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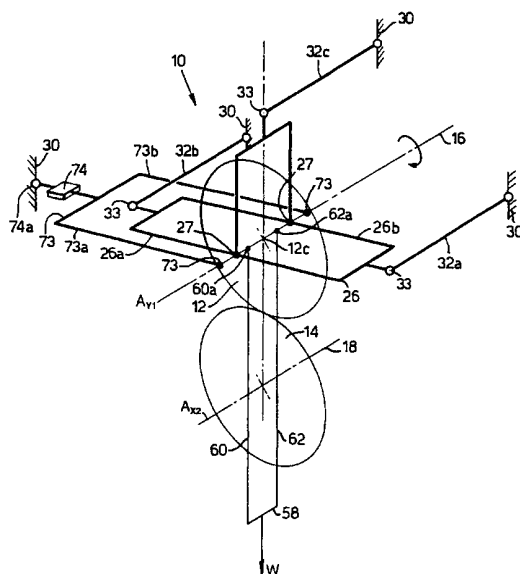
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(54) Title: TEST APPARATUS



(57) Abstract: The present invention provides an apparatus for and method of determining the traction conditions between engaged rotating members. A first roller member (12), in frictional engagement with a second roller member (14), is provided with means (32, 34) of support which facilitate adjustment of the position of member (12) so as to maintain a desired planal position of said member (12) relative to the second member (14). The accuracy of data obtained from this arrangement is greatly enhanced.



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TEST APPARATUS

5 The present invention relates to an apparatus for and method of determining the traction conditions between engaged rotating members such as the rollers and discs in an infinitely-variable-transmission (IVT). The apparatus and method also lend themselves to determining traction properties between other elements such as bearings and the like.

10 In some mechanical systems, such as IVTs, a high traction fluid is desirable. Instead of transmitting power through gears, it is possible to transmit power across a heavily-loaded contact between two rotating disk/roller arrangements. The maximum force, and therefore power that can be transmitted is directly related to the traction or shear force developed in the fluid contact between the rollers/disks. Higher traction fluids
15 can transmit more power and reduce the amount of sliding between the driving and driven disks. Another component in which low traction may not be desirable is roller bearings. In this case, some traction is required to reduce the amount of skidding that can take place between the rollers and bearing raceways. The traction force is a function of the following parameters: load; lubricant properties; temperature; slip and
20 space between surfaces; shape of surfaces; and elastic properties of the contact materials.

US-A-5372033 discloses a method and apparatus for measuring the thickness and traction properties of elastohydrodynamic lubricant (EHL) films which utilises at
25 least one ball or roller loaded against the interior diameter of a transparent ring having a larger radius than said ball or roller. A lubricant is placed between the rotating roller and ring thereby forming an EHL film where the ball and ring contact. Roller and ring rotating speeds are controlled to obtain different amounts of relative sliding motion between the surfaces. Contact between the surfaces and the resultant film are

observed via the ring which is transparent, thereby allowing optical measurement of lubricating film thickness. Traction forces generated during contact may be measured by any suitable force measuring device. Load is applied to the roller test assembly by means of a lever arm arrangement pivoting about a pivotal shaft, thereby to create
5 some mechanical advantage associated with the application of the load and the test rollers are forced upwardly towards the ring. Whilst this apparatus provides a perfectly adequate means of determining the traction properties of elastrohydrodynamic lubricants it has been found that the direction of the plane in which the load is applied will vary as the load is increased. Consequently, it is
10 difficult to accurately reproduce real life operating conditions with this apparatus.

As the direction of the applied load varies as the load increases this device does not lend itself to use in determining the magnitude of the traction conditions between rotating bodies as it is not possible to ensure that a component of the applied load is
15 not affecting the traction force reading.

It is an object of the present invention to provide an apparatus for and method of determining the traction properties of elastrohydrodynamic lubricants and the like and the operating characteristics of engaged rotating roller members when subjected to
20 constant or varying contact loads which reduces and possibly eliminates the problems associated with the prior art.

