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PATENT SPECIFICATION

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(54) ROTARY FLUID MOTOR

(71) We, DYNAMIT NOBEL AKTIENGESELLSCHAFT, a German Company, of 521 Troisdorf, Near Cologne, Germany, 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:-

The invention relates to a rotary fluid motor for use in particular, but not exclusively, in the tensioning of vehicle safety belts in crash situations.

A safety belt for the protection of occupants of a vehicle, for example, an aircraft or motor vehicle, is described in German Offenlegungsschrift No. 2,121,101. The belt comprises a tensioning means which, in the event of a sudden acceleration or deceleration characteristic of an accident is actuated by means of a sensor to pull in the belt or roll it up until it is fitting sufficiently tightly against the body of the passenger. Such a sensor is, for example, described in German Offenlegungsschrift No. 2,207,831. The tensioning means of German Offenlegungsschrift No. 2,121,101 is constructed as a rotary fluid motor and comprises a housing with a device for supplying a gas under pressure, hereinafter termed a pressure gas device, arranged therein and a shaft which is connected to that end of the belt which is to be drawn in. A turbine wheel operated by gas pressure produced by the gas generator serves preferably as driving element for the shaft.

For example, the pressure gas device for operating the driving element may be a compressed air bottle which is under a suitably high internal pressure. However, a more compact arrangement is obtained if the pressure gas device is a propellent charge or a pyrotechnic composition which can be ignited electrically or mechanically by impact and only produces the required gases under pressure at the time of their reaction. For example, there can be be used a propellent charge having a composition of the type described in German Patent Specification No. 1,646,313.

A particular advantage of the use of a rotary fluid motor in a safety belt tensioning means, in contrast to a linear tensioning means, for exmple of the type described in German Offenlegungsschrift No. 2,253,657, is that the number of rotational movements carried out by the driving element is not, in principle, limited so that when greater than usual tightening is required, involving longer travel of the safety belt, this is possible. However, when the pressurised gas acts on the driving element, it is often found that the torque transmitted from the driving element to the shaft is unsatisfactory in view of the low density of the pressurised gas.

According to the present invention, there is provided a rotary fluid motor which comprises a rotatable driving element, a pressure gas device as hereinbefore defined and a tube having liquid contents therein and communicating at one end with the pressure gas device and being closed at its other end by means which keep said other end closed until subject to a prescribed liquid pressure, which other end is so juxtaposed in relation to the rotatable driving element that liquid issuing, in use, from said other end when said prescribed liquid pressure exists in the tube acts on the rotatable driving element to effect driving thereof.

The liquid-containing tube will generally be closed at its outlet end, for example, with a spring-loaded ball valve, and be connected for example, by means of a screwthread, to the pressure gas device which is preferably a propellent charge cartridge arranged in a cartridge chamber. The cost of manufacture which is relatively high when, for example, a piston cylinder with an outlet has to be machined from solid material, is avoided, since it is, possible to use normal commercially available pressure tubes made of steel. The liquid-containing tube can be of very small cross-sectional dimensions so that it may be fitted into a very confined space, provided that the space for housing the tube has the necessary length to enable installation of the tube to be effected, the tube having a length sufficient to accommodate a prescribed quantity of liquid for achieving driving of the driving element for a prescribed length of time at a prescribed rotational speed.

The liquid employed in the tube is preferably water to which an anti-freeze agent and/or an anti-corrosion agent may be added. However, it is also possible to use other non-gaseous flowable substances which can be displaced from the tube under the action of pressurised gas and which possess a high density in relation to the gas supplied by the pressurised gas device. For example, it is possible to use oil-like liquids, emulsions and even suspensions. It may even be possible in certain circumstances to use a liquid which vaporises because of a fall in pressure at the time of or after its ejection from the tube. In this case, in particular, although generally desirable with other liquids, the driving element can be arranged in a housing with encloses the tube, that is to say, it is completely encapsulated. The driving element itself can then, for example, take the form of a rotary piston having a shaft which is to be rotated, which is provided with a single radial bar, wing or blade acted on by the liquid. Nevertheless, a rotary piston only executes less than one revolution, so that the tightening path of for example a safety belt is correspondingly small, without using an additional transmission, for example, a gearing transmission. Consequently, it is preferred to use instead a driving element which is able to carry out a plurality of revolutions, depending on the duration of liquid jet flow. For example a driving element which travels along a helical channel as described in our copending patent application No. 18577/75 (Serial No. 1500819) may be used. Turbine wheels, for example, Pelton wheels, without an additional external housing, are however, preferably employed as driving elements.

