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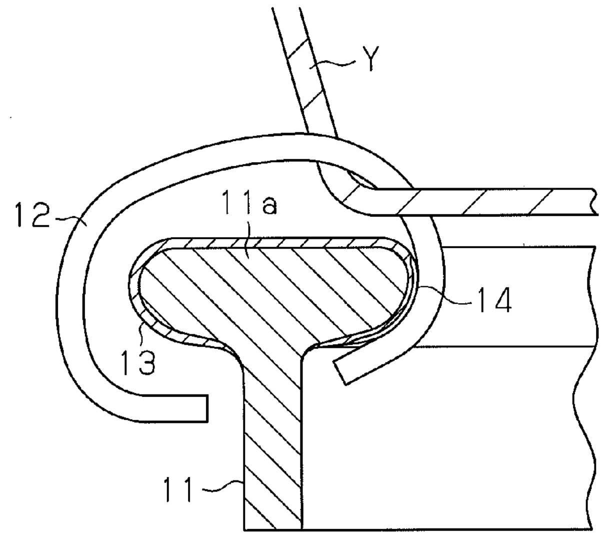
(54) **Ring-traveler system of ring spinning machine**

(57) A ring-traveler system of a ring spinning machine is of a non-liquid lubrication type. The ring-traveler system includes a ring and a traveler that travels along the ring. One of the ring and the traveler includes 400 or more recesses per centimeter in a surface portion on which the other one of the ring and the traveler slides when the traveler travels.

Fig.1C



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a ring-traveler system of a ring spinning machine such as a spinning frame and a twisting frame that twists a yarn using a ring and a traveler.

[0002] Various techniques have been proposed for ring-traveler systems of ring spinning frames to decrease frictional wear and seizing that affect the performance of the ring-traveler system, while increasing the speed and prolonging the life of the system. Such techniques include material variation, surface treatment, shape variation, and the use of liquid lubrication. In particular, the use of liquid lubrication is effective and relatively inexpensive. However, the passing yarn may be smeared with lubricating oil, and the use of oil leads to frequent maintenance. Thus, liquid lubrication is used for only limited applications such as spinning of woolen yarns.

[0003] Japanese Laid-Open Patent Publication No. 8-27633 describes a ring-traveler system having a longer durability and higher productivity. The ring that comes into contact with the traveler includes a polycrystalline ceramic surface. The ceramic surface of the ring has a surface structure including spherical grains. Gaps between the spherical grains provide a storage volume for a spontaneously formed fiber lubrication thin film. The traveler is formed from a resilient material such as metal and has a metal and/or ceramic surface. The metal and/or ceramic surface has a hardness that is greater than or equal to the hardness of the ceramic surface of the ring.

[0004] The ring-traveler system of the publication uses gaps between spherical grains as the storage space for a fiber lubrication thin film. Thus, the fiber lubrication thin film has insufficient adhesive force. This may result in separation of the thin film during operation and thereby increase the traveling resistance of the traveler.

SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to provide a ring-traveler system of a ring spinning machine that decreases wear and improves durability (prolong life) by using a friction reduction effect obtained by lubrication with a thin film of fibers separated from yarns and adhered to sliding surfaces of the ring-traveler system instead of liquid lubrication.

[0006] To achieve the above object, one aspect of the present invention is a ring-traveler system of a ring spinning machine that is of a non-liquid lubrication type. The ring-traveler system includes a ring and a traveler that travels along the ring. One of the ring and the traveler includes 400 or more recesses per centimeter in a surface portion on which the other one of the ring and the traveler slides when the traveler travels.

[0007] The ring spinning machine includes a ring spinning frame and a ring twisting frame that wind a yarn through a traveler that travels (slides) along a ring, which is supported by a ring rail and lifted and lowered. The recess includes a groove and a dimple surround by a flat surface.