According to one aspect of the present invention there is provided a test apparatus comprising a first roller member; a second roller member, in frictional engagement
25 with said first roller member; and load application means for applying a load to said first or second member, in which the load application means comprises means for confining the direction of the applied load to a given plane.

According to another aspect, the present invention provides a test apparatus comprising a first roller, having a first plane of rotation; a second roller, having a second plane of rotation and being in frictional contact with said first roller; load applying means, for applying a load to said first roller; and traction force determining
5 means for determining the traction force between the two rollers; characterised by adjustment means for adjusting the plane of rotation of the first roller member; and in which the traction force determining means is connected to the points either side of said first disk and equidistant from the plane of rotation (P_{R2}) of said disk. Such an arrangement more accurately reproduces real life operating conditions associated with
10 roller bearings and the disc/roller combinations associated with infinitely-variable-transmissions (IVT's).

Advantageously the load application means comprises adjustment means for adjusting the plane of rotation of one or both of the first and/or second roller members.

15

Preferably, the apparatus further includes a support which is secured to a fixed portion by a support member, said support member including said adjustment means.

In one arrangement the support member comprises a plurality of support members
20 extending substantially perpendicular to the axis of rotation A_{x2} of the disc.

In a preferred arrangement the support member comprises three support members, a first and a second support member extending in a common plane and a third support member extending in a different plane, each of said planes being substantially co-
25 planar with the axis A_{x2} of the disc.

Preferably, the apparatus includes determining means for determining the relative position of the planes of rotation of the roller members.

Conveniently, the determining means may comprise load measuring means for determining the load on the adjustment means.

5 Said adjustment means may comprise means for adjusting the length of the support member or members.

The apparatus further includes loading means for applying a load to a roller member, thereby to create a contact force between the two rollers.

10 Preferably, the loading means comprises means for applying a load to the roller in the plane of said roller P_{r2} .

Conveniently, the apparatus further includes force measuring means for measuring the traction force experienced by a roller. Said force measuring means may comprise a
15 simple load cell.

Advantageously, the apparatus further includes backlash adjustment means for adjusting the position of a roller to reduce any tolerance within bearing supporting said roller.

20

Each of said rollers may be provided with driving means for driving said rollers in a direction opposite to each other. The driving means may further include speed adjustment means for adjusting the relative speeds of rotation.

25 The present invention will now be more particularly described by way of example only with reference to the following drawings in which:

Figure 1 is a front elevation of an apparatus according to the present invention;

Figure 2 is a side elevation of the apparatus shown in Figure 1;

- Figure 3 is a partial cross sectional view taken in the direction of arrows A-A in Figure 1;
- Figure 4 is a schematic representation of an idealised apparatus;
- Figure 5 is a diagrammatic representation of the roller lubrication system;
- 5 Figure 6 is an isometric view of the support structure shown schematically in figures 1 to 3;
- Figure 7 is an end elevation of part of the apparatus and illustrates the roller/bobbin interaction;
- Figure 8 is a side view taken in the direction of arrow B in figure 6; and
- 10 Figure 9 illustrates the mounting of the bobbin on the apparatus.

Referring to the drawings in general but particularly to Figures 1 to 3, the apparatus shown generally at 10 has first and second roller members 12, 14 driven by respective drive shafts 16, 18. A pair of motors shown at 20a, 20b drive said shafts 16, 18 and a

15 speed adjusting means 21 allows for adjustment of the relative rotational speed of said shafts as and when necessary. A static base or plinth 22 upon which said motors are mounted forms a rigid and dimensionally stable base which, in use, acts as a reference datum for the positioning of various additional components. The first of said components comprises a roller shaft support member 24 securely mounted to said

