

[54] **HYDRAULIC FLEXION CONTROL DEVICE**

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[58] Field of Search **128/80 C, 80 R, 80 Q, 80 F; 3/1.2, 22, 29, 34**

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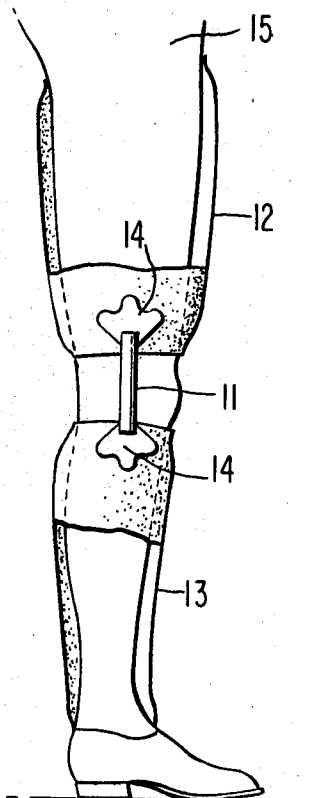
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[57] **ABSTRACT**

A hydraulic knee flexion control device which when unlocked is completely flexible and free to align with the knee joint axis. It is comprised of a rectangular cross-section spring wound tight with a flexible cable positioned in the center of the spring. A hydraulic system holds the cable immovable when the joint is to remain rigid and lets the cable extend thus permitting the spring to bend when flexion is desired.

9 Claims, 4 Drawing Figures



HYDRAULIC FLEXION CONTROL DEVICE

The present invention relates to novel means for controlling the flexion of a brace joint of particular value for use at the knee joint of a leg brace.

In the field of orthotics, the problem of fitting a fixed axis mechanical device to the human knee is a serious one. The human knee is a polycentric joint, that is, there is a different axis of rotation for every increment of flexion. Therefore, when an attempt is made to utilize a single axis joint, i.e., one with only one center of rotation, adjacent to the knee in an orthotic device, undesirable motion will exist between the brace and the limb. This is particularly true if inflatable structures are used as the thigh and skin braces.

A recent development in the field orthotic bracing has been the use of pneumatic structures. These structures are lightweight, strong, comfortable and inexpensive braces that can be readily adjustable by increasing or decreasing the amount of air pressure contained in the inflatable structure. Furthermore, the structure can be easily tailored to the contours of the individual patient and can be readily changed to meet the needs of the body segments for bracing as they change as a result of treatment, growth or both.

It has been found that an airmat type of structure formed into a double-walled cylinder with a simple closure to permit application to the patient has adequate mechanical strength to provide the necessary support to the limb in all applications including those of weight bearing. The only problem involved is how to handle the flexion of the knee.

The brace structures known in the prior art are of the single-axis joint type. However, due to the fact that the human knee has a polycentric axis, when a single axis brace is used there will be some linear displacement of the brace segments along the body. Since there is greater contact with the body when using an inflatable brace, this problem is somewhat more critical and could produce considerable discomfort to the patient. Actual motion of the skin with respect to the skeletal structure would be required in order to provide this movement.

The device of the present invention has no fixed axis of its own. It is flexible under one condition and sufficiently rigid under another condition to withstand the forces required across the knee. It can adapt to any knee axis without deforming the brace structure in any way. It has a relatively small diameter and due to the fact that it extends only between the thigh and calf section of the brace it is relatively good from the cosmetic standpoint. The combination of the present device with inflatable structures provide a feasible application of the inflatable structure system to long leg bracing. The device may also be used to advantage in combination with conventional leg braces.

In its preferred embodiment, the present invention consists of a rectangular cross-section spring, wound solid. A flexible cable passes through the spring and is centered therewithin by means of nylon or polyethylene spacers. The cable is attached to one brace bar at one end and at the other end is attached to a hydraulic assembly consisting of a piston and cylinder, a check valve, a control valve, and a small accumulator with pressurization springs. The theory of operation is that in order for the spring to bend with the cable suspended at its center, the length of the cable must be made

longer. If the cable were retained mechanically so that it could not become longer it would be impossible to bend the spring. The retention of the length of the cable is the function of the small closed circuit hydraulic system.

Accordingly, it is an object of the present invention to provide a polycentric knee joint for use with leg braces.

It is another object to overcome the defects of the prior art, as indicated above.

It is another object of the present invention to provide a flexion control device which is flexible under one condition and rigid under another.

It is another object to provide for improved support of joints.

It is a further object to provide a joint device for use with pneumatic braces.