In order to reduce demands on space imposed by the rotary fluid motor, it is preferred that the liquid-containing tube be given a curvature over at least a part of its length. Such curvature is particularly desirable, at or near the outlet of the tube, in order to obtain an incidence angle of the jet on the driving element which enables utilisation of the kinetic energy of the liquid to be as complete as possible. A liquid-containing tube differs characteristically from the aforementioned cylinder with a piston and curved outlet in that the internal wall wetted by the liquid is curved, and the outer tube surface has a different radius of curvature as a result of the actual thickness of the tube wall. It is thus possible, by suitably curving the tube, to achieve a best possible guiding of the liquid and efficient adaptation to external space conditions.

In fact the tube is preferably of coiled form. For example, the tube may be wound in a helical or in a frustoconical form with the two end regions of the tube generally remaining uncoiled. A helical winding with a straight coiling axis is generally preferred, the adjacent turns preferably bearing one against the other. With a coiled tube it is possible, in principle, for the winding axis of the tube in its turn to be given a curvature in two or three dimensions.

It may happen that the dynamic impact stress on a coiled tube caused by the liquid therein being accelerated to an extremely high extent at the initiation of operation of the rotary fluid motor will cause undesirable alteration in the shape of the curved zone of the tube to take place, the tube generally being returned to a straight formation. Hence the tube is preferably locked in or onto a support therefor in the endangered region thereof. With a coiled tube, the different turns can for example be screwed to one another. However, it is generally sufficient for the adjacent turns to be connected to one another by adhesive bonding, soldering or welding, in which case usually a few punctiform points of connection distributed over the circumference of tube is sufficient. In addition or as an alternative to such arrangement and particularly suitable for a cylindrical coiled tube, the coiled tube may be enclosed by an outer supporting sleeve. In this case, the relatively thin-walled supporting sleeve of a material of suitable strength, preferably steel, bears from the outset against the individual turns, so that in practice any radial enlargement of the turns of the coiled tube is prevented.

The cost of the rotary fluid motor can be significantly reduced if the piston usually provided for the sudden displacement of a liquid from a cylinder by means of gas pressure, is absent, and provision is made for the gas to be operative directly on the liquid to expel the liquid from the tube as a substantially homogeneous column. A preliminary condition for this purpose is that having regard to the properties of the liquid and the gas pressure, the internal cross-section of the tube is not so large that a through gas duct can be formed in the column of liquid which is in the tube, through which duct a substantial part of the pressure gas would in practice escape without being utilised. Generally, the cross-sectional dimensions which are critical in a particular case and which separate the homogeneous liquid flow from the non-homogeneous liquid-gas flow have to be established by experimentation.

Although the outlet end of the tube can be closed by means of a spring loaded ball valve, the fluid motor can be kept in a satisfactory state of readiness for operation over relatively long time periods, for example 10 years, in an inexpensive manner if the outlet end is closed by a pressure rupturable element which is preferably formed of metal. For example, the outlet end can be closed by a thin metal disc, which is held by means of a screw cap on the tube. However, the rupturable disc is preferably adhesively bonded, soldered or welded to the tube at the circumference of its outlet opening. If requied, the rupturable disc may also be formed with weakened zones. As an alternative to using a metal disc, the disc may be formed of synthetic plastics or glass.