20 base and been provided with taper roller bearings 28a, 28b for accurately supporting said shaft whilst allowing for its rotation about A_{x1} and for maintaining the plane of rotation P_{R1} of roller 14 within a given plane. Roller shaft support member 26 supports shaft 16 and roller 12 attached thereto by means of taper roller bearings 30a, 30b discussed in detail later herein. Remote from the roller end is a support member

25 30 again also securely attached to base member 22. This support member provides an anchor point for support arms 32 connected at a proximal end to member 26 and at a distal end to support number 30. Connection to each of these members is by means of a universal or Rose joint 33 (available under part number 70MKTF from John Handley Bearings, Unit 39 Burnt Tree, Tipton, West Midlands, DY4 8XP) such that

member 26 and the roller 12 associated therewith is, subject to restraining forces, free to move both vertically and sideways as will be described in detail later herein. In the example shown, the support members 32 extend substantially perpendicular to the axes of rotation of the discs 12, 14. As shown, support members 32a & 32b extend in a common plane and a third 32c extends in a different substantially perpendicular plane which itself contain the axis A_{x2} of disc 12. It will, however, be appreciated that member 32c need not be an upper support member and that, in fact, other positional relationships of these arms are possible whilst still maintaining the ability to move the roller to align its plane of rotation P_{r2} such that it is co-planar with plane P_{r1} .

The universal joints 33 allow arms 32 to pivot about their mounting point on support 30 whilst also allowing the planal position of item 26 to be altered as and when required. In effect the combination of supports 32, joints 33 and adjustment means 34 facilitate correction of the plane of rotation of disk 12 and ensure the accuracy of operation and of the data collected. It is quite possible to dispense with support arms 32 and replace them by an adjustable plate system (not shown) which sandwiches member 26 and is adjustable so as to adjust the planal position of said member and, hence, the planal position P_{R2} of disc 12. Each of members 32 is provided with a length adjusting means shown generally at 34 which, in effect, provides the means for adjusting the plane of rotation of roller 12. As shown, the adjusting means comprises a simple double threaded bar provided with a thread portions of slightly different pitches 38, 40 which operably engage with corresponding internal threads on different portions of each of members 32. Upon rotation of a knurled nut 42 associated with the threaded portion 38, 40, the threads co-operate to lengthen or shorten the support member 32. A suitable locking mechanism shown in the form of a simple handle lock 44 is provided in order to lock the adjustment means in position as and when desired. An additional item of equipment shown on supports 32 is load cell 46 which may be used in order to determine the axial load on the support during rotation of the rollers.

The magnitude of this "skew" force is indicative of the degree of misalignment of plane P_{R2} relative to plane P_{R1} and is a major consideration of the present design. Adjustment of support members 32 in order to eliminate this load is undertaken in order to align the two planes. It will, however, be appreciated that alternative means for correcting the planar position of roller 12 may also present themselves such as, for example, the use of multiple dial test gauges on the flat side surface 12a, 14a of roller 12 and roller 14 respectively. Consequently, load cells 38 form just one suitable apparatus for achieving this requirement. A micrometer 48 may also be positioned such that it bridges the threaded portions of member 32, thereby to determine the magnitude of any adjustment.

Referring once again to roller shaft support members 24, 26, it will be appreciated that the positioning of the shaft relative thereto must be as accurate and stable as possible in order to ensure accurate positioning of the rollers 12, 14. To this end, taper roller bearings 28a, 28b and 30a, 30b are provided within members 24, 26 respectively and engage with shafts 18, 16 in the appropriate manner. Such bearings may be adjusted in a manner well known to those skilled in the art thereby to reduce and possibly eliminate undesirable relative movements between the shafts and their respective supports. Such adjustment would only be required on initial installation of the shafts as it has been found that any minor relative movement is well within acceptable limits for successful operation of the present apparatus.

