a suitable dielectric is that the residue of the dielectric formed upon breakdown form no highly conductive path between the sliding surfaces. That is, the residue must be a dielectric, e.g., it must have a relatively high resistance, or the residue must escape in the form of a gas, for example, if it is a conductor. Fluorocarbon oils are another dielectric exhibiting the property of having a dielectric breakdown residue. Another desirable characteristic of the dielectric is that the dielectric provide a relatively constant shear force or friction with changes in temperature. To apply a film to an electro-adhesive device, such as the clutch of FIGS. 1 and 2, the wheel comprised of the hub **12** and the material **24** may be rotated slowly and the dielectric generously applied to the surface **25**. The surface **25** is then wiped off with a clean tissue. This film may be maintained by the wiper **31** which is first soaked in the dielectric and then squeezed out. Very little lubricant is required, and an excess is undesirable. After operating a clutch, so constructed, under load for many hours, a clean white wiper shows no discoloration, indicating little or no wear of the clutch members.

By referring to FIGS. 3 and 4, it may be seen that a clutch constructed according to the present invention has characteristics unlike the characteristics of any other electro-adhesive device. FIG. 3 shows a typical torque-versus-speed curve for a clutch constructed according to the teachings of the above-mentioned copending application. FIG. 4 shows a typical torque-versus-speed curve for a clutch constructed in accordance with the present invention. With the clutch of the present invention, as the speed approaches zero the torque also approaches zero, giving the clutch a "fluid drive" characteristic that is highly desirable in many applications. Also, a higher torque output with less applied voltage is available. In theory, the higher torque might be explained by a high dielectric film replacing an air film, but, by this reasoning, it is difficult to explain the vanishing torque at zero speed. With a clutch constructed according to the present invention, another advantage is that the torque output is more uniform and stable than with dry electro-adhesive clutches of comparable torque output.

Referring to the torque-versus-speed curve at zero voltage of FIG. 4, a peak is seen near 50 r.p.m. With fewer perforations **29** than are shown in the band **26** of FIGS. 1 and 2, or with no perforations, this peak will appear at a higher r.p.m. speed. With more perforations, the peak will move toward zero r.p.m. or disappear entirely. This can possibly be explained by the fact that the dielectric may require exposure to air through the band **26** to rapidly break the viscous bond of adhesion. The perforations thus facilitate this action.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. An electro-adhesive clutch comprising, in combination, a conductive member comprising a band having perforations therethrough and having a first surface, a semi-conductive member comprised of conductive material bound in an insulating binder and having a second surface disposed to face said first surface, means for moving said members relatively to each other along their facing surfaces, a dielectric lubricant having a high resistance breakdown residue disposed between said surfaces, and means for applying an electrical potential difference between said surfaces to thereby clutch said members together.

2. An electro-adhesive clutch comprising, in combination, a first member comprising a band having perforations therethrough and having a first surface, a second member having a second surface disposed to face said first surface, one of said members being of conductive material and the other member being of semi-conductive material, means for moving said members relatively to each other along their facing surfaces, a dielectric lubricant having a high resistance breakdown residue disposed between said surfaces, and means for applying an electrical potential difference between said surfaces to thereby clutch said members together.

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