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(54) **PRINT MEDIA TENSIONING APPARATUS INCLUDING GIMBALED ROLLER**

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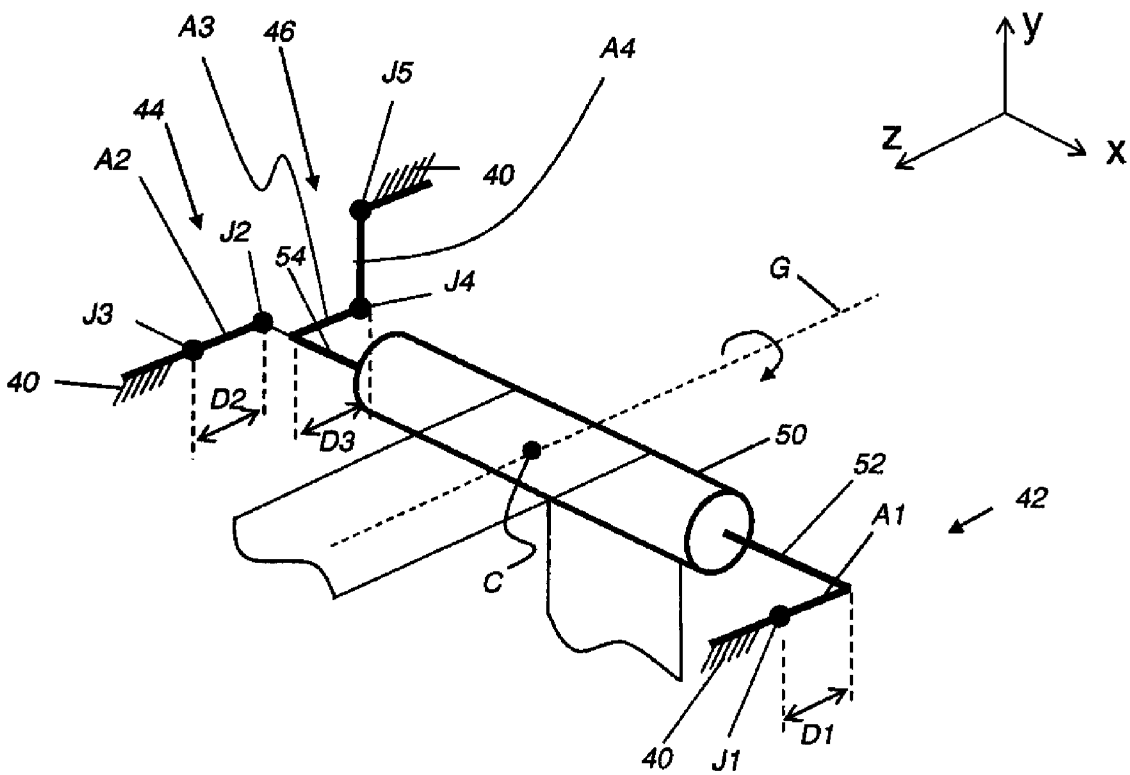
(57) **ABSTRACT**

An apparatus for maintaining uniform tension across a width of a web is provided. The apparatus includes a frame, a roller, a first coupling, a second coupling, and a third coupling. The roller includes a shaft about which the roller rotates. The roller shaft defines an axis of rotation and includes a first end and a second end. The first coupling includes a first arm and a first joint that couples the first end of the roller shaft to the frame such that the roller shaft is free to rotate. The first joint is offset relative to the roller axis by a first distance. The second coupling includes a second arm, a second joint, and a third joint that couples the second end of the roller shaft to the frame. The second arm is free to pivot relative to the roller shaft and the frame through the second joint and the third joint. The third joint is offset relative to the roller axis by a second distance that is substantially equal to the first distance and in the same direction relative to the roller axis. The third coupling includes a third arm and a fourth joint that couples the second end of the roller shaft to the frame. The third arm is coupled to the frame through the fourth joint. The fourth joint is offset relative to the roller axis by a third distance that is substantially equal to the first distance. The offset is in an opposite direction relative to the roller axis.