Additional components, best seen in Figure 1 and 2, comprise loading means 58 suspended below the rollers 12, 14 and connected to horizontally extending portions 26a, 26b of member 26. Preferably, the support arms 60, 62 of loading means 58 extend in the same plane as roller 12 such that, in operation, any applied load is applied within that plane P_{R2} . However, slight variations of this planal position are possible without adversely affecting the accuracy of roller loading. Applying the load through a point mid-way between the bearings 28a, 28b and joints 33 might help

reduce still further any minor errors that might be introduced as a result of minor movements between the components within item 26. Such an idealised arrangement is actually shown in Figure 4 in which member 26 straddles the roller 12 such that it supports the roller 12 at points 27, each of which are equidistant from the centre 12c of roller 12. The remainder of the support arrangement 30, 32, 33 etc is as described with reference to the other drawings and is, therefore, not discussed again here. In this arrangement support arms 60, 62 are also repositioned so as to straddle the centre of disk 12c and extend upwardly to points 60a, 62a on the centre line axis A_{x1} and equidistant from centre 12c. The combination of these two arrangements will ensure that the load applied by M_1 is applied within the plane P_{r2} of roller 12 and the roller is evenly supported such that the application of the load will not result in the roller being displaced out of the desired plane of operation. A further member 73 straddles the centre-line A_{x2} and is connected to the shaft 16 by means of suitable bearings 75 whilst also being connected to load cell 74 which is, in turn, pivotally attached at 74a by means of a suitable universal joint to fixed portion 30. As a consequence of such an arrangement the load cell 74 should not experience any load other than that created as a result of traction forces.

It will be appreciated that Figure 4 is schematic and that a full embodiment would include the provision of bearings 30a, 30b either side of roller 12 as well as suitable anchor points at 60a, 62a to ensure load M_1 is applied evenly and in the correct plane. In practice the anchor points may be provided on support 26 and load cell 74 may be connected to a support 26 at a point selected such that the cell is aligned with the axis of roller 12 and operates in a plane perpendicular to that in which the load W is applied, thereby ensuring accurate determination of the traction forces. Referring once again to Figure 2 there is shown a back-lash adjustment mechanism shown generally at 64 which allows for the elimination of back-lash associated with bearings 28a, 28b. The mechanism comprises a mass M_2 suspended on wire 66 which passes over low friction roller 68 before being attached to item 26 at a point on a horizontal

plane H_{P2} which passes through axis A_{X2} . A further load cell 70 is positioned for confirming the magnitude of the pre-load applied by mass M_2 . Load cell 74 positioned on the opposite side of 26 is used to measure traction force T_f . An optional load cell 75 may be grounded at 76 and connected to a vertically extending portion 26c of item 26 such that it is able to measure the bearing torque reaction load.

Further components of apparatus 10 are shown in Figures 6 & 7 and include a bobbin member 80 having upper and lower contact surfaces 82, 84 respectively. Bobbin 80 is mounted for rotation about vertical axis A_b by means of bearings 86 provided at each end of a support shaft 88 housed in housing 90. The housing is mountable on an outer casing 92 which also acts to retain lubricants within the confines of the rollers. Contact surfaces 82, 84 fit between rollers 12', 14' which are of a reduced size relative to those in Figures 2, 3. roller 12' is still loaded vertically in the manner described above but in this arrangement it is loaded onto the flat contact surface 82 rather than roller 14, thereby to facilitate reproduction of the "spin" characteristics sometimes associated with contact between engaged rotating bodies. Spin is the component of relative motion out of the plane P_{R2} of the roller 12 and must be reproduced accurately if one is to fully evaluate the properties of any fluid under test. The degree of spin can be varied by adjusting the displacement of the bobbin axis A_B relative to plane P_{R1} and P_{R2} of roller 12' and 14' respectively. Spacers (not shown) may be provided at the mounting points 96 for this purpose but other means will present themselves to those skilled in the art. A drive motor 88 may be provided to vary the speed of bobbin 80 relative to discs 12', 14' without slip. In this arrangement, each of discs 12', 14' are provided with a convex contact surface for engagement with surfaces 82, 84.