Another pressure rupturable element may also be arranged on the other end of the tube. This element is likewise preferably formed as a thin metal disc and is clamped between the pressure gas device (the cartridge chamber when a propellent charge cartridge is provided) and the other end of the tube which is usually screwed into the pressure gas device. Such an arrangement ensures that a sealing action with respect to possible discharge of liquid is improved, and that the reaction of a propellent charge powder, a pyrotechnic composition disposed in a propellent charge cartridge, is assisted in that after actuation of the pressure gas device, the additional rupturable element prevents small particles which may be projected from the pressure gas device and which are in fact ignited but are still not completely burnt out from being projected into the liquid and extinguished thereby so that they are no longer able to contribute to the supply pressurised gas. After a predetermined gas pressure is reached, this rupturable element is also destroyed, so that the pressurised gas can act directly on the liquid. This action can be further improved if the additional rupturable element is formed as a cup-like closure element which preferably fits into the tube with its open end facing the pressure gas device. The cup-shaped closure element which preferably fits into the tube is inserted into the pressure gas device and is pressed radially against the surrounding wall surface by the pressure gas as it penetrates into the tube. As a result of this packing effect, the initial sealing of the tube in relation to the pressure gas is additionally improved and the satisfactory reaction of a propellent charge powder or pyrotechnic composition is assisted.

Finally, the tube itself is preferably of circular cross-section, but it could be, for example, of oval or rectangular cross-section. Moreover, the tube is preferably formed with an internal cross-section which is constant throughout its length, so that in particular, it does not undergo any constriction at the outlet end.

For a better understanding of the invention and to show how the same can be carried into effect, reference will now be made, by way of example only, to the accompanying drawing, wherein:

Figure 1 shows, in elevation and partly in section, a form of rotary fluid motor according to this invention for use in an automatic belt-tightening arrangement;

Figure 2 is a an elevation of the fluid motor of Figure 1 along the arrow A in Figure 1; and

Figure 3 shows a modified portion of the fluid motor of Figures 1 and 2.

Referring to Figures 1 and 2, a rotary fluid motor 1 has a safety belt 2 wound around and extending from a shaft 3 extending laterally from a rotatable driving element 4 thereof to which it is connected fast, the shaft 3 having end portions 3*a*. The driving element 4, is contructed as a turbine wheel, e.g. a Pelton wheel, which, because of its rigid connection to the shaft 3, responds to every motion of the belt during normal use thereof. A tube 5, which is for example made of steel and which has a very small internal circular cross-section in relation to its length, is wound as a cylindrical coiled tube 6, the turns of which are in mutual contact. The winding or coiling axis 7 of the coiled tube 6 is here arranged parallel to the shaft 3. The tube 5 terminates in an outlet 8 above the driving element 4 and at a small distance from the latter. The outlet 8 is closed off by means of a pressure destructable thin metal plate 9 which is welded on to the periphery of the outlet 8. The other end 10 of the tube 5 is screwed fast by means of a thread 11 into a pressure-tight cartridge chamber 12, into which a pressurised gas generator 13, which in this case is a propellent charge cartridge, is inserted from the other end. The propellent charge cartridge 13 is held by means of a threaded union 14 in the cartridge chamber 12 and is capable of being initiated electrically through two firing lines 15.

A liquid 16, preferably water containing an antifreeze agent, is housed in the tube 5. At its end 10, the tube 5 is closed off by means ofa rupturable metallic disc 17. No piston is arranged in a free space 18 which exists between the pressurised gas generator 13 and the liquid 16. The disc 17 is destroyed before the bursting element 9 at the outlet end 8 of the tube 5 has been destroyed, so that it does not act as a piston and therefore the pressurised gas is directly operative on the liquid 16. In order to avoid any tendency for the coiled tube 6 to undergo untwisting under the dynamic pressure stress, the coiled tube is enclosed by an outer supporting sleeve 19, formed, for example, of steel. The turns of the coiled tube 6 bear directly on the internal wall of the supporting sleeve 19. The two end sections of the tube 5, which are substantially straight, are situated externally of the supporting sleeve 19. A screw 20 serves to fix the belt tensioning arrangement in a motor vehicle.

The side elevation in Figure 2 clearly shows the inclined arrangement of the outlet 8 of the tube 5 with respect to the driving element 4, which is formed as a turbine wheel having blades 21. The driving means of the rotary fluid motor is fixed directly to the automatic belt as a result of the welding of the supporting sleeve 19 to the two side portions $3a$ of the automatic belt arrangement 1, for example, along the rim 22. Although not shown, it is also possible for the coiled tube 6 to be additionally welded to the sleeve 19.