[0008] Other aspects and advantages of the present invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1A is a perspective view showing a ring;
Fig. 1B is a partial enlarged view of the ring of Fig. 1A;
Fig. 1C is a schematic cross-sectional view showing the relationship between the ring and a traveler during spinning;
Fig. 2 is a schematic view showing a friction reduction portion;
Fig. 3 is a graph showing the relationships between traveling resistance and traveling distance;
Fig. 4A is a schematic view showing wear of a traveler that is used with a ring including a friction reduction portion;
Fig. 4B is a schematic view showing wear of a traveler that is used with a conventional ring;
Fig. 5 is a schematic perspective view showing a friction reduction portion of the second embodiment;
Fig. 6 is a graph showing the relationships between traveling resistance and traveling distance;
Fig. 7 is a schematic perspective view showing a friction reduction portion of the third embodiment;
Fig. 8 is a graph showing the relationships between traveling resistance and traveling distance;
Figs. 9A and 9B are schematic perspective views showing wear of travelers that are used with rings including friction reduction portions;
Fig. 9C is a schematic perspective view showing wear of a traveler that is used with a conventional ring;
Fig. 10 is a schematic view showing a periodic structure of a friction reduction portion in another embodiment;
Fig. 11 is a partial cross-sectional view showing the shapes of a ring and a traveler in another embodiment; and
Figs. 12A and 12B are schematic views showing the structures of friction reduction portions in other embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

[0010] Referring to Figs. 1A to 4B, a first embodiment of a ring-traveler system of a ring spinning frame will now be described.

[0011] Referring to Figs. 1A to 1C, a ring-traveler system includes a ring 11 and a traveler 12. The ring 11 includes a flange 11a having a T-shaped cross-section. The traveler 12 has a C-shaped cross-section. The ring 11 is made of a bearing steel. A hard chromium plating layer 13 is applied to the flange 11a as shown in Figs. 1B and 1C. The hard chromium plating layer 13 has a thickness of about 10 to 20 μm.

[0012] The plating layer 13 includes a surface portion on which the traveler 12 slides when the traveler 12 travels. The surface portion defines a friction reduction portion 14. In the present embodiment, the friction reduction portion 14 is formed in the inner circumference surface of the flange 11a as shown in Fig. 1C.

[0013] As shown in Fig. 2, the friction reduction portion 14 includes 400 or more grooves 15 per centimeter. The grooves 15 are also referred to as recesses. The grooves 15 are microcracks formed in a surface of the hard chromium plating layer 13. According to Japan Industrial Standard H8615 "Electroplated Coatings of Chromium for Engineering Purposes," microcracks are cracks that are formed with a density of 250 or more cracks per centimeter. Specifically, the microcracks of the present embodiment include not only the microcracks that are originally present when the hard chromium plating layer 13 is formed, but also additional microcracks formed through a surface treatment (electrolytic etching in this embodiment). The microcracks have different lengths and extend in random directions. The number of microcracks is obtained by drawing a straight line on a micrograph of the surface of the hard chromium plating layer 13 and counting the number of cracks intersecting a centimeter-long portion of the straight line. The cracks include cracks that are shaped like dimples and do not elongate like grooves. Since the microcracks vary in length and orientation, the straight line can be drawn at any position in the micrograph.

[0014] A method for increasing the number of microcracks formed in the surface of the hard chromium plating layer 13 will now be described. The present embodiment uses electrolytic etching as a surface treatment.

[0015] A known electrolytic etching process may be performed. The number of microcracks increases in accordance with the electrolytic etching time. The microcracks are not clearly visible on the surface of the hard chromium plating layer 13 before performing electrolytic etching. After electrolytic etching, many microcracks become visible.

[0016] The operation of the ring-traveler system will now be described. A yarn Y, which is fed from a draft part (not shown), passes through the traveler 12 as shown in Fig. 1C and is wound around a bobbin (not shown) that rotates at a high speed. The maximum rotation speed of the ring spinning frame during normal spinning operation is about 25,000 rpm. The yarn Y applied tension, when being wound, to the traveler 12 so that the traveler 12 travels along the flange 11a. Although the orientation of the running traveler 12 slightly varies depending on the rotation speed, the traveler 12 travels in contact with the inner lower portion of the flange 11a.

[0017] When metal objects are in sliding engagement with each other without lubrication in such a manner, severe wear would generally occur. Under such friction conditions of the ring-traveler system, seizing or severe wear may be expected to occur in the ring and traveler after several minutes or hours. However, the actual ring-traveler system has significantly low wear. In a cotton spinning machine, for example, the traveler 12 is usually replaced after one or two weeks. Thus, in terms of tribology, the ring-traveler system is considered as being in an interface lubrication condition and not in a non-lubrication condition. An analysis has shown that a cellulose film serving as lubrication is formed on the surface portion of the ring 11 on which the traveler 12 slides. The cellulose film is formed by fibers that are separated from a yarn Y passing through the traveler 12 during spinning and caught between the ring 11 and the traveler 12.