The apparatus of figures 1 to 4 is set-up by first positioning the discs 12, 14 in planes approximately co-planar and then adjusting the plane P_{R2} until it lies within or substantially within the same plane as that of roller 14. Adjustment may be achieved

by using multiple dial test gauges (not shown) against the flat surface 12a, 14a of rollers 12, 14 and adjusting members 32 until no discernible difference between the planal positions can be detected. Surfaces 12a, 14a are machined such that they are perpendicular to plane P_{R2} in order to facilitate this operation. In effect, this aligns the
5 planes of the rollers 12, 14 (defined by axes A_A and A_B in Figure 5) so they are coplanar as required for correct operation of the apparatus. Alternatively, one might engage the motors and drive discs 12, 14 without slip and adjust the length of members 32 until the forces are balanced in the load cells associated therewith. This is indicative of axis A_{X2} being directly above axis A_{X1} as is required before
10 commencement of testing. Once the discs are positioned relative to each other, bearing back-lash is eliminated by increasing weight M_2 until load cell 74 remains in traction independent of the relative slip between 12,14 or 12', 82, according to the configuration employed.

15 Once the apparatus has been set-up the motors may be run up to a speed associated with a required test speed at the roller contact point and lubricant flow commence by pumping lubricant/traction fluid through supply pipes 100 best seen in Figure 5. Once the required speed and lubrication supply conditions have been achieved, roller 12 is loaded by applying the desired weight M_1 to loading struts 58, 60, 62 thereby to
20 reproduce the desired operating conditions. The relative rotational speeds of rollers 12, 14 are adjusted by adjustment means 21 in order to achieve the desired slip/roll test conditions. Measurements from the load cells on supports 32 and at 74/75 give an indication of the performance of the lubricant under test and are recorded in the usual manner for subsequent analysis. Tests are repeated for a series of differential speeds
25 and loads in order to provide a full "map" of fluid properties.

In order to determine the fluid properties associated with "spin" between two bodies rollers 12, 14 are replaced by smaller diameter rollers best seen in Figures 7, 8 & 9 and bobbin 80 inserted there between. The magnitude of "spin" between the rollers

and the bobbin may be varied by moving the rotating axis of the bobbin member closer to or further away from the plane of rotation of rollers 12, 14. The closer said axis is to said plane the greater the magnitude of "spin" between the two bodies. Testing to determine the traction characteristics comprises the same steps as outlined
5 above which are, therefore, not repeated herein.