Referring next to Figure 3, here the cartridge chamber 12 again has the tube 5 screwed thereinto. The rupturable closure element is consituted by a cup-shaped member 23 fitted into the outlet 10 of the tube 5 and in such a way that it points with its open end 24 towards the propellent charge cartridge 13.

The rotary fluid motor of this invention operates as follows.

Actuation of the motor in a crash situation is effected by a sensor which is fitted in the motor vehicle having the belt tensioning arrangement which causes ignition of the propellent charge cartridge 13 to be effected electrically. The pressurised gas produced by the cartridge 13 is admitted to the liquid 16 after destruction of the rupturable disc 17 or the cup 23. The liquid pressure set up is then responsible for the destruction of the rupturable element 9 and allows free passage of the liquid 16 out of the tube 6. The jet or stream of liquid produced acts on the turbine blades 21 to set the driving element 4 in rotation. As a result, the shaft 3 is rotated and the looseness of the belt is eliminated as the belt is subjected to a retightening force of 2000 to 3000N. With such an arrangement, it is possible to achieve retightening of the belt around the passenger of a motor vehicle under crash conditions before the person to be protected undergoes forward motion.

Tubes having an internal diameter of from 8 to 20 mm and a length of from 200 to 400 mm have proved satisfactory for use in safety belt tensioning arrangements. The wall thickness of such tubes when produced from steel normally used for pressurised tubes, was in the range of from 0.5 to 2 mm.

A rotary fluid motor in accordance with the invention, can be used in conjunction with safety belts in, for example, motor vehicles and aircraft. However, the rotary motor need not only be used with safety belts, safety nets and similar safety devices to be tensioned in an accident situation and in transport means. The rotary motor can be used in any kinematic operation, in which a rotational movement is to occur on supply of a signal thereto. For example, the rotary motor may be used in the winding of ropes, the tensioning of helical springs and the starting of piston engines as well as other translatory movement operations which are initiated through a rotational movement with interposition of a rack to achieve translation of the original motion to the required form of motion.

WHAT WE CLAIM IS:-

1. A rotary fluid motor which comprises a rotatable driving element, a pressure gas device as hereinbefore defined and a tube having liquid contents therein and communicating at one end with the pressure gas device and being closed at its other end by means which keep said other end closed until subject to a prescribed liquid pressure, which other end is so juxtaposed in relation to the rotatable driving element that liquid issuing, in use, from said other end when said prescribed liquid pressure exists in the tube acts on the rotatable driving element to effect driving thereof.

2. A rotary fluid motor as claimed in claim 1 wherein the tube contains water.

3. A rotary fluid motor as claimed in claim 1 or 2, wherein the tube is curved along at least part of its length.

4. A rotary fluid motor as claimed in claim 3, wherein the tube is of helical coiled form.

5. A rotary fluid motor as claimed in claim 4, wherein end regions of the coiled tube are straight.

6. A rotary fluid motor as claimed in claim 4 or 5, wherein the adjacent turns of the tube contact each other.

7. A rotary fluid motor as claimed in any one of claims 3 to 6, wherein the curved tube is constrained against opening out of the curvature thereof.

8. A rotary fluid motor as claimed in claim 7 when appended to claim 4, 5 or 6, wherein the adjacent turns of the coiled

tube are united with each other by adhesive bonding, soldering or welding.

9. A rotary fluid motor as claimed in claim 7 when appended to claim 4, 5 or 6, or in claim 8, wherein the coiled tube is enclosed by an outer supporting sleeve.

10. A rotary fluid motor as claimed in any one of the preceding claims, wherein the tube is formed of steel.

11. A rotary fluid motor as claimed in any one of the preceding claims, wherein the tube is of uniform internal cross-section along its length.

12. A rotary fluid motor as claimed in any one of the preceding claims, wherein the tube and pressure gas device are so constructed and juxtaposed that the pressure gas produced, in use, acts directly on the liquid in the tube.