[0018] In the ring-traveler system of the present embodiment, the ring 11 includes the friction reduction portion 14 in the surface portion on which the traveler 12 slides when the traveler 12 travels. The friction reduction portion 14 includes 400 or more grooves 15 per centimeter. The grooves 15 are microcracks formed in the surface of the hard chromium plating layer 13. The abundance of microcracks facilitates the formation of the film, which is formed by cellulose fibers that are separated from the yarn Y and adhere to the grooves 15. The fiber film produces a friction reduction effect without using liquid lubrication. As a result, the ring-traveler system improves the friction reduction effect as compared to a conventional system, and the friction reduction effect continues for a long time.

Example 1

[0019] To evaluate the effectiveness of the friction reduction portion 14, a ring 11 was prepared that includes a friction reduction portion 14 having 700 microcracks per centimeter. In addition, a ring 11 was prepared that includes a friction reduction portion 14 having 1,000 microcracks per centimeter. A conventional ring was used as a comparative example. A spinning test was conducted to determine the relationship between traveling resistance and traveling distance without performing any preconditioning operation. The spinning was performed at the rotation speed of 20,000 rpm. The traveling resistance was obtained by rotatably supporting the ring and measuring the drag force applied to the ring by the traveler. Fig. 3 shows the test results.

[0020] As shown in Fig. 3, the rings 11 having 400 or more microcracks (grooves 15) per centimeter in the friction reduction portions 14 each had a lower traveling resistance than the conventional ring after a traveling distance of 800 km. This verified the effectiveness of the friction reduction portion 14. To determine the stability of friction reduction effect of the friction reduction portion 14, the ring 11 having 700 microcracks per centimeter and the ring 11 having 1,000 microcracks per centimeter were operated until the traveling distance reached 54,000 km. The test showed that the each ring 11 at a traveling distance of 54,000 had a traveling resistance that was generally the same as that at a traveling distance of 2,000 km. Thus, each ring of the present embodiment was confirmed to have a significantly high, continuous friction reduction effect compared to the conventional ring. The traveling resistance of the conventional ring increased at a short traveling distance. This is assumed to be resulted from a cellulose layer that was formed unevenly and increased the resistance.

[0021] Further, a ring 11 having 400 microcracks per centimeter in the friction reduction portion 14 was tested to determine the relationship between traveling distance and traveling resistance and confirmed to have a lower traveling resistance than the conventional ring.

[0022] In addition, the travelers 12 were checked for abrasion. As shown in Fig. 4B, the traveler 12 used with the conventional ring had an abrasion 20 in the surface portion that was in contact with the ring. However, as shown in Fig. 4A, the traveler 12 that was used with the ring 11 having the friction reduction portion 14 had an abrasion 20' that was smaller than the abrasion 20.

[0023] The advantages of the present embodiment will now be described.

(1) The ring-traveler system of the ring spinning machine (ring spinning frame) includes the ring 11 having 400 or more grooves 15 per centimeter in the surface portion on which the traveler 12 slides when the traveler 12 travels. The grooves 15 serve as recesses. Entry of the fiber film into the recesses increases the adhesive force of the fiber film to the ring 11 and suppresses separation of the fiber film. The fiber film serves as lubrication and produces a friction reduction effect that maintains the traveling resistance of the traveler 12 at a low level. The fiber film, which is formed by fibers separated from a yarn and adhere to a sliding surface of the ring-traveler system, serves as lubrication. This improves the friction reduction effect and prolongs durability (life).

(2) The recesses are microcracks formed in the surface of the hard chromium plating layer. Thus, a greater portion of the fiber film is received in the recesses compared to when the recesses are dimples. This increases the friction reduction effect resulted from lubrication of the fiber film. In general, the surface of a normal hard chromium plating layer includes about 300 microcracks per centimeter. The number of the microcracks can be increased relatively easily to 400 or more by performing etching to the hard chromium plating layer.

(3) Electrolytic etching is performed to the hard chromium plating layer of the ring 11 to form 400 or more microcracks in the surface of the hard chromium plating layer. The surface of the hard chromium plating layer originally includes about 300 microcracks per centimeter before performing etching. A hard chromium plating layer having 400 or more microcracks per centimeter in the surface may be prepared through treatments such as chemical etching and electrolytic etching. Electrolytic etching is more suitable than chemical etching to form a hard chromium plating layer having a desired number of microcracks.