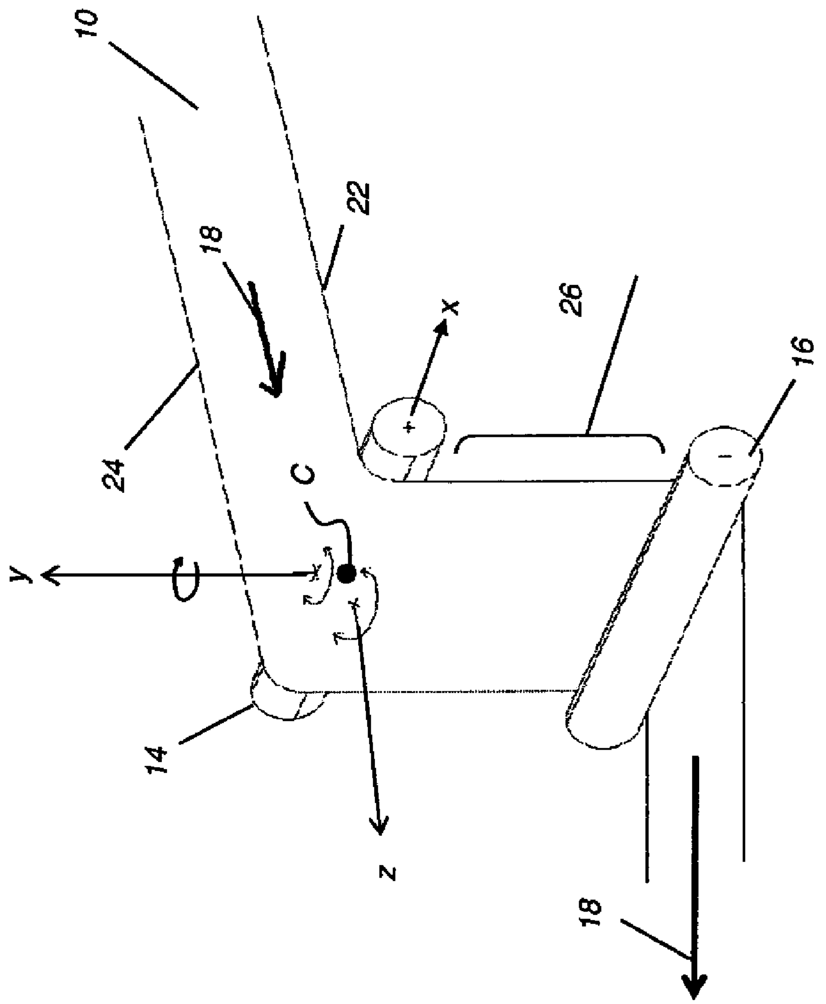


FIG. 1

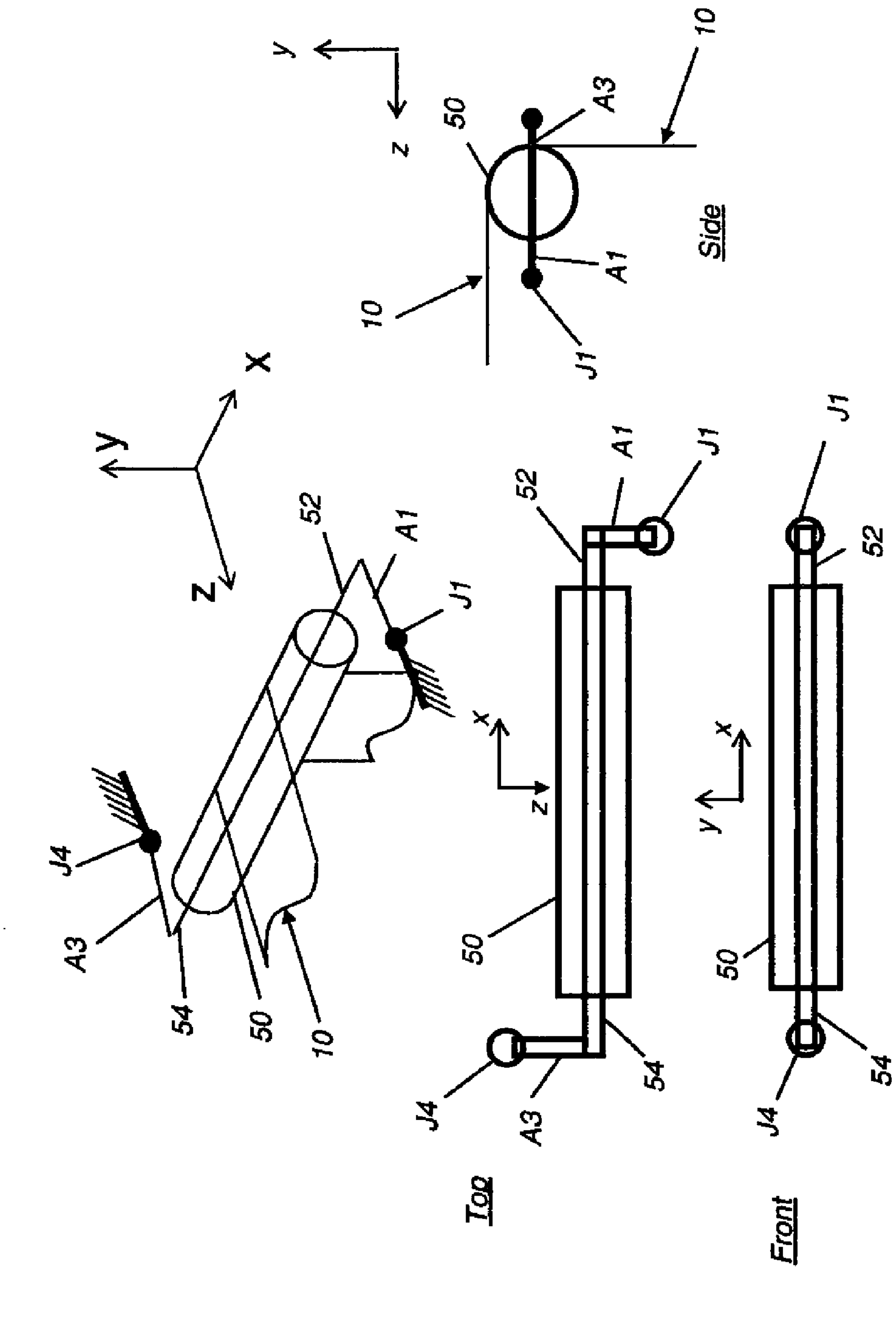


FIG. 2

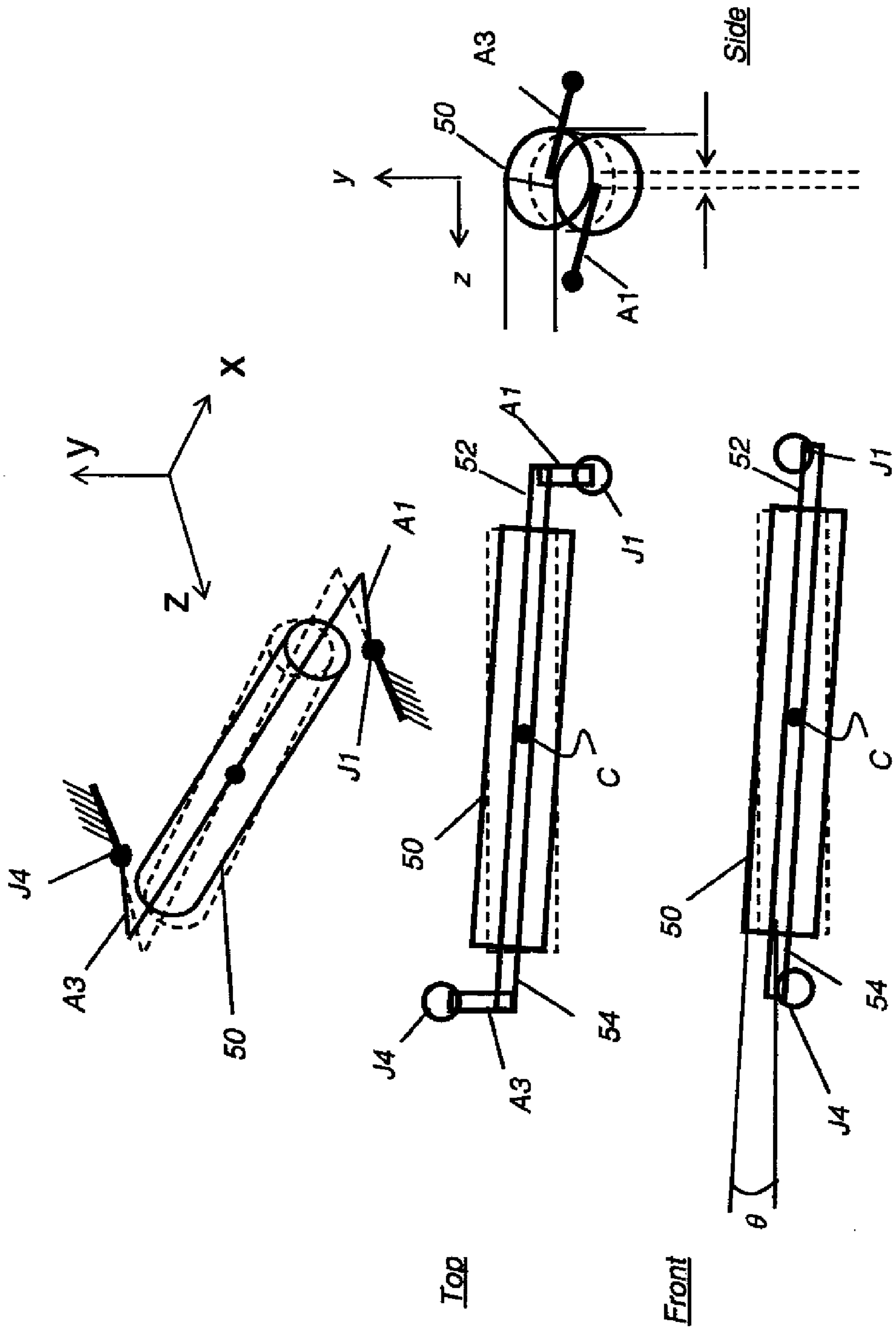


FIG. 3

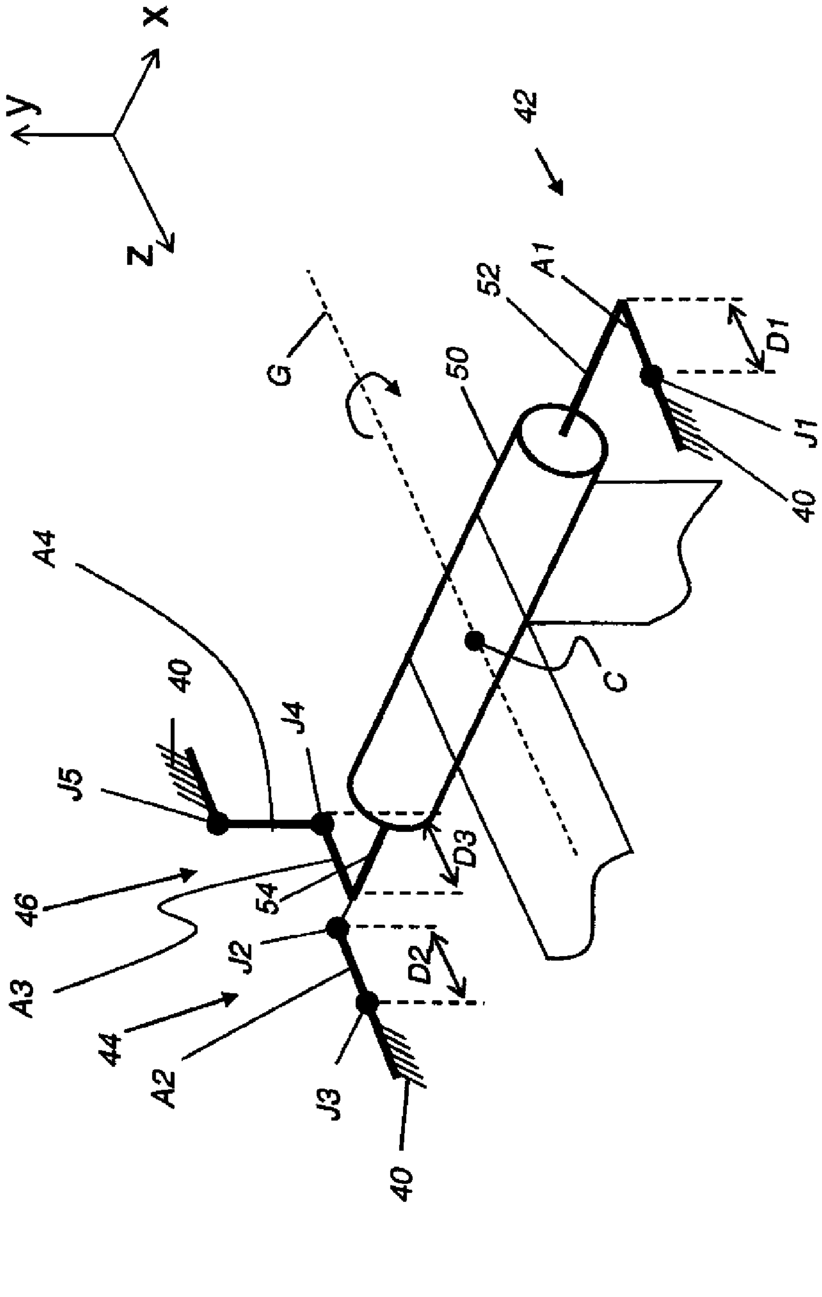


FIG. 4

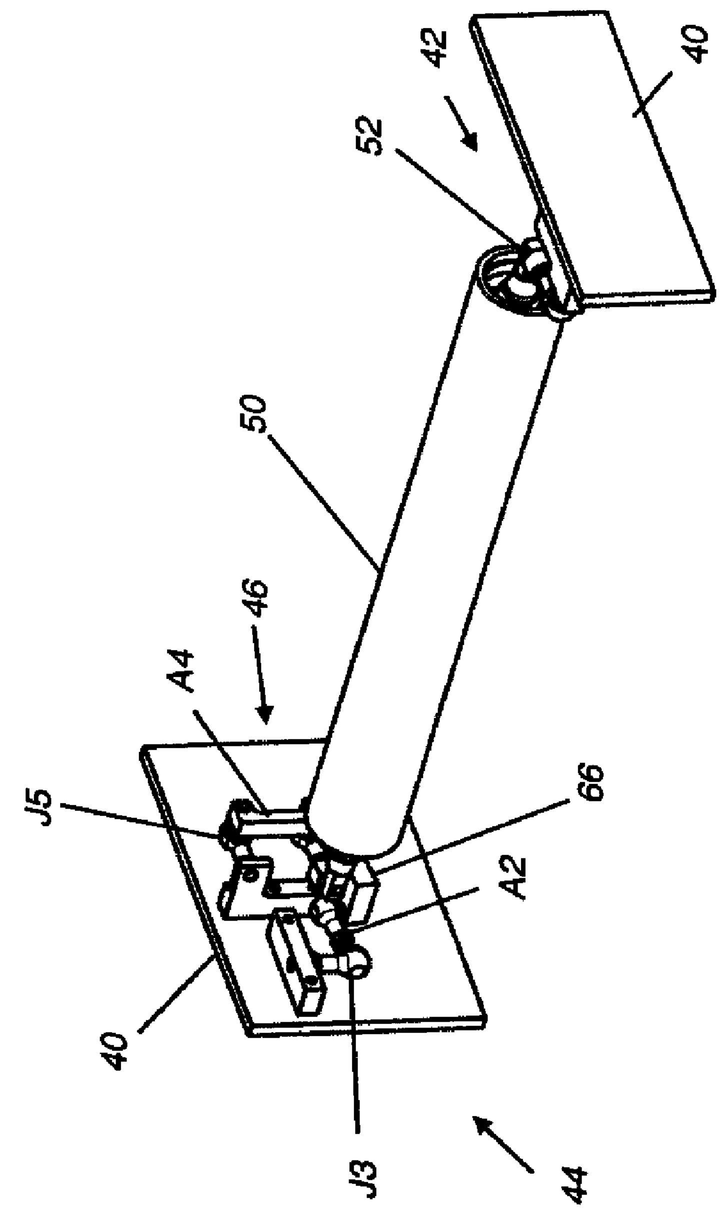


FIG. 5A

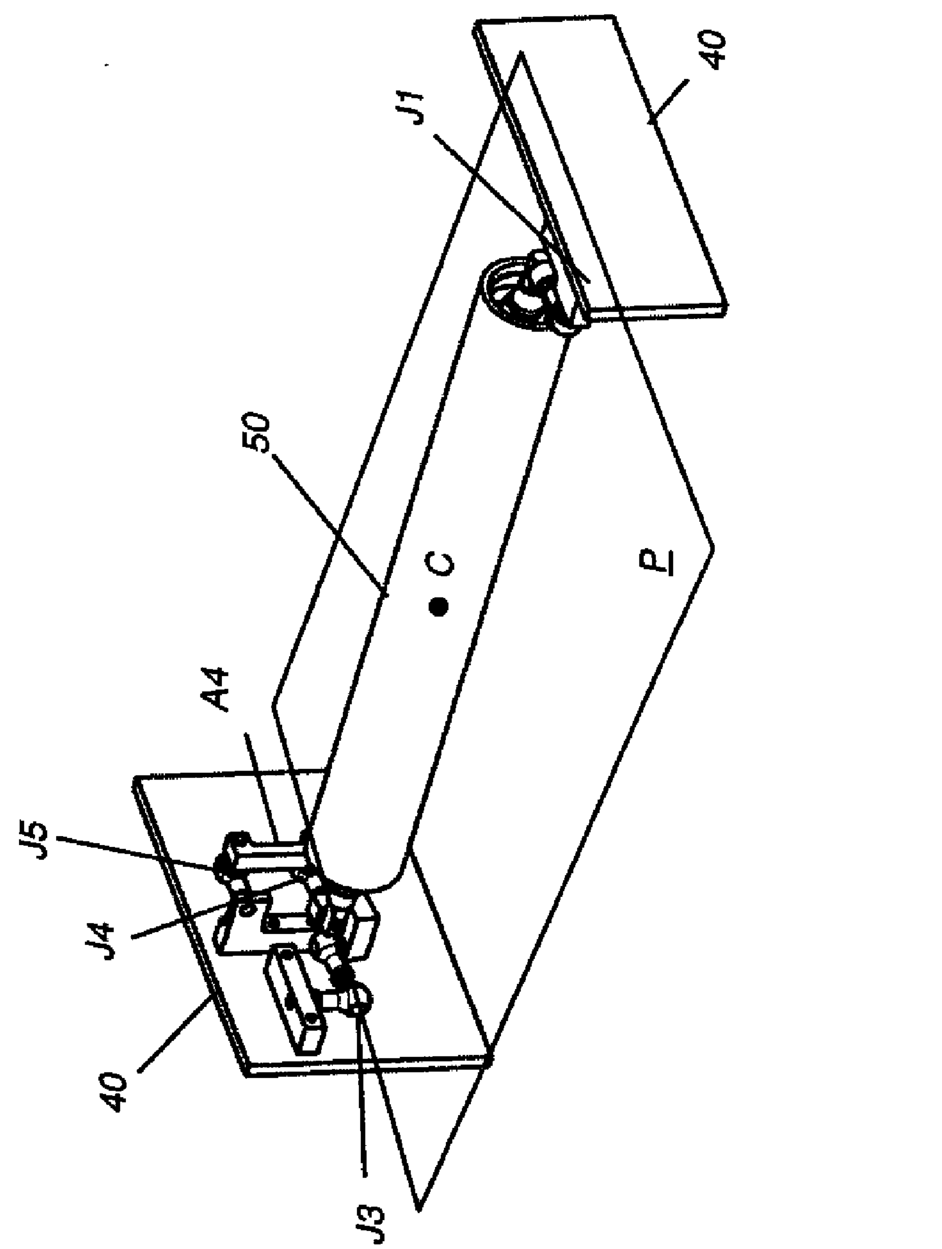


FIG. 5B

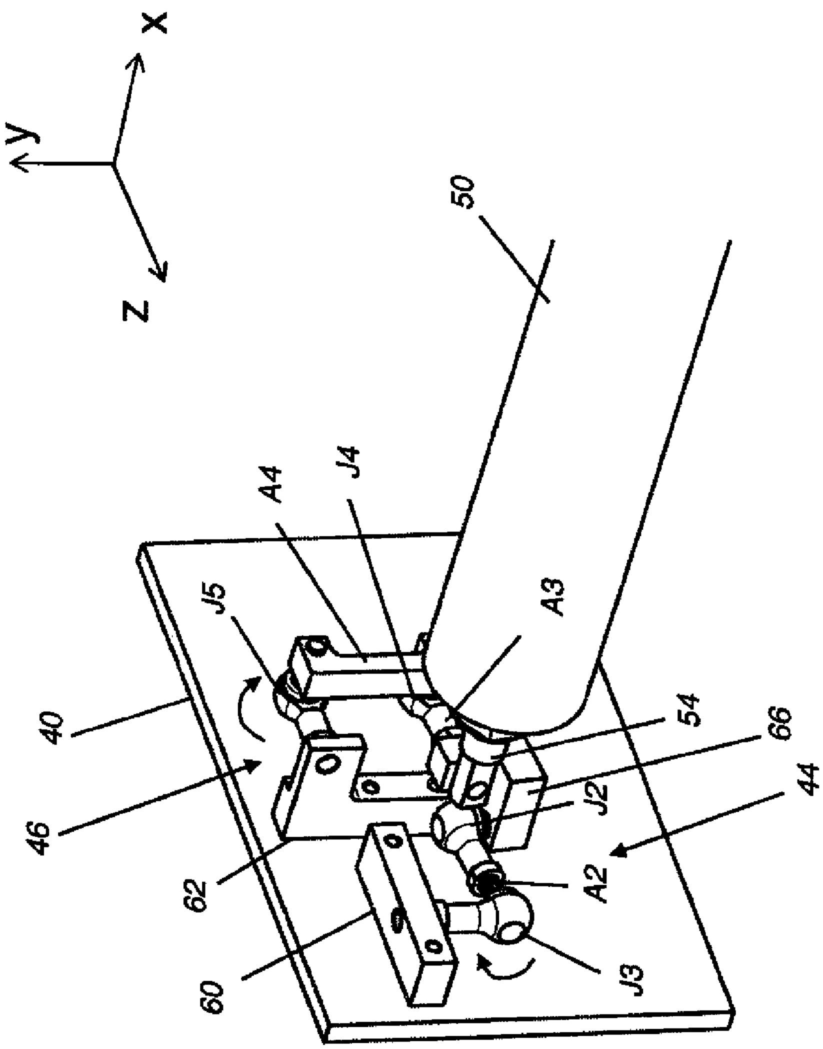


FIG. 6

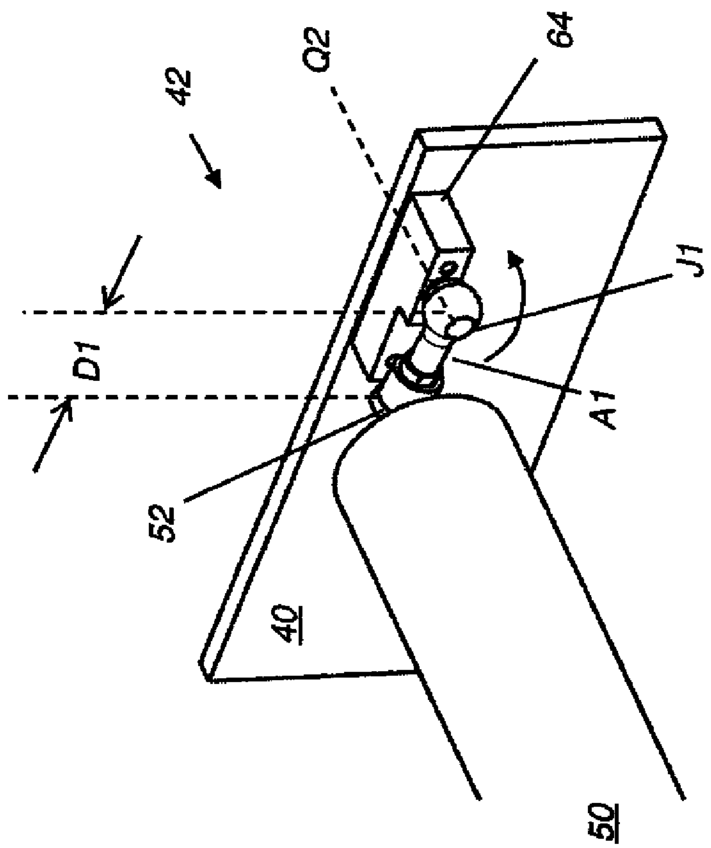


FIG. 7

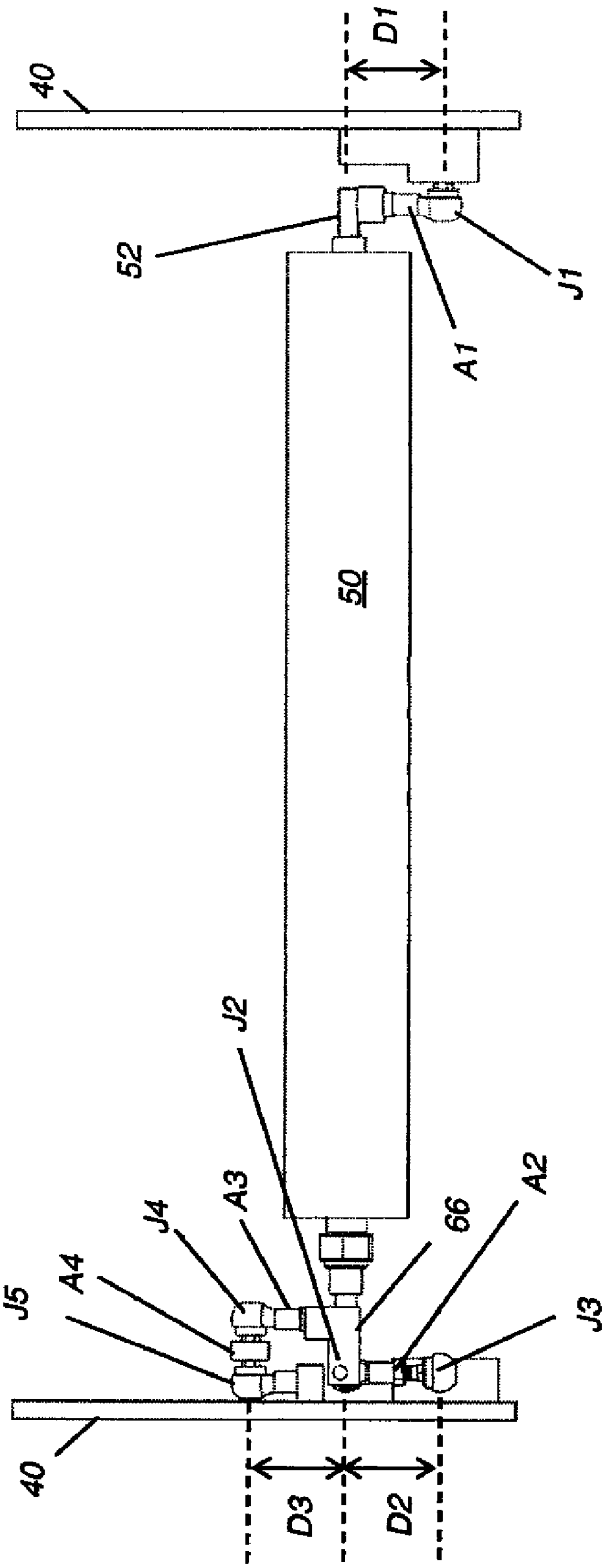


FIG. 8

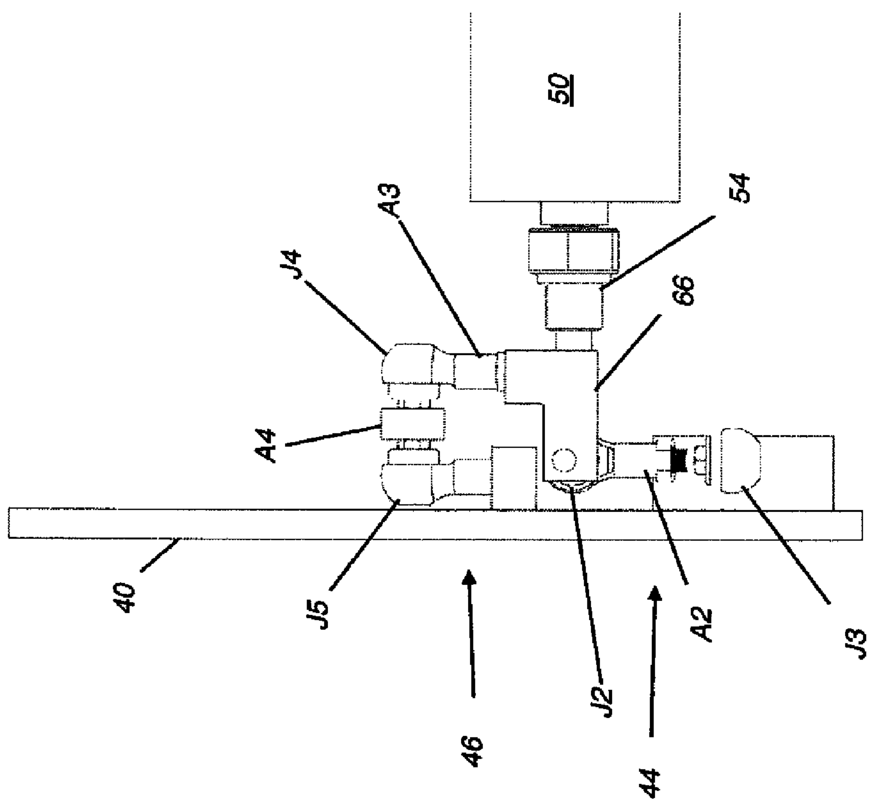


FIG. 9

PRINT MEDIA TENSIONING APPARATUS INCLUDING GIMBALED ROLLER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] Reference is made to commonly-assigned copending U.S. patent application Ser. No. 12/627,018 filed Nov. 30, 2009 entitled "MEDIA TRANSPORT SYSTEM FOR NON-CONTACT PRINTING", by Muir et al. and to commonly-assigned copending U.S. patent application Ser. No. 12/627,003 filed Nov. 30, 2009 entitled "PRINT MEDIA TENSIONING APPARATUS"