13. A rotary fluid motor as claimed in any one of the preceding claims, wherein said other end of the tube is closed by a rupturable element.

14. A rotary fluid motor as claimed in claim 13, wherein the rupturable element is a thin metal disc.

15. A rotary fluid motor as claimed in claim 14, wherein the metal disc is welded to periphery of the end of the tube.

16. A rotary fluid motor as claimed in any one of the preceding claims, wherein a pressure rupturable element is disposed between the pressure gas device and said one end of the tube.

17. A rotary fluid motor as claimed in claim 16, wherein the pressure rupturable element is formed of metal.

18. A rotary fluid motor as claimed in claim 16 or 17, wherein the pressure rupturable element is of cupshape, being fitted into said end of said tube with its open end facing the pressure gas device.

19. A rotary fluid motor as claimed in any of the preceding claims, wherein the rotatable driving element has the form of a turbine wheel.

20. A rotary fluid motor as claimed in any one of the preceding claims, wherein the pressure gas device is constituted by a propellent charge cartridge housed in a cartridge chamber.

21. A rotary fluid motor substantially as hereinbefore described with reference to and as shown in Figures 1 and 2, optionally as modified by Figure 3, of the accompanying drawing.

22. A passenger vehicle safety device which comprises means releasable when a vehicle fitted with the same is subject to a predetermined acceleration or deceleration, which means comprises a rotary fluid motor as claimed in any one of the preceding claims.

23. A passenger vehicle safety device as claimed in claim 22, wherein said releasable means carries a safety belt wound around a surface rotated, in use, by the action of said liquid on the rotatable driving element.

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1587460 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

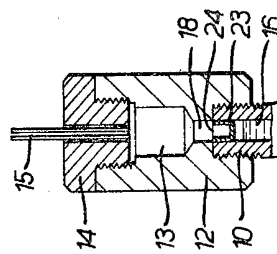

FIG. 3.

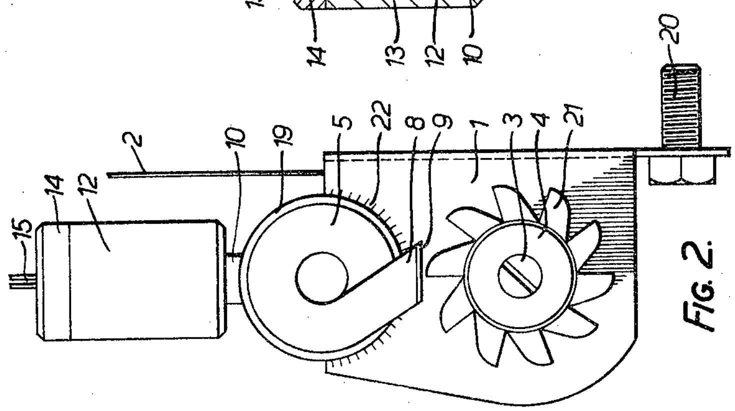

FIG. 2.

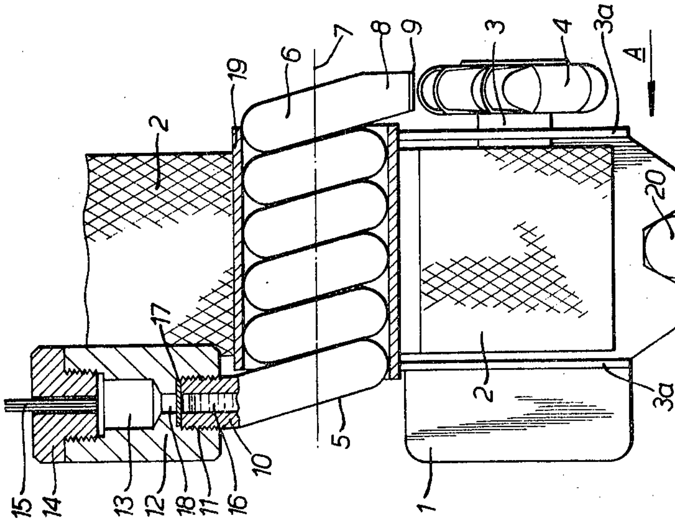

FIG. 1.