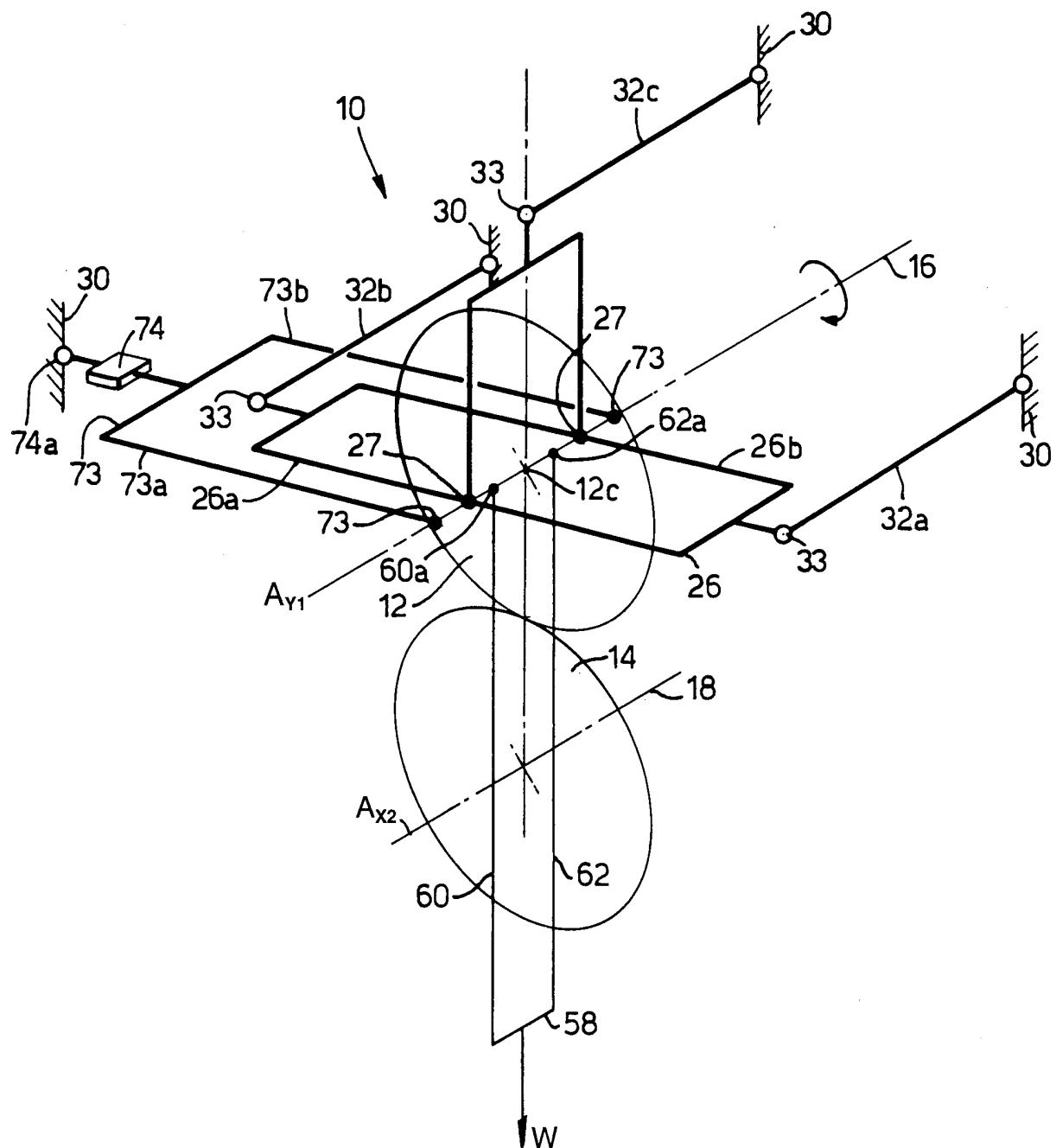
CLAIMS

1. A test apparatus (10) comprising:
- a first roller member (12);
 - 5 - a second roller member (14), in frictional engagement with said first roller member (12); and
- load application means (60, 62, W), for applying a load to said first or second member; characterised in that said load application means comprises means for confining the direction of the applied load to a given plane.
- 10
2. A test apparatus (10) as claimed in Claim 1, in which the load application means (60, 62, W) comprises adjustment means (34) for adjusting the plane of rotation of one or other or both of the first and/or second roller members (12, 14).
- 15
3. A test apparatus comprising:
- a first roller (12), having a first plane of rotation;
 - a second roller (14), having a second plane of rotation and being in frictional contact with said first roller (12);
 - load applying means (60, 62, W), for applying a load to said first roller
 - 20 (12); and
 - traction force determining means (74) for determining the traction force between the two rollers (12, 14); characterised by
- adjustment means (32) for adjusting the plane of rotation of the first roller member (12); and in which the traction force determining means (74) is connected to points
- 25 (75) either side of said first disk (12) and equidistant from the plane of rotation (P_{R2}) of said disk.