FIELD OF THE INVENTION

[0002] This invention relates generally to the field of digitally controlled printing systems, and in particular to the media transport portion of these systems.

BACKGROUND OF THE INVENTION

[0003] In high speed inkjet printing systems, print media typically moves through the printing system as a continuous web of print media rather than individual sheets of print media. As the web of media passes through the print system, the print media is held under tension. Variations in the tension of the print media across the width of the print media cause the print media to drift laterally. Precision alignment of the rollers which support and guide the print media reduces the tendency of the print media to drift laterally, but achieving precision alignment of the rollers is, typically, a costly process. As precision alignment of the rollers can reduce or even eliminate drifting of the print media, conventional printing systems typically include servo-controlled web guides to steer the print media to the desired lateral position. While such web guides can be effective, they add significant cost to the printing system.

[0004] As such, there is an ongoing need to provide, at a relatively low cost, an apparatus that equalizes the tension of the print media across the width of the print media to reduce or even eliminate the tendency of the print media to drift laterally.

SUMMARY OF THE INVENTION

[0005] According to an aspect of the present invention, an apparatus for maintaining uniform tension across a width of a web is provided. The apparatus includes a frame, a roller, a first coupling, a second coupling, and a third coupling. The roller includes a shaft about which the roller rotates. The roller shaft defines an axis of rotation and includes a first end and a second end. The first coupling includes a first arm and a first joint that couples the first end of the roller shaft to the frame such that the roller shaft is free to rotate. The first joint is offset relative to the roller axis by a first distance. The second coupling includes a second arm, a second joint, and a third joint that couples the second end of the roller shaft to the frame. The second arm is free to pivot relative to the roller shaft and the frame through the second joint and the third joint. The third joint is offset relative to the roller axis by a second distance that is substantially equal to the first distance and in the same direction relative to the roller axis. The third coupling includes a third arm and a fourth joint that couples the second end of the roller shaft to the frame. The third arm is coupled to the frame through the fourth joint. The fourth joint is offset relative to the roller axis by a third distance that is substantially equal to the first distance. The offset is in an opposite direction relative to the roller axis.