Second Embodiment

[0024] Referring to Figs. 5 and 6, the second embodiment will now be described. The second embodiment is the same as the first embodiment except for the structure of the friction reduction portion 14. Like or same reference numerals are given to those components that are the same as the corresponding components of the first embodiment. Such components will not be described in detail.

[0025] The second embodiment includes a friction reduction portion 14 having a periodic structure 16. As shown in Fig. 5, the periodic structure 16 includes submicron projections and depressions. Unlike the first embodiment in which the grooves 15 are microcracks, the grooves 15 of the present embodiment are grooves 15 of the periodic structure 16 having submicron projections and depressions. The grooves 15 serve as recesses that form the friction reduction portion 14. Unlike the microcracks, the grooves 15 do not vary in length or orientation. The grooves 15 have a uniform length and extend in parallel to one another.

[0026] The periodic structure 16 of projections and depressions are formed by emitting an extremely-short pulse laser beam such as a femtosecond pulsed laser beam on a portion where the periodic structure 16 is to be formed. This forms submicron periodic structure relatively easily.

[0027] A test was conducted to evaluate the effectiveness of the periodic structure 16.

Example 2

[0028] In the same manner as the first embodiment, the ring 11 including the periodic structure 16 as the friction reduction portion 14 was tested to determine the relationship between traveling distance and traveling resistance. Fig. 6 shows the test results. The test was conducted on a ring 11 having the periodic structure 16 in which projections and depressions extend parallel to the circumferential direction of the ring 11. In the test, the traveler 12 was separated from the ring 11 when the traveling distance reached 10,400 km. Thus, Fig. 6 shows the test results obtained before the traveling distance reached 10,200 km. The graph of the Fig. 6 partially includes the test results of the first embodiment for reference.

[0029] As shown in Fig. 6, the traveling resistance of the ring 11 including the periodic structure 16 in the friction reduction portion 14 became lower than the traveling resistance of the conventional ring at a short traveling distance. This verified the effectiveness of the friction reduction portion 14. When the traveling distance is relatively short, the ring 11 including the periodic structure 16 in the friction reduction portion 14 had a lower friction resistance than the rings 11 including microcracks in the friction reduction portion 14.

[0030] The second embodiment has the following advantage in addition to advantage (1) of the first embodiment.

(4) Recesses are grooves 15 forming the periodic structure 16 of projections and depressions. The grooves 15 discharge abrasion particles when the traveler 12 slides. This further reduces the friction resistance.

(5) The periodic structure 16 of projections and depressions are formed by emitting an extremely-short pulse laser beam such as a femtosecond pulsed laser beam to a portion where the periodic structure 16 is to be formed. Although the periodic structure 16 can be formed through etching, the submicron periodic structure 16 is formed relatively easily with an extremely-short pulse laser such as a femtosecond pulsed laser.

Third Embodiment

[0031] Referring to Figs. 7 to 9C, the third embodiment will now be described. The third embodiment is the same as the first embodiment except for the structure of the friction reduction portion 14. Like or same reference numerals are given to those components that are the same as the corresponding components of the first embodiment. Such components will not be described in detail.

[0032] As shown in Fig. 7, a solid lubrication coating layer 18 is applied to the friction reduction portion 14 of the hard chromium plating layer 13. The friction reduction portion 14 includes a flat portion 19, and the solid lubrication coating layer 18 is required to be applied at least to the flat portion 19. In the present embodiment, the solid lubrication coating layer 18 is applied to the surface of each groove 15 of the friction reduction portion 14 in addition to the flat portion 19. The grooves 15 are microcracks. In Fig. 7, the groove 15 is schematically illustrated to have a V-shaped cross-section. The flat portion 19 is a non-crack portion that is free from microcracks.

[0033] The solid lubrication coating layer 18 is formed by immersing at least the friction reduction portion 14 of the ring 11 in a solution of solid lubrication (polytetrafluoroethylene) and then drying the ring 11.

[0034] As described in the first embodiment, the friction reduction portion 14 produces a friction reduction effect without using liquid lubrication. The friction reduction effect is achieved by lubrication of the fiber film. The fiber film is formed by cellulose fibers that are separated from the yarn Y during spinning and adhere to the grooves 15. However, the friction reduction effect is low until the fiber film is stably formed after the ring-traveler system begins to operate. However, in the present embodiment, the friction reduction portion 14 of the hard chromium plating layer 13 includes the solid lubrication coating layer 18 on the surface. The solid lubrication coating layer 18 reduces the friction between sliding surfaces of the ring-traveler system before the fiber film is stably formed and serves as lubrication.

Example 3

[0035] To evaluate the effectiveness of the solid lubrication coating layer 18, a ring 11 having microcracks as the friction reduction portion 14 and a ring 11 having the solid lubrication coating layer 18 on the hard chromium plating layer 13 including microcracks were prepared. A conventional ring was used as a comparative example. The relationship between traveling distance and traveling resistance was evaluated in a similar manner as the first embodiment. Fig. 8 shows the test results.

[0036] As shown in Fig. 8, the ring 11 with microcracks had a similar traveling resistance as the conventional ring when the traveling distance was about 300 km. However, the ring 11 with microcracks and the solid lubrication coating layer 18, which is also referred to as the ring 11 with microcracks and lubrication, had about half the traveling resistance of the conventional ring and the ring with microcracks from the early stage. This verified the friction reduction effect of the solid lubrication coating layer 18.

[0037] In an early stage, the traveling resistance of the ring 11 with microcracks and lubrication increased with the traveling distance. After a traveling distance of 1,500 km, the traveling resistance of the ring 11 with microcracks and lubrication remained at the same level as the ring 11 with microcracks. After 1,500 km, the ring 11 with microcracks and the ring 11 with microcracks and lubrication had traveling resistances that were about 4 to 5 gf (gram-force) lower than the traveling resistance of the conventional ring.

[0038] The test results showed that the solid lubrication coating layer 18 reduced the friction of sliding surfaces of the ring-traveler system until the fiber film was stably formed and served as lubrication. After the fiber film was stably formed, the fiber film served as lubrication that reduced the friction of sliding surfaces of the ring-traveler system.

[0039] In addition, the travelers 12 were checked for abrasion. Fig. 9A shows an abrasion of the traveler 12 that was used with the ring 11 having the friction reduction portion 14 with microcracks and lubrication. Fig. 9B shows an abrasion of the traveler 12 that was used with the ring 11 having the friction reduction portion 14 with microcracks. Fig. 9C shows an abrasion of the traveler 12 that was used with the conventional ring.

[0040] As shown in Fig. 9C, the traveler 12 used with the conventional ring had an abrasion 20 in the surface portion that was in contact with the conventional ring. However, as shown in Figs. 9A and 9B, each traveler 12 that was used with the rings 11 having the friction reduction portion 14 had an abrasion 20' that was smaller than the abrasion 20.

[0041] The third embodiment has the following advantages in addition to advantages (1) to (3) of the first embodiment.

(6) The solid lubrication coating layer 18 is applied at least to the flat portion 19 of the hard chromium plating layer 13 having microcracks. This structure reduces the friction of sliding surfaces of the ring-traveler system even before the fiber film is stably formed and serves as lubrication after the ring-traveler system begins to operate. In addition, at the beginning of operation, the solid lubrication coating layer 18 applied to the flat portion 19 improves cooperation between the traveler and the ring.

[0042] It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the present invention may be embodied in the following forms.

[0043] The friction reduction portion 14 may include as recesses both of the grooves 15 that are microcracks in the surface of the hard chromium plating layer 13 and the grooves 15 forming the periodic structure 16 of projections and depressions. This structure has both of the benefits of microcracks and the benefits of grooves 15 forming the periodic structure 16 of projections and depressions.

[0044] When the friction reduction portion 14 includes the periodic structure 16, the grooves 15 do not have to extend in only one direction. For example, as shown in Fig. 10, a set of grooves may extend in parallel in a first direction, and another set of grooves may extend in parallel in a second direction. For example, the first direction may be parallel to the circumferential direction of the ring 11, and the second direction may be perpendicular or diagonal to the first direction. Further, the first direction may be diagonal to the circumferential direction of the ring 11, and the second direction may be diagonal to the first direction.

[0045] The grooves 15 extending diagonally to the circumferential direction of the ring 11 may be arranged at any angle relative to the circumferential direction.

[0046] The recesses are not limited to grooves 15. As shown in Figs. 12A and 12B, the grooves 15 may be dimples 17 surrounded by a flat portion. Dimples 17 are not required to have round openings as shown in Fig. 12A. For example, each dimple 17 may have an oval, elliptical, rectangular, tetragonal, or polygonal opening. The dimples 17 having round openings may be formed by performing bead blasting. Further, the dimples 17 are not required to have a uniform shape or size and may vary in shape and size as shown in Fig. 12B.

[0047] The periodic structure 16 may be formed on the flange 11a without forming the hard chromium plating layer 13. However, when the ring 11 is formed from the material used for present commercially available rings, the formation of plating layer 13 is desirable.

[0048] A method for forming the periodic structure 16 is not limited to the application of an extremely-short pulse laser such as a femtosecond pulsed laser to the portion that requires the periodic structure 16. For example, any chemical or physical process such as microetching may be performed.

[0049] The solid lubrication coating layer 18 of the third embodiment, which is applied to the hard chromium plating layer 13 including microcracks, is required to be applied at least to the flat portion 19. The solid lubrication coating layer 18 does not have to be applied to surfaces of the grooves 15.

[0050] The solid lubrication coating layer 18 does not have to be evenly formed on the flat portion 19. The solid lubrication coating layer 18 may vary in thickness.

[0051] The grooves 15 may be filled with lubrication. Sliding of the traveler will eventually peel the lubrication at least partially. Thus, even if the grooves 15 are filled with lubrication at an early stage, the grooves 15 later become capable of holding fibers.

[0052] A method for forming the solid lubrication coating layer 18 is not limited to the method described for the third embodiment. Other chemical or physical process may be performed.

[0053] The flange 11a of the ring 11 of the ring-traveler system is not required to have a T-shaped cross-section. For example, the ring 11 may include a tilted flange 11a as shown in Fig. 11C. This structure requires a traveler 12 having a shape corresponding to the tilted flange 11a.

[0054] The friction reduction portion 14 may be formed on the traveler 12 of the ring-traveler system instead of on the ring 11. However, the friction reduction portion 14 is preferably formed on the ring 11 since the friction reduction portion 14 on the traveler 12 has a significantly smaller area than the friction reduction portion 14 on the ring 11.

[0055] In addition to a ring spinning frame, the present invention may be embodied in other spinning machines having rings, such as a ring twisting frame.

[0056] Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

Claims

1. A ring-traveler system of a ring spinning machine, wherein the ring-traveler system is of a non-liquid lubrication type, the ring-traveler system comprising:

   a ring (11); and
   a traveler (12) that travels along the ring (11), the ring-traveler system being **characterized in that**
   one of the ring (11) and the traveler (12) includes 400 or more recesses (15) per centimeter in a surface portion on which the other one of the ring (11) and the traveler (12) slides when the traveler (12) travels.

2. The ring-traveler system according to claim 1, wherein
   the one of the ring (11) and the traveler (12) includes a hard chromium plating layer (13), and
   the recesses (15) are microcracks (15) formed in a surface of the hard chromium plating layer (13).

3. The ring-traveler system according to claim 2, wherein
   the hard chromium plating layer (13) includes a non-crack portion (19) that is free from the microcracks (15), and
   a solid lubrication coating layer (18) is formed at least on the non-crack portion (19).

4. The ring-traveler system according to claim 1, wherein the recesses (15) are grooves (15) forming a periodic structure (16) of projections and depressions.

5. The ring-traveler system according to claim 1, wherein
   the one of the ring (11) and the traveler (12) includes a hard chromium plating layer (13), and
   the recesses (15) include microcracks (15) formed in a surface of the hard chromium plating layer (13) and grooves (15) forming a periodic structure (16) of projections and depressions.

6. The ring-traveler system according to claim 5, wherein
   the hard chromium plating layer (13) includes a non-crack portion (19) that is free from the microcracks (15), and
   a solid lubrication coating layer (18) is formed at least on the non-crack portion (19).

7. A ring (11) of a ring spinning machine, the ring (11) comprising a surface portion on which a traveler (12) slides when the traveler (12) travels, the ring (11) being **characterized in that**
   the surface portion includes 400 or more recesses (15) per centimeter.

8. A traveler (12) of a ring spinning machine, the traveler (12) comprising a surface portion on which a ring (11) slides when the traveler (12) travels, the traveler (12) