(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 195 262 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.04.2002 Bulletin 2002/15

(51) Int Cl.[7]: **B41N 7/00**

(21) Application number: **01121795.7**

(22) Date of filing: **21.09.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **04.10.2000 US 679421**

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(54) Layered roller

(57) A roller that is insensitive to changes in engagement and drag torque, includes a rigid core; a first layer surrounding the core and having a Poisson's ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 MPa; a second layer surrounding the first layer and having a modulus of elasticity between 50 thousand and 210 thousand MPa; and a third layer surrounding the second layer and having a Poisson ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 Mega-Pascals.

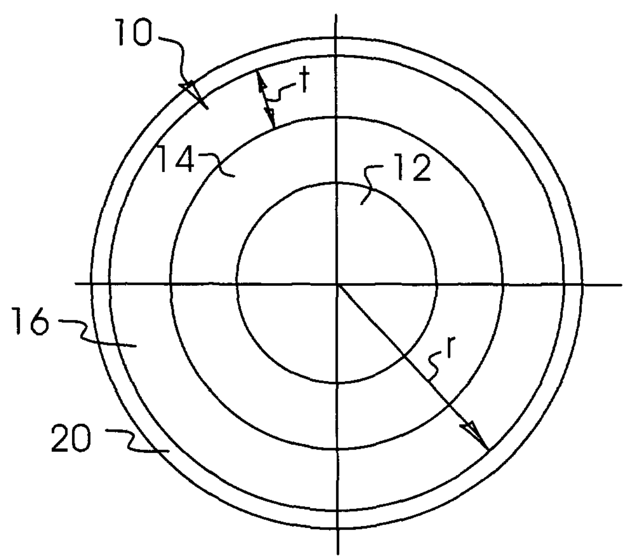

FIG. 3

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Description

Field of the invention

[0001] The present invention relates to rollers having an elastomeric covering, and in particular to rollers that are used in applications that require precise or consistent control of position or motion.

Background of the invention

[0002] Elastomeric covered rollers are used in a variety of applications for moving things such as continuous webs, cut sheets and other mechanical parts. For example media transport rollers are used in printing presses, photographic processing apparatus, printers, tape recorders, fax machines, scanners, web manufacturing and coating equipment. Rollers are used in apparatus such as phonograph players to move a turntable.

[0003] Many of these applications require precise or consistent control of the position or motion of the thing being moved by the roller. However, since the elastomeric covered roller deforms due to contact with the other surface, the points on the surface of the roller near the contact zone or nip will travel a different distance in the same amount of time as those points farther away from the nip. In other words, due to the circumferential straining, the arc length of the roller surface changes. This also means that the points near or in the nip are traveling in different surface speed than the points on the roller surface away from the nip. This speed variation exists in the pressure nip formed by frictionally driven rollers and is well known as overdrive or underdrive depending upon whether a point on the layered roller will bulge or contract during engagement. Engagement is defined herein as the difference between the radius r of the roller and the distance H between the center of the roller and the surface of the thing being contacted by the roller, the difference being due to the amount of distortion of the surface of the roller.

[0004] This phenomenon is a common problem in all applications mentioned above. It will be evident that the accuracy of the roller in controlling the position or motion is affected by the engagement of the roller with the thing being moved, or with the engagement of the roller with a driving member. If the engagement is not precisely controlled, the roller overdrive or underdrive will change. Additionally, the overdrive or underdrive can vary over the length of the contact zone of the roller resulting in variable degrees of slippage between the roller and the thing being driven.

[0005] Another problem with prior art elastomeric coated rollers is that they are sensitive to any drag torque that is transmitted through the contact between the roller and the thing being driven. Drag torque variations cause motion changes in the thing being driven.

[0006] An example of an elastomeric coated roller is found in US Patent Number 5,768,990 issued Jun. 23, 1998 to Vrotacoe et al. Vrotacoe et al. disclose a tubular printing blanket for a blanket cylinder in an offset printing that includes a cylindrical sleeve, a compressible layer over the sleeve, and an inextensible layer over the compressible layer. The problem with such a roller is that the compressible layer will result in high sensitivity to engagement and drag torque fluctuation.

[0007] There is a need therefore for an improved roller for which the surface velocity in the nip has a reduced sensitivity to the external changes such as the degree of engagement and drag torque.

Summary of the invention

[0008] The need is met according to the present invention by providing a roller that includes a rigid core; a first layer surrounding the core and having a Poisson's ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 Mega-Pascals (MPa); a second layer surrounding the first layer and having a modulus of elasticity between 50,000 and 210,000 MPa, and a third layer surrounding the second layer and having a Poisson ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 Mega-Pascals.

[0009] The roller according to the present invention has the advantage that it is insensitive to changes in engagement and drag torque.

Brief description of the drawings

[0010]

Fig. 1 is a schematic diagram showing a layered roller in contact with a web;

Fig. 2a-b are plots showing the range of Poisson's ratio and modulus of elasticity for the first layer of the present invention and the range of modulus of elasticity and the thickness for the second layer of the present invention respectively;

Fig. 3 is a schematic diagram showing a layered roller having a further elastomeric coating according to the present invention;

Fig. 4a-b are plots showing the sensitivity of a prior art layered roller and the roller of the present invention to changes in engagement. and to changes in drag torque respectively;

Figs. 5a -b are plots showing the sensitivity of a prior art layered roller and the roller of the present invention (examples 2) to changes of engagement respectively.

Detailed description of the invention

[0011] Referring to Fig. 1, a roller **10** according to the present invention includes a rigid core **12**, a first layer **14** surrounding the core, and a second layer **16** surrounding the first layer. The roller is shown in engagement with a web or sheet **18**. The core **12** can be a solid bar, or a tube. In the preferred embodiment of the present invention, the core **12** is a metal tube, for example steel. As shown by the cross hatched region **22** in Fig. 2a, the first layer **14** has a normalized effective axial stiffness (NEAS), as defined in Equation (1), in a range 0.125-6.0 MPa, preferably in a range 0.25-4.25 MPa, a Poisson's ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 MPa.

$$NEAS = \frac{AE}{\pi \, r^2} = \left[2t / r - (t^2 / r^2)\right] E = \left(2n - n^2\right) E \qquad (1)$$

Where $n = t/r$, A, E, r and t are the area, modulus of elasticity, radius and the thickness of the first layer as shown in Fig. 1.

[0012] In a preferred embodiment of the invention, the first layer is an elastomeric material such as polyurethane. The first layer can also be made up of two or more layers having different moduli of elasticity, as long as the overall properties of the combined layers fall within the specified ranges of Poisson's ratio and modulus of elasticity. The second layer **16** has a modulus of elasticity between 50,000 MPa and 210,000 MPa, and is preferably a metal such as nickel. As shown by the cross hatched region **24** in Fig. 2b, the second layer has a normalized effective axial stiffness (NEAS), in a range 100-12500 MPa, preferably in a range 500-4500 MPa. In Figs. 2 a and b, the contours are the normalized effective axial stiffness for the second layer. The thickness of the layered roller was normalized by the radius of the layered roller for the horizontal axis.

[0013] The existence of the second layer significantly reduces the speed ratio sensitivity by constraining the compliant layer beneath it. As a result, the tendency of changing the circumference thereby changing the speed ratio, due to the change of external conditions is greatly minimized in the present invention as compared to a prior art roller.

[0014] Referring to Fig. 3, the roller **10** may optionally include a third layer **20** surrounding the second layer **16** and having a Poisson's ratio and a modulus of elasticity which is in the same range as the first layer, i.e. a Poisson's ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 MPa.

[0015] The basic issue involved with the present invention is how accurate do various elastomeric-covered layered rollers transport media, parts and other machine component for processing such as calendaring and coating. As noted above, it is well known that the elastomeric-covered layered roller tends to bulge during contact and forms a nip area. Therefore media or machine components moving through the nip travel at speeds which are different than would be predicted based on simple tangential-speed calculations using the undeformed outer radius of the layered roller. Let us assume that, referring to Fig. 1, the core **12** that the elastomeric roller is attached to is rigid and spins at a known rotational rate □. Therefore the surface speed of the roller is just $r \cdot \omega$. Imagine this rotating elastomeric roller forms a pressure nip with a surface or a counter-rotating roller using a frictional drive between the roller during contact. In fact, points on the surface of the roller far away from the nip (contact) region are moving with the nominal surface speed, $r \cdot \omega$. As we move closer to the contact region however, the particles on the surface of the roller will begin to feel the effects of the deformation that is taking place. Therefore, the velocity of the particles in the nip region is affected by the deformation of the roller. Depending upon this deformation these surface particles can move at a rate that is either faster or slower than the nominal surface speed, of the roller.

[0016] Now the question becomes: "will a particular roller bulge or contract in the nip region?". In other words, for a prior art roller that has an outer rubber layer, the mechanical properties such as modulus of elasticity and Poisson's ratio of the elastomeric material have the most influence over the bulging or contracting behavior. With a high Poisson's ratio, e.g. 0.49, a ratio usually associated with elastomeric materials, as the roller is pressed into a rigid surface, the points close to the nip would bulge out. Since the arc length of the roller surface has increased, the points must be moving faster. To help us characterize this behavior, we will introduce the concept of the speed ratio. The speed ratio is simply the ratio of the actual speed of the media V_0 or machine component that is frictionally driving or driven by the elastomeric-covered roller to the actual surface speed of the elastomeric-covered roller in the nip region $r \cdot \omega$. Depending on the functionality of the prior art roller in the system, the speed ratio can be greater (overdrive), less (underdrive) than or equal to unity. Due to the fact that the elastomeric materials tend to be very compliant with a modulus of the elasticity thousands, even tens of thousands, times smaller than that of metals, e.g. aluminum and steel, the speed ratio of the prior art roller is very sensitive to the changes of external conditions such as engagement and drag torque. With reference to Fig. 1, engagement is defined as:

$$Engagement = r - H.$$

[0017] By including a stiffening layer in a layered roller of the invention, sensitivities of the speed ratio to the external excitation such as the variation of engagement and drag torque are reduced significantly. The resulting roller is stiff in the axial direction, but compliant in the radial direction. To obtain speed ratios and speed ratio sensitivity information for a preferred layered roller, both preferred layered roller embodiments of Figs. 1 and 3 were examined numerically. Furthermore, in order to define the preferred range of material properties, twenty-five rollers with various Poisson's ratio ranging from 0.4 to 0.499 and modulus of elasticity of 0.18 to 8 MPa of the first layer and thickness of 0.08 - 0.8 mm for the second layer were investigated. For the benchmark comparison, the results were compared with the numerical results of a prior art roller having identical geometry and materials except for a second stiffening layer.

[0018] A finite element model that simulates the deformation of layered roller of invention under contact and the free rotation due to frictionally driven by a media was constructed. As shown in Fig. 1, the roller **10** was brought into contact with the media **18** then the media **18** was moved toward the right hand side at a speed of 15 mm/s and frictionally drives the roller **10**. Fig. 4a shows the calculated speed ratios of the layered rollers of the present invention **26** and the prior art roller **28** in several engagements. It is noted that the speed ratios of the layered roller of the invention lie in a tight range near unity and are insensitive to engagement despite the fact that the layered rollers of the invention have a wide variation of physical and mechanical properties. Fig. 4b shows that the speed ratios of the layered roller **30** of the present invention are insensitive to the drag torque, while the speed ratios of the prior art rollers **32** are very sensitive to the drag torque. These results concluded that the existence of the second layer significantly reduces the speed ratio sensitivity by constraining the compliant layer beneath it. Consequently, the tendency of changing the circumference thereby changing the speed ratio, due to the change of external conditions is greatly minimized in the present invention as compared to a prior art roller. From the results of the computer simulation, the preferred range of material properties represented by normalized effective axial stiffness (NEAS) was determined as shown by the shaded regions in Figs. 2a and 2b.