[0006] According to another aspect of the present invention, the fourth joint is constrained to lie substantially in a plane defined by the first joint, the third joint, and a center point located along the length of the roller shaft. The third coupling further comprises a fourth arm and a fifth joint that couples the second end of the roller shaft to the frame, the third arm being coupled to a first end of the fourth arm through the fourth joint located between the third arm and the fourth arm such that the fourth arm is free to pivot relative to the third arm, the fourth joint being offset relative to the roller axis by a second distance that is substantially equal to the first distance but in an opposite direction relative to the roller axis, the second end of the fourth arm being coupled to the frame through the fifth joint such that the fourth arm is free to pivot relative to the frame.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In the detailed description of the example embodiments of the invention presented below, reference is made to the accompanying drawings, in which:

[0008] FIG. **1** is an isometric view of a roller guiding a print media web;

[0009] FIG. **2** gives perspective, top, front, and side views of a roller that is configured to allow rotation about a gimbal axis;

[0010] FIG. **3** gives perspective, top, front, and side views of the roller of FIG. **2** as the roller pivots;

[0011] FIG. **4** is a schematic diagram showing an arrangement of pivoting arms and joints used for allowing gimbaled motion in an embodiment of the present invention;

[0012] FIG. **5**A is a perspective view of a gimbal mechanism in one embodiment;

[0013] FIG. **5**B is a perspective view of a gimbal mechanism in one embodiment, showing a plane that helps to define preferred component positioning for a gimbal apparatus used to maintain uniform web media tension;

[0014] FIG. **6** is an enlarged perspective view that shows components of the second and third couplings for a gimbal mechanism;

[0015] FIG. **7** is an enlarged view that shows components of the first coupling for a gimbal mechanism;

[0016] FIG. **8** is a bottom view showing gimbal mechanism components and distances; and

[0017] FIG. **9** is a bottom view showing components of the second and third couplings.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The present description will be directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the present invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

[0019] Although the term "paper" is used in this application to refer to print media that is printed on by a printing system, the term "print media" should not be restricted to paper or paper based media. Instead, print media includes any media type that is printed on by the printing system, for example, those that include polymeric or metallic films or foils. Additionally, print media includes media types that include those having woven or non-woven structures.

[0020] FIG. **1** shows a portion of a paper path for a web of print media **10** passing through a printing system, for example, one of the printing systems described in U.S. patent application Ser. No. 12/627,018 filed Nov. 30, 2009 entitled "MEDIA TRANSPORT SYSTEM FOR NON-CONTACT PRINTING", by Muir et al.

[0021] In FIG. **1**, the print media **10** comes in from the right and passes over a roller **14** and around a roller **16** before exiting to the left. The print media **10** wraps around a portion of the roller **16** and exits from the bottom of the roller **16** as indicated by the arrows **18**. The print media **10** is under tension in the direction of paper motion. If the tension of the print media **10** isn't balanced across its width in the span just preceding roller **14**, for example, the tension can be higher along the front edge **22** of the print media web than along the back edge **24** of the print media web. If this happens, the print media as it wraps around the roller **14** tends to drift laterally in the direction of the front edge of the web. Similarly if the tension of the print media isn't balanced across its width in the span **26** between rollers **14** and **16**, for example, the tension is higher along the back edge **24** of the print media web than along the front edge **22** of the print media web, the print media as it wraps around the roller **16** then tends to drift laterally in the direction of the back edge **24** of the web.

[0022] Print media transport systems, particularly systems that utilize exact constraint or kinematic design, can use various arrangements of castered and gimbaled rollers in order to maintain uniform web tension and reduce or eliminate unnecessary constraints that would otherwise cause unwanted steering or other misalignment along the media path. For example, one such system that applies kinematic principles along the media path for a printing system, called kinematic media transport, is described in commonly assigned U.S. patent application Ser. No. 12/627,018 entitled "MEDIA TRANSPORT SYSTEM FOR NON-CONTACTING PRINTING" by Muir et al. Kinematic media transport is particularly well suited for printing apparatus that provide non-contact application of ink or other colorant onto a continuously moving medium. There are often dynamic considerations with such systems, in which changing conditions of the traveling print medium necessitate compensation by the media handling apparatus in order to maintain proper registration. The printhead of such a device, for example, selectively moistens at least some portion of the media as it courses through the printing system, which can impact media weight and stiffness, including cross-track stiffness, in a variable manner.

[0023] Depending on the relative configuration of rollers along the media path, an arrangement of castered and gimbaled rollers can be used to correct for cross-track drift caused by incorrect or variable cross-track web tensioning and thus help to prevent misalignment of the media. With respect to the orthogonal axes shown in FIG. **1**, both caster and gimbal movement relate to rotational degrees of freedom (DOF) at a center point C along the roller **14**. In the orientation shown, caster relates to rotation about the y-axis. Gimbal relates to rotation about the z axis. Axis x indicates the cross-track direction.

[0024] FIG. **2** provides perspective, top, front, and side views of a roller **50** that is configured with a gimbaled mounting, rotatable around joints J1 and J4. Coordinate axes are shown for perspective, top, and front views. Joints J1 and J4 are not aligned with the corresponding first and second ends of the roller shaft **52** and **54**, but are offset from the roller axis. The first and second ends of the roller shaft, **52** and **54** are connected to the joints by arms A1 and A3. Arm A1 is rigidly connected to the first end of the roller shaft **52**, and arm A3 is rigidly connected to the second end of the roller shaft **54**. Print media **10** is approaching the roller **50** from the left. It wraps partially around the roller and leaves the roller in a downward direction.

[0025] With the arrangement of FIG. **2**, a tension variation across the width of the web as it leaves the roller produces a force at the end of shaft **52** that differs from the force at the end of shaft **54**, resulting in a moment (torque), through arms A1 and A3, at joints J1 and J4. As a result, roller **50** rotates about the z axis until forces at either end of the roller shaft are equalized, thereby equalizing cross-track web tension in the span downstream of the roller.

[0026] FIG. **3** shows how the gimbal motion occurs with respect to different views and coordinate axes. A rotated position is shown with solid lines, while the unrotated position is represented with dashed lines. As represented in the perspective and front views, gimbal motion relates to rotation about the z axis, relative to center point C, shown as rotating an angle θ in the front view. As shown in the top view of FIG. **3**, the rotation about the z axis is accompanied by a smaller amount of rotation about the y axis, causing a small amount of caster angle of the roller. This small rotation about the y axis that accompanies the rotation around the z axis is called a parasitic rotation.

[0027] In many applications, the parasitic rotation about the y-axis shown in FIG. **3** is of no consequence, particularly where an upstream roller also has a gimbaled arrangement. In such a case, the upstream roller compensates for the slight amount of caster so that uniform web tension can be maintained across the span approaching the roller **50**. However, there are applications for which this parasitic y-axis rotation can cause problems. In printing applications, for example, wherein proper web tensioning is an important factor in dot-to-dot registration, parasitic caster can steer the web, causing misalignment of the media and misregistration. In such applications, then, it is necessary to allow gimbal rotation of a roller to maintain web tension, but to constrain caster rotation to near zero.

[0028] Embodiments of the present invention address the problem of maintaining a uniform media web tensioning by providing a web tensioning apparatus that allows gimbal action but more effectively constrains caster rotation, so that parasitic caster rotation is reduced or eliminated, in turn reducing a tendency for unwanted cross-track motion of the moving media within the media transport system.