4. A test apparatus (10) as claimed in any one of claims 1 to 3 and further including a support (26), said support is secured to a fixed portion (30) by a support member (32), said support member including said adjustment means (34).
- 5 5. A test apparatus (10) as claimed in Claim 3 or Claim 4 in which said support member (32) comprises a plurality of support members (32) extending substantially perpendicular to the axis A_{X2} of rotation of the disc (12).
6. A test apparatus (10) as claimed in Claim 4 or Claim 5 in which said support
10 member comprises three support members (32), a first and a second support member (32a, 32b) extending in a common plane and a third support member extending in a different plane.
7. A test apparatus (10) as claimed in Claim 6 in which each of the planes are
15 substantially co-planar with the axis A_{X2} of said disc (12).
8. A test apparatus as claimed in any one of the preceding claims including determining means (46) for determining the relative position of the planes of rotation of the roller members (12, 14).
20
9. A test apparatus as claimed in Claim 8 in which the determining means comprises load measuring means (46) for determining the load on the adjustment means (34).
- 25 10. A test apparatus as claimed in any one of Claims 2 to 9 in which the adjustment means (34) comprises means for adjusting the length of the support member (32).

11. A test apparatus (10) as claimed in any one of Claims 1, 2 and 4 to 10 and further including loading means for applying a load to a roller member, thereby to create a contact force between the two rollers.
- 5 12. A test apparatus (10) as claimed in Claim 11 in which the loading means (60, 62, W) comprises means for applying a load to the roller (12) in the plane of said roller (P_{R2}).
- 10 13. A test apparatus (10) as claimed in any one of the preceding claims and further including force measuring means (74) for measuring the traction force experienced by a roller (12).
14. A test apparatus (10) as claimed in Claim 13 in which said force measuring means (74) comprises a load cell.
- 15 15. A test apparatus (10) as claimed in any one of Claims 1 to 14 including backlash adjusting means for adjusting the position of a roller to reduce any tolerance with bearings supporting the roller (12).
- 20 16. A test apparatus (10) as claimed in any one of the preceding claims including driving means (20a, 20b) for driving each roller (12, 14) in a direction opposite to the other.
- 25 17. A test apparatus (10) as claimed in any one of Claims 1 to 16 and further including speed adjusting means (21) for adjusting the relative speed of rotation of the rollers (12, 14).

Fig.4.



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Fig.5.

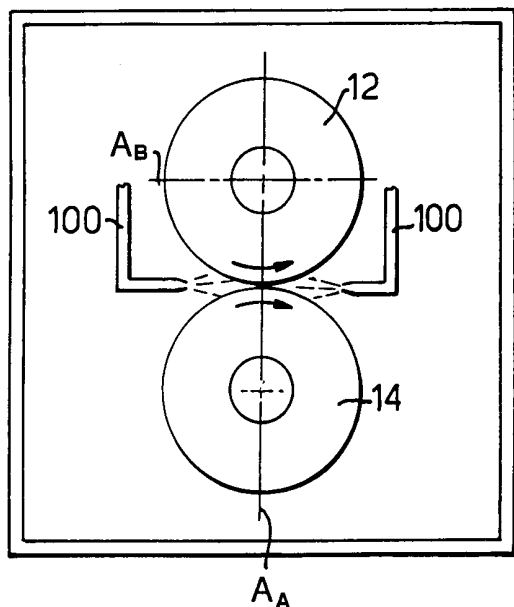


Fig.7.

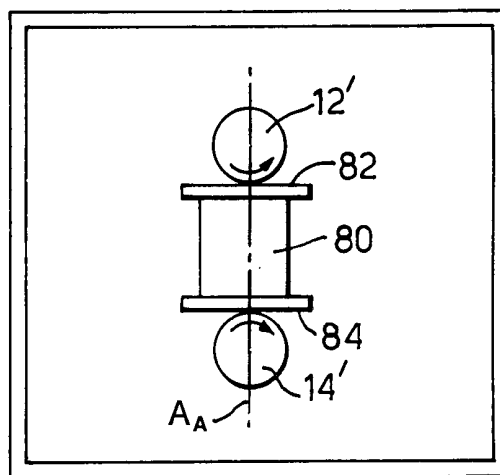
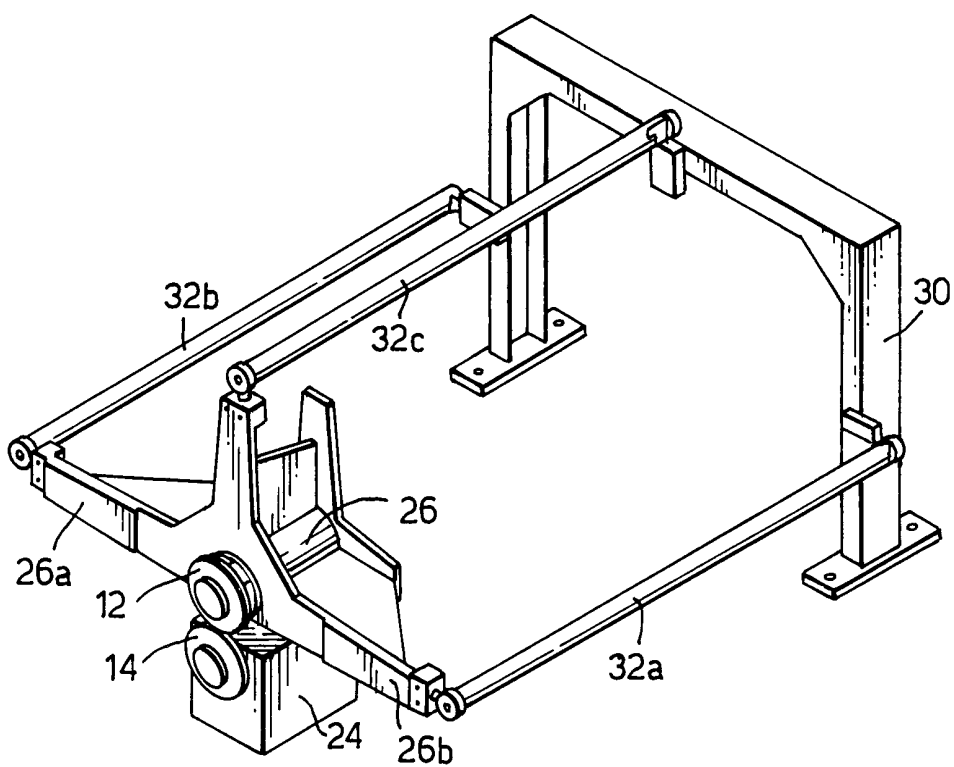


Fig.6.



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Fig.8.

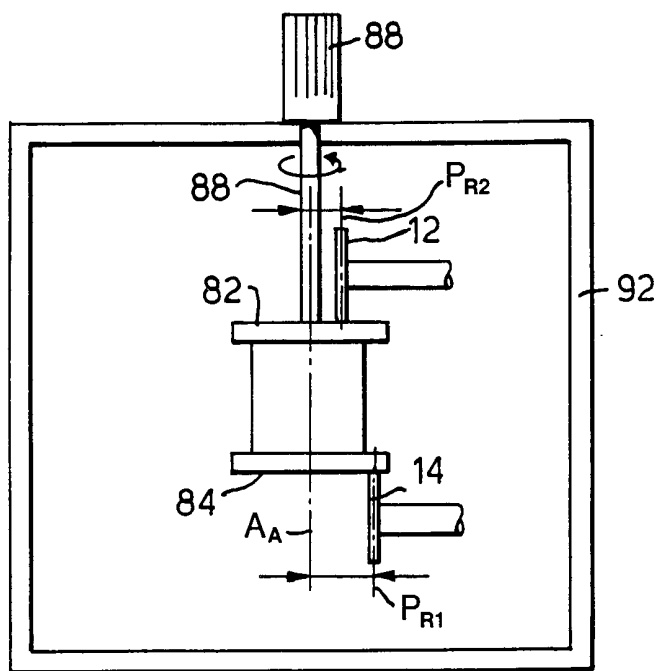


Fig.9.