[0019] It is also noted that the speed ratios of preferred layered rollers as represented by the embodiment of Fig. 1 are always greater than unity. The speed ratios of preferred layered rollers as represented by embodiment of Fig. 3 can be less than unity when appropriate physical and mechanical properties of materials were used. Therefore, if a design calls for speed ratio less than unity, the preferred layered rollers represented by the embodiment of Fig. 1 should be selected. To obtain speed ratios and speed ratio sensitivity information for the preferred layered roller of the embodiment of Fig. 3, a finite element model similar to the one discussed previously was modified to include an additional outer layer for the third layer **20** of polyurethane. In the model, the first layer **12** and the third layer **20** are polyurethane having Poisson's ratio of 0.495 and modulus of elasticity of 5.72 MPa. The second layer **16** is 0.2 mm thick and has a modulus of elasticity varying from 50 to 210 GPa (see Fig. 2b). For the benchmark comparison, the results were compared with the numerical results of a prior art roller having identical geometry and materials except for the absence of a second layer. Two sets of the preferred layered rollers with different third layer thickness (1mm and 2mm) were investigated. Fig. 5a (1mm thick third layer) and 5b (2mm thick third layer) clearly show the surface velocity in the nip of the preferred layered rollers embodiment of Fig. 3 have a reduced sensitivity to the degree of engagement. The speed ratio vs. engagement **34** and **38** for the prior art rollers is clearly greater than for the layered rollers of the present invention as shown by curves **36** and **40**.

EXAMPLE 1

[0020] An example of a roller according to the embodiment of the present invention shown in Fig. 1 has core **12** of steel tubing 4 mm thick, 50.8 cm in diameter and 30 cm in length. A first 6 mm thick layer **14** of polyurethane having a density of 1.1 gm/cm^3, a Poisson's ratio of between 0.4 to 0.499 and a modulus of elasticity of between 0.1 to 10 MPa is molded on the roller. A second 0.03mm to 0.8mm thick layer **16** of nickel is deposited, for example by sputtering, on the polyurethane layer **14**, or by molding the roller in a sleeve of the metal.

EXAMPLE 2

[0021] An example of a roller according to the embodiment of the present invention shown in Fig. 3 has core **12** of aluminum tubing 8 mm thick, 50.8 cm in diameter and 30 cm in length. A first 6mm thick layer **14** of polyurethane having a density of 1.1 gm/cm^3, a Poisson's ratio of 0.495 and a modulus of elasticity of 3.45 MPa is molded on the roller. A second 0.2mm thick layer **16** of nickel is deposited, for example by sputtering, on the polyurethane layer **14.** A third 1 mm thick layer **14** of polyurethane having a density of 1.1 gm/cm^3, a Poisson's ratio of 0.495 and a modulus of elasticity of 3.45 MPa is molded on the roller.

[0022] 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 spirit and scope of the invention.

PARTS LIST

[0023]

10	roller
12	rigid core
14	first layer
16	second layer
18	web or sheet
20	third layer
22	cross hatched region
24	cross hatched region
26	speed ratio of roller according to invention
28	speed ratio of roller according to prior art
30	speed ratio of layered roller
32	speed ratio of prior art roller
34	speed ratio vs. engagement for prior art rollers
36	speed ratio vs. engagement for layered rollers of the present invention
38	speed ratio vs. engagement for prior art rollers
40	speed ratio vs. engagement for layered rollers of the present invention

Claims

1. A roller (10), comprising:

a) a rigid core (12);
b) a first layer (14) surrounding the core and having a Poisson ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 MPa;
c) a second layer (16) surrounding the first layer and having a modulus of elasticity between 50 thousand and 210 thousand MPa, whereby the roller (10) is insensitive to changes in engagement and drag torque; and
d) a third layer (20) surrounding the second layer (16) and having a Poisson ratio of between 0.4 and 0.5 and a modulus of elasticity of between 0.2 and 10 Mega-Pascals.

2. The roller claimed in claim 1, wherein the core (12) is a metal cylinder, the first layer (14) is an elastomeric compound and the second layer (16) is a metal.

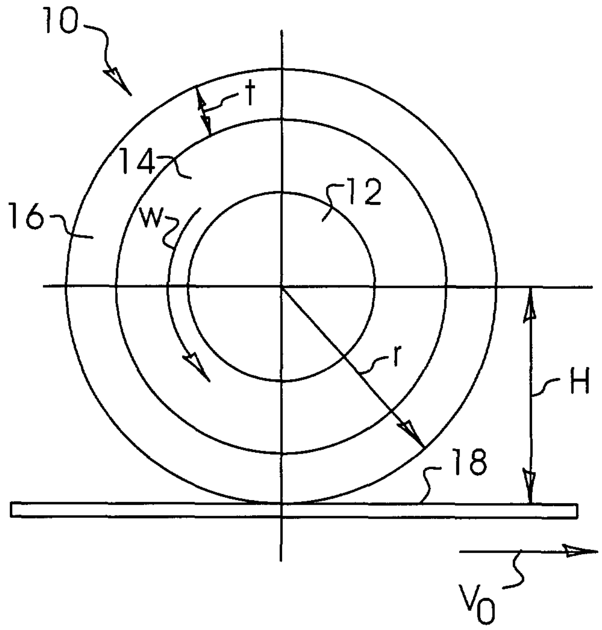

FIG. 1

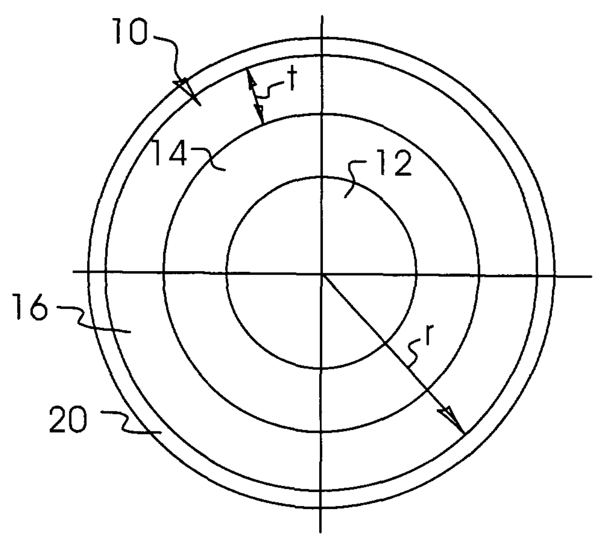

FIG. 3

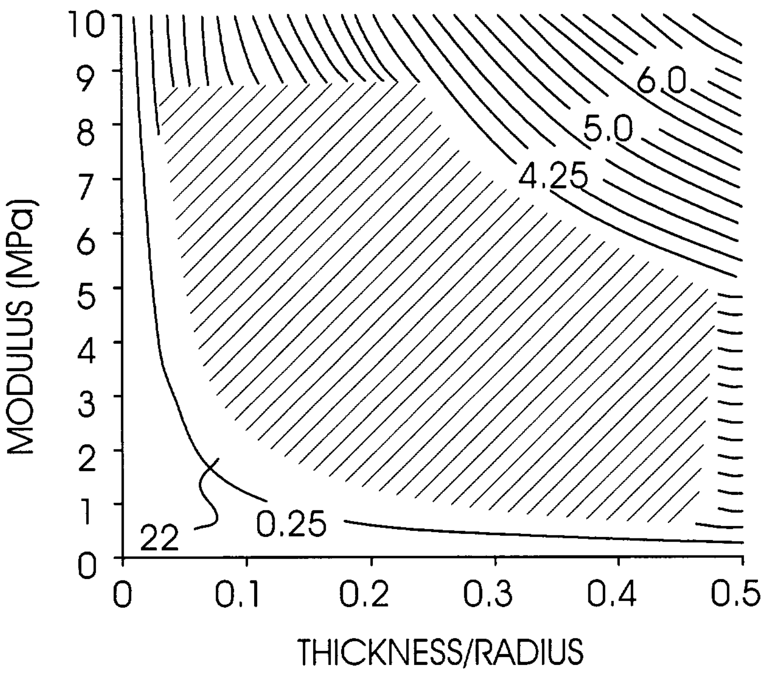
10
9
8
7
6
5
4
3
2
1
0
MODULUS (MPa)
6.0
5.0
4.25
0.25
22
0
0.1
0.2
0.3
0.4
0.5
THICKNESS/RADIUS

FIG. 2A

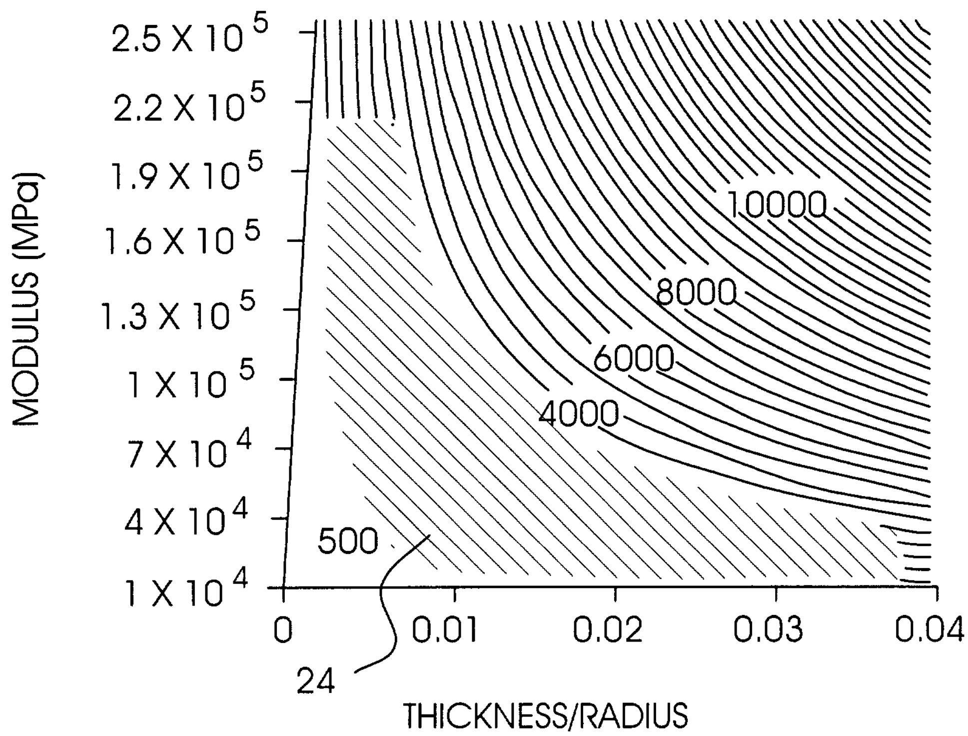
2.5 X 10 5
2.2 X 10 5
1.9 X 10 5
1.6 X 10 5
1.3 X 10 5
1 X 10 5
7 X 10 4
4 X 10 4
1 X 10 4
MODULUS (MPa)
10000
8000
6000
4000
500
24
0
0.01
0.02
0.03
0.04
THICKNESS/RADIUS

FIG. 2B

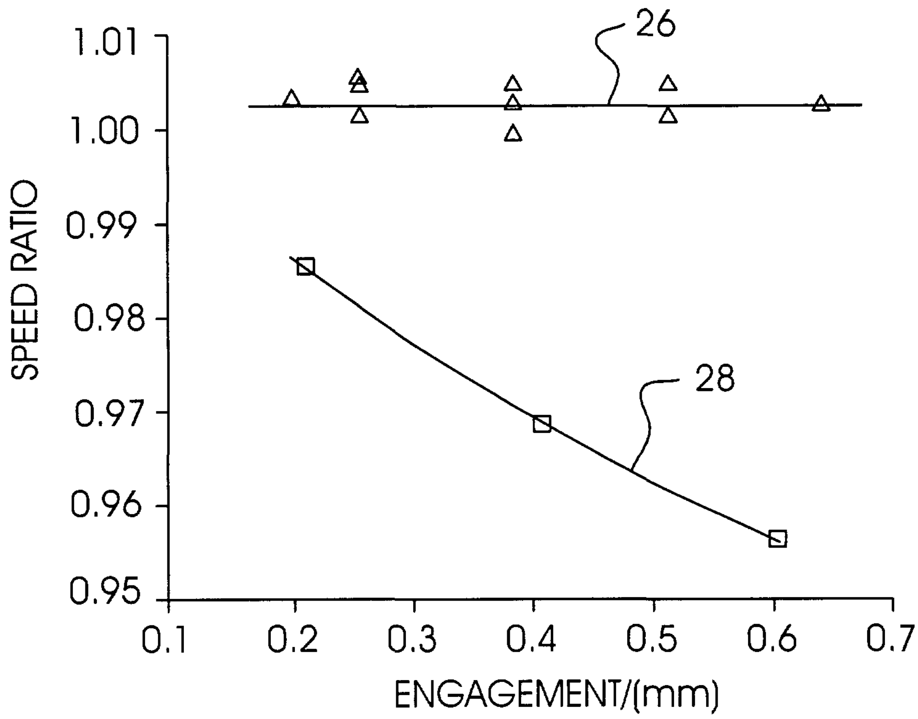
26
1.01
1.00
0.99
0.98
0.97
0.96
0.95
SPEED RATIO
28
0.1
0.2
0.3
0.4
0.5
0.6
0.7
ENGAGEMENT/(mm)

FIG. 4A

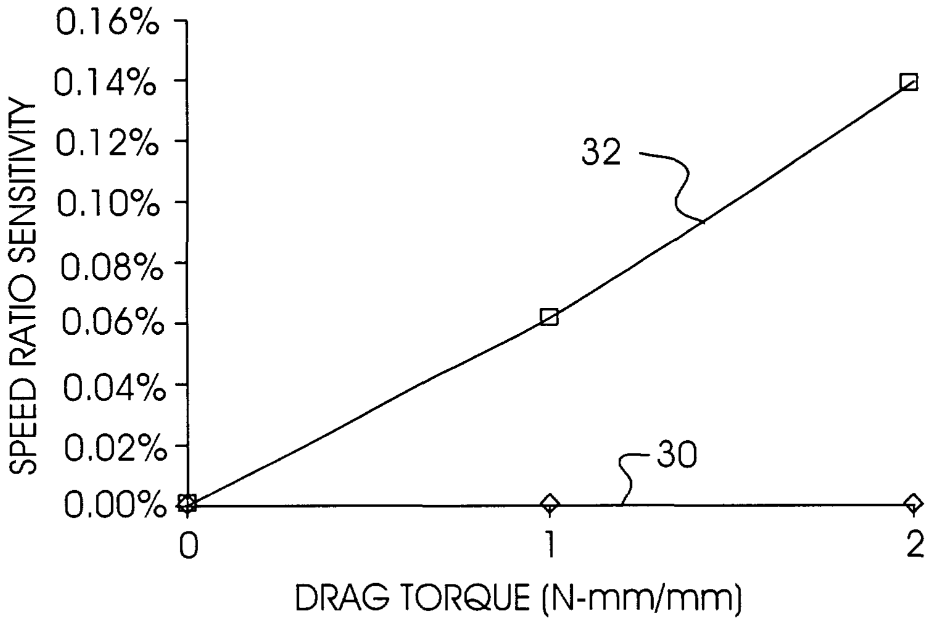
0.16%
0.14%
0.12%
0.10%
0.08%
0.06%
0.04%
0.02%
0.00%
SPEED RATIO SENSITIVITY
32
30
0
1
2
DRAG TORQUE (N-mm/mm)

FIG. 4B

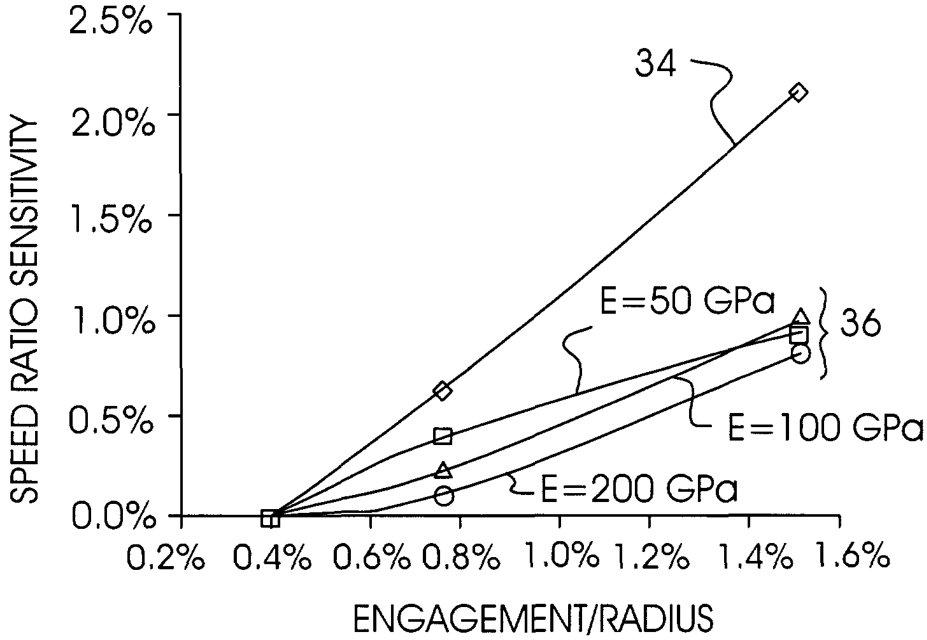
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
SPEED RATIO SENSITIVITY
34
E=50 GPa
36
E=100 GPa
E=200 GPa
0.2% 0.4% 0.6% 0.8% 1.0% 1.2% 1.4% 1.6%
ENGAGEMENT/RADIUS

FIG. 5A

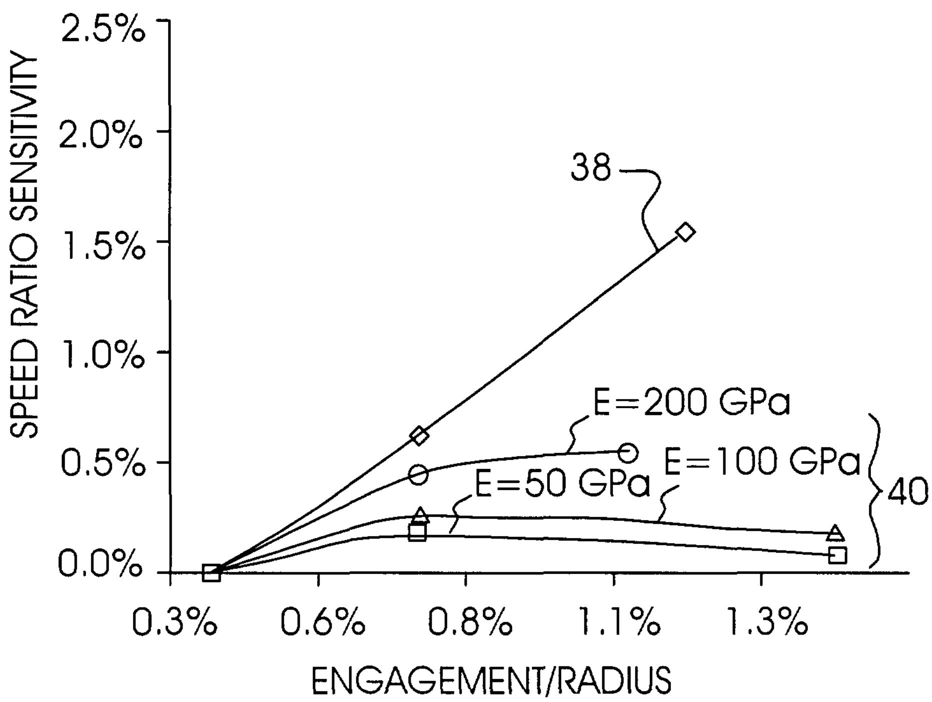
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
SPEED RATIO SENSITIVITY
38
E=200 GPa
E=100 GPa
E=50 GPa
40
0.3% 0.6% 0.8% 1.1% 1.3%
ENGAGEMENT/RADIUS

FIG. 5B