[0029] The schematic diagram of FIG. **4** shows an apparatus for maintaining uniform tension across the width of a moving print medium. There are a number of features for providing gimbaled roller **50**, rotating about gimbal axis G, with constrained caster rotation according to one embodiment. In this embodiment, a series of links and corresponding joints are used to enable the needed gimbaled movement of roller **50** without appreciable caster. Roller **50** is mounted within an equipment frame **40** and is rotatable about its shaft.

[0030] In a first coupling **42**, first end **52** of the roller shaft is rigidly connected to a first arm A1 that extends away from the roller axis to a first joint J1 that is mounted to the equipment frame **40**, thereby coupling the first end **52** of the roller shaft to the frame **40** through arm A1 and joint J1. The roller shaft is thus free to rotate in all directions around joint J1.

[0031] A second coupling **44** and a third coupling **46** are at the opposite end of the roller **50** shaft from the first coupling **42**. The second coupling couples the second end **54** of the roller shaft to the frame **40** by means of a second arm A**2** and joints J**2** and J**3**. Joints J**2** and J**3** individually allow arm A**2** to pivot freely in all directions relative to the roller shaft **54** and the frame **40**, respectively. In one embodiment, joint J**2** is substantially in line with the roller **50** axis. The second end **54** of the roller shaft is rigidly connected to a first arm A**3** that extends away from the roller axis to a fourth joint J**4** that is coupled to the equipment frame **40**, thereby coupling the second end **54** of the roller shaft to the frame **40** through arm A**3**; this coupling forming a third coupling. The fourth joint J**4** is not rigidly coupled to the frame. Joint **4** is coupled to frame in a manner that allows the joint **4** to move in the z direction but constrains it to lie substantially in a plane defined by the first joint J**1**, the third joint J**3**, and a center point along the length of the roller shaft. This corresponds to constraining joint J**4** to lie substantially in the X-Z plane passing through these three points. In the embodiment shown in FIG. **4** this constraint on the position of joint J**4** is provided by a fourth arm A**4**. The fourth arm A**4** is coupled to arm A**3** by means of joint J**4** and is coupled to the frame **40** by means of fifth joint J**5**. The radius of rotation of rotatable arm A**2** is substantially equal to distance D**1**. Preferably, one or more of joints J**1**, J**2**, J**3**, J**4**, and J**5** are spherical or ball joints although others joint types are permitted.

[0032] The length of first arm A**1** is an offset distance D**1**, measured from the roller axis to the pivoting center of joint J**1**. The length of second arm A**2** is a distance D**2**, the distance between the pivoting centers of joints J**2** and J**3**. The length of third arm A**3** is a distance D**3**, measured from the roller axis to the pivoting center of joint J**4**. Each of these distances is measured along the z axis. Distances D**1**, D**2**, and D**3** are substantially equal to each other.

[0033] Still referring to FIG. **4**, operation of the apparatus for maintaining uniform web tension is described. The print media **10** moves around a portion of roller **50**. A tension variation across the width of the web of print media **10** in the web span leaving the roller **50** produces a force at the end of shaft **52** that differs from that at the end of shaft **54**, resulting in a moment (torque) at joints J**4** and J**1**. As a result, roller **50** rotates about the z-axis (G) to equalize forces at either end of the roller shaft, causing one end of the roller shaft to move up while the other end of the roller shaft moves down, these movements being in the plus and minus Y directions of FIG. **4**. As arm A**1** rotates about joint J**1**, the end of arm A**1** attached to the roller shaft moves in the z direction. This also moves the first end **52** of the roller shaft in the z direction. Failure to move the second end of the roller shaft by the same amount in the z direction would impart an unwanted caster angle rotation of roller **50** about the y axis. Second and third couplings **44** and **46** cooperate to eliminate such parasitic caster rotation.

[0034] As arm A**1** rotates, pivoting about joint J**1** in one direction, arm A**3**, pivoting at joint J**4**, rotates in the opposite direction by a corresponding amount. Since distances D**1** and D**3** are equal, the rotations at the two ends of the roller shaft are equal. As a result rotation of the roller takes place about center point C, along axis G. Arms A**2** and A**4** cooperate in such a way that joint J**4** is able to move slightly in the z direction, thereby forcing roller shaft end **54** to move in the z direction by the same amount as shaft end **52** does. Arm A**2** is attached at one end to frame **40**, and at the other end to the roller shaft. Thus, as arm A**3** rotates, arm A**2** also rotates. Rotation of arm A**2** moves that end of the roller shaft in the z direction a distance equal to the equivalent z direction movement of the other end of the shaft as connected to arm A**1** since distance D**2** is substantially equal to distance D**1**. Thus, angular rotation about the y axis, or caster, is eliminated.

[0035] It can be observed that end of roller shaft **54** is free to move in the z direction by its connection to frame **40** through arm A**4**. One end of arm A**4** is connected to arm A**3** at joint J**4**. The other end of arm A**4** connects to frame **40** through joint J**5**. Preferably joint J**5** and joint J**4** lie in a Y-X plane that is substantially perpendicular to the X-Z plane, which contains joints J**1** and J**3** and the center point C; the X-Y plane being parallel to the roller axis. Small rotations of arm A**4** around joint J**5** permit joint J**4** to move small amounts in the z direction without significant motion in the y direction. As a result the fourth joint J**4** is constrained to lie substantially in the plane defined by the first joint, J**1**, the third joint J**3**, and the center point C that is located along the length of the roller shaft.

[0036] The cooperative effect of arms A**1** and A**2** in preventing caster rotation can be more readily visualized by considering their equal lengths D**1** and D**2**, respectively, with joints J**1** and J**3** both mounted to frame **40**. Since joint J**2** remains substantially in line with the roller shaft during gimbal rotation about the z axis, rotation about the y axis, or caster, is effectively constrained with this mechanical arrangement.

[0037] The perspective views of FIGS. **5**A, **5**B, and **6** show an embodiment of roller **50** within frame **40** using the components and mechanical linkage described with reference to the schematic diagram of FIG. **4**. The perspective view of FIG. **6** shows an enlarged view of mechanical components closest to second end **54** of the roller shaft. Mounts **60** and **62** are fastened to frame **40** and provide a platform for pivoting movement about appropriate axes for other joint and arm components. In this arrangement, as shown in FIG. **5**B, fourth joint J**4** is constrained so that it lies substantially in the same plane P as a center point C along the length of the roller **50** shaft and first and third joints J**1** and J**3**, respectively. Fifth joint J**5** can be offset relative to this plane.

[0038] Referring to FIG. **6**, the second end **54** of the roller shaft is coupled to the frame **40** by a third coupling **46** made up of third arm A**3**, fourth joint J**4**, fourth arm A**4**, and fifth joint J**5**. Third arm A**3** is coupled to a first end of fourth arm A**4** through joint J**4** that lies between third arm A**3** and fourth arm A**4**. Fourth arm A**4** is free to pivot relative to third arm A**3**; the fourth joint J**4** is offset relative to the roller **50** axis by distance D**2** (FIG. **4**), with the displacement offset in the opposite direction relative to the roller axis from offset distance D**1**. A second end of fourth arm A**4** is coupled to frame **40** through fifth joint J**5**, so that fourth arm A**4** is free to pivot relative to frame **40**.

[0039] The second end **54** of the roller shaft is also coupled to the frame **40** by second coupling **44** that is made up of second joint J**2**, second arm A**2**, and third joint J**3**. In the embodiment of FIG. **6**, joint J**2** is coupled to the second end **54** of the roller shaft by means of suspended block **66** that is rigidly connected to the second end **54** of the roller shaft. As shown in FIG. **6**, joint J**2** is aligned with the roller axis, while joint J**3** is offset relative to the roller **50** axis. As FIG. **4** showed, this offset is distance D**2**, which is equal to distance D**1**.

[0040] The perspective view of FIG. **7** shows an enlarged view of mechanical components closest to first end **52** of the roller shaft. A mount **64** is attached to frame **40** and provides the stationary pivot point for joint J**1**. At this end of roller **50**, first coupling **42**, made up of the first arm A**1** and first joint J**1**, thus couples the roller **50** shaft to frame **40**, allowing rotation of roller **50** about the axis of arm A**1** and also allowing rotation of arm A**1** and roller **50** about a second axis Q**2** that is parallel to the roller axis and offset relative to the roller axis by distance D**1**.

[0041] FIG. **8** is a bottom view of roller **50** and its support components, showing equal distances D**1**, D**2**, and D**3** from a different perspective. The bottom view of FIG. **9** is an enlarged view of components nearest to second end **54** of the roller shaft. A suspended block **66** is the movable member that is coupled to second end **54** of the roller shaft and is suspended from the frame by virtue of the jointed coupling to arm A**2** at joint J**2** and its coupling to arm A**3**. Suspended block **66** is rigidly coupled to second end **54** of the roller shaft. Joint J**2** and arm A**3** both couple to the second end **54** of the roller shaft by means of this suspended block

[0042] As shown in FIG. **9**, fourth arm A**4**, pivoted on a fifth joint J**5**, forces a constraint in the y direction (normal to the page in this view). Because its pivoting action provides a degree of freedom in the z direction, along the arc of curvature from joint J**5**, as best seen in FIG. **6**, it is advantageous to make fourth arm A**4** longer than the other arms of the gimbal control link assembly, longer than distances D**1**, D**2**, and D**3**. This arrangement helps to minimize movement of fourth joint J**4** out of the plane P (FIG. **5**B) defined by joints J**1** and J**3** and center point C.

[0043] In operation, unwanted z-direction movement of one end of roller **50** relative to the other end of the roller, corresponding to unwanted caster movement, is controlled by the combination of linkages on both sides of frame **40**, while allowing gimbal movement at the same time. The combined interaction of these components provides equal foreshortening in the z direction, effectively compensating any rotation about the y-axis and constraining caster.

[0044] Since both the second arm A**2** and the fourth arm A**4** can rotate freely as a result of joints J**2** and J**3**, and joints J**4** and J**5** respectively, the mounting of the second end of the roller shaft **54** by means of couplings **44** and **46** is insensitive to small variations in the spacing between the frame portions on the first and second end of the roller shaft. This simplifies installation of the gimbaled roller assembly and makes it insensitive to thermal expansion differences between the roller shaft and the frame.

[0045] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention.

PARTS LIST

[0046] **10** Print media
[0047] **12** Roller
[0048] **14** Roller
[0049] **16** Roller
[0050] **18** Arrow
[0051] **22** Front Edge
[0052] **24** Back Edge
[0053] **26** Span
[0054] **40** Frame
[0055] **42** First coupling
[0056] **44** Second coupling
[0057] **46** Third coupling
[0058] **50** Roller
[0059] **52** First end of roller shaft
[0060] **54** Second end of roller shaft
[0061] **60** Mount
[0062] **62** Mount
[0063] **64** Mount
[0064] **66** Suspended Block
[0065] A**1** First arm
[0066] A**2** Second arm
[0067] A**3** Third arm
[0068] A**4** Fourth arm
[0069] C Center point
[0070] D**1** First distance
[0071] D**2** Second distance
[0072] D**3** Third distance
[0073] J**1** First joint
[0074] J**2** Second joint
[0075] J**3** Third joint
[0076] J**4** Fourth joint
[0077] J**5** Fifth joint
[0078] G Gimbal axis
[0079] Q**2** Axis
[0080] P Plane

1. An apparatus for maintaining uniform tension across a width of a web, the apparatus comprising:
- a frame;
- a roller including a shaft about which the roller rotates, the roller shaft defining an axis of rotation, the roller shaft including a first end and a second end;
- a first coupling including a first arm and a first joint that couples the first end of the roller shaft to the frame such that the roller shaft is free to rotate, the first joint being offset relative to the roller axis by a first distance;
- a second coupling including a second arm, a second joint, and a third joint that couples the second end of the roller shaft to the frame, the second arm being free to pivot relative to the roller shaft and the frame through the second joint and the third joint, the third joint being offset relative to the roller axis by a second distance that is substantially equal to the first distance and in the same direction relative to the roller axis; and
- a third coupling including a third arm and a fourth joint that couples the second end of the roller shaft to the frame, the third arm being coupled to the frame through the fourth joint, the fourth joint being offset relative to the roller axis by a third distance that is substantially equal to the first distance, the offset being in an opposite direction relative to the roller axis.

2. The apparatus of claim **1**, wherein the first coupling couples the first end of the roller shaft to the frame such that the roller shaft is free to rotate around a first axis that is perpendicular to the roller and a second axis that is substantially parallel to the roller axis and offset relative to the roller axis by the first distance.

3. The apparatus of claim **1**, wherein the fourth joint is constrained to lie substantially in a plane defined by the first joint, the third joint, and a center point located along the length of the roller shaft.

4. The apparatus of claim **3**, wherein the third coupling further comprises a fourth arm and a fifth joint that couples the second end of the roller shaft to the frame, the third arm being coupled to a first end of the fourth arm through the fourth joint located between the third arm and the fourth arm such that the fourth arm is free to pivot relative to the third arm, the fourth joint being offset relative to the roller axis by a second distance that is substantially equal to the first distance but in an opposite direction relative to the roller axis, the second end of the fourth arm being coupled to the frame through the fifth joint such that the fourth arm is free to pivot relative to the frame.

5. The apparatus of claim **4**, wherein the fifth joint is located offset relative to the plane.

6. The apparatus of claim **4**, wherein the fifth joint is located offset relative to the fourth joint by a fourth distance that is greater than or equal to the first distance.

7. The apparatus of claim **1**, wherein the second joint is located substantially in line with the roller axis.

8. The apparatus of claim **1**, wherein the third joint is located substantially in line with the second axis that is substantially parallel to the roller axis and offset relative to the roller axis by the first distance.

9. The apparatus of claim **1**, wherein one or more of the joints include spherical joints.

10. A method of maintaining uniform tension across a width of a web of media comprising:

providing an apparatus including:

a frame;

a roller including a shaft about which the roller rotates, the roller shaft defining an axis of rotation, the roller shaft including a first end and a second end;

a first coupling including a first arm and a first joint that couples the first end of the roller shaft to the frame such that the roller shaft is free to rotate, the first joint being offset relative to the roller axis by a first distance;

a second coupling including a second arm, a second joint, and a third joint that couples the second end of the roller shaft to the frame, the second arm being free to pivot relative to the roller shaft and the frame through the second joint and the third joint, the third joint being offset relative to the roller axis by a second distance that is substantially equal to the first distance and in the same direction relative to the roller axis; and

a third coupling including a third arm and a fourth joint that couples the second end of the roller shaft to the frame, the third arm being coupled to the frame through the fourth joint, the fourth joint being offset relative to the roller axis by a third distance that is substantially equal to the first distance, the offset being in an opposite direction relative to the roller axis; and

causing a media to move around a portion of the roller of the apparatus.

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