It is still another object of the present invention to provide an automatic control for the flexion control device so that when weight is applied the device will remain rigid and when weight is removed the device will become flexible.

These and other objects will become evident from the following detailed description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an elevational side view of a leg having a pneumatic brace and the flexion control unit of the present invention.

FIG. 2 is a front view of the leg of FIG. 1.

FIG. 3 is a cross-sectional view of the flexion control device of the present invention.

FIG. 4 is an elevational view of an automatic control device which may be used with the device of FIG. 3.

Referring to FIGS. 1 and 2 it is seen that one or a pair of flexion control units 11 connect the upper leg brace 12 with the lower brace 13. The leg of the patient is shown at 15. In these drawings, the braces 12 and 13 are shown to be of the inflatable pneumatic type. The flexion device 11 is joined to the braces 12 and 13 by a metal gusset 14 or the like.

A view of the unit 11 in more detail is seen in FIG. 3. A coil spring 28 is wound closed using a rectangular cross-section spring wire. A flexible, but inelastic, cable 30 passes through the center of spring 28 and is held centered by a series of spacers 29. These spacers 29 may be of any suitable material, such as Teflon, nylon or polyethylene heads. As there is little or no relative motion between spacers 29 and cable 30, no internal wear of the heads is anticipated; only a very small amount of wear will occur on the outside between spacers 29 and spring 28.

The cable 30 terminates at one end in an adjustable end fitting 34. This fitting 34 is in turn connected to the lower brace bar 35 which is attached to a lower leg brace, such as the brace 13 via the gusset 14.

The other end of cable 30 is connected to a main piston 25 which may be provided with suitable gaskets. A closure 27 cooperates with the piston 25 to define the main hydraulic cylinder 37. A return spring 26 within the cylinder 37 maintains a light tension on the flexible cable 28 by urging the piston 25 away from the closure 27.

The main cylinder 37 is connected via a fluid passage 31 to an accumulator assembly 21. This assembly 21 includes a piston 23, seal 24 and spring 22. The accumulator 21 is connected to the upper brace bar 36 which in turn is attached to the upper leg brace. The

accumulator assembly 21 provides storage under pressure of the hydraulic fluid in the system. Spring 22, which constantly urges the piston 23 in the direction of the seal 24, allows the volume of fluid stored to vary during actuation of main piston 25. A one way check valve 32 permits fluid to pass from the accumulator 21 to the main cylinder 37 but not return. A control valve 33 in the fluid passage 31 determines whether the unit is flexible or rigid by controlling return of fluid from the main cylinder 37 to the accumulator 21.

The theory of operation is based on the fact that in order for the spring to bend as assembled, the relative length of the cable through its center must become longer. Thus, as the device is bent, the coil spring 28 separates and the cable 30 extends so that the main piston 25 is pulled into its cylinder 37. Thus, with the control valve 33 open, fluid is free to pass through the fluid passage 31 into storage in the accumulator 21, in effect permitting cable 30 to lengthen and allowing spring 28 to bend; the unit becomes flexible when the control valve 33 is open. With the control valve 33 closed, fluid cannot pass from the cylinder 37 to the accumulator 21 either through the check valve 32 or the control valve 33. Therefore, the main piston 25 is locked with respect to movement in the direction required for the unit to bend and the unit is rigid.

If the control valve 33 is closed with the unit bent, it cannot be bent any further but can straighten since fluid can bypass the control valve 33 through the check valve 32 in this direction. The force of the two springs 22 and 26 tend to cause the unit to straighten. Once the unit is fully straightened it cannot bend in any direction as long as the control valve 33 is closed.

When the patient is walking it is most desirable for the knee to be free to bend during the swing portion of his gait and for the joint to be rigid when he needs it for weight bearing. With the control unit shown in FIG. 4, this can be accomplished automatically. As an alternative, suitable electrical controls may be provided.

A suitable automatic control unit may be located between the accumulator assembly 21 and the upper brace bar 36, if desired. A body 39 of the automatic control unit houses the lower end of the upper brace bar 36. Springs 38 urge the upper brace bar 36 away from the floor of the body 39. A suitable connection device 40 connects the upper brace bar 36 with the control valve 33. A slot 41 in the body 39 and a knob 43 on the brace bar 36 cooperate to limit the possible travel of the brace bar 36 with respect to the control unit body 39. In operation, downward pressure on the upper brace bar 36 will cause it to deflect against springs 38. Deflection of the bar 36 with respect to the body 39 of the control unit will cause connector 40 to actuate control valve 33. In this way when weight is applied to the brace, control valve 33 will be closed resulting in locking of the device. When weight is removed from the brace, the upper brace bar 36 will be returned by springs 38 and the control valve 33 will be open causing the device again to be flexible.

With automatic operation, the patient is able to flex his knee in a normal manner during the swing through phase of walking but have the knee locked as soon as weight is born on the braced limb. A manual override is necessary to allow the patient to sit down. On rising from the seated position, the patient would return the lock to the automatic position. The units would then

extend freely but would not bend further until fully extended. This action assists the patient in rising.

The units are preferably used in pairs, as seen in FIG. 2, one on each side of the limb to be braced at knee or ankle, depending on where support is needed. It is also possible to adapt this unit for use at the hip joint for totally involved patients.

It is often desirable to provide a resistance to flexion of the knee in an orthotic device when the knee is free to flex during the swing phase of gait. An adjustable needle valve 42 (FIG. 3) in the fluid passage 31 will restrict the flow of hydraulic fluid and consequently dampen or act as a brake to flexion of the knee. The adjustable needle valve 42 will permit the brace to provide the exact amount of resistance to flexion required.

A simple automatic control device has been described but it should be understood that other mechanisms could also be used with the present device. Devices sensing the application of the patient's weight in the shoe, strain gauges in the vertical support members of the brace, or myoelectrically sensing the muscle activity in remaining leg muscles are other means to activate the control.

The knee flexion control unit described may be manufactured with a relatively small diameter and due to the fact that it extends only between the thigh brace section and the calf brace section it is cosmetically acceptable. When in a flexible position its ability to conform easily to any relative motion between the thigh and skin makes it extremely comfortable to the patient. Although it may be adapted for use with any conventional leg bracing device, its combination with inflatable structures provides a feasible application of the inflatable structure system to long leg bracing for the first time.

Various changes may be made in the specific embodiments of this invention without departing from the spirit thereof or from the scope of the appended claims. Other modifications and adaptations — such as use of the device in artificial limbs — may be made without departing from the scope of the invention.

What is claimed is:

1. A flexion control device, for use on human limb joints, connecting an upper brace with a lower brace, comprising:

a flexion spring;
a flexible cable passing through the center of said flexion spring;
first connection means connected to one end of said flexion spring and one end of said cable for connecting the device to one of the braces;
mechanical control means connected to the other end of said flexion spring and the other end of said flexible cable for allowing said flexible cable to be completely flexible when in one mode and causing said cable to be rigid when in another mode; and
second connection means connected to said control means for connecting the device to the other one of the braces.

2. A flexion control device in accordance with claim 1 wherein said control means comprises:

a main cylinder closed at one end thereof and connected at the open end thereof to said flexion spring;
a piston within said cylinder connected to said flexible cable;

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a closure means within said cylinder near the open end thereof, said piston and said closure means forming a chamber within said cylinder;
 spring means connected to said piston for urging said piston away from said closure means;
 hydraulic fluid within said chamber;
 accumulator means for storing said fluid;
 fluid passage means connecting said chamber and said accumulator means for allowing fluid to pass therebetween; and
 a control valve in said fluid passage means for controlling the flow of said fluid.

3. A flexion control device in accordance with claim 1, further including:
 rigid spacers having an outside diameter approximately equal to the inside diameter of said flexion spring and having an inside diameter approximately equal to the outside diameter of said cable whereby said cable is held centered within said flexion spring.

4. A flexion control device in accordance with claim 1, wherein:
 said flexion spring is of a rectangular cross-section.

5. A hydraulic flexion control device in accordance with claim 1, further including:
 a one way check valve in said fluid passage means and bypassing said control valve whereby said fluid can pass through said check valve from said accumulator means to said chamber but cannot return.

6. A hydraulic flexion control device in accordance with claim 1, wherein said accumulator means in-

cludes:

a cylinder,
 a sealed piston within said cylinder;
 an accumulator spring connected to said sealed piston for urging said sealed piston in the direction which forces said fluid out of said accumulator means.

7. A hydraulic flexion control device in accordance with claim 1, further including:

needle valve means in said fluid passage means for restricting the flow of said fluid and thereby dampening the flexion of the device.

8. A hydraulic flexion control device in accordance with claim 1, further including:

automatic control means connected to said control valve for closing said control valve when weight is applied to the device and opening said control valve when weight is released.

9. A hydraulic flexion control device in accordance with claim 8; wherein said automatic control means includes:

a body connected to said main cylinder, and having an opening adapted to receive one of said connection means;

a control spring connected to said body urging said connection means away from said body;

control means connected to said connecting means for opening and closing said control valve in response to the relative motion between said connecting means and said body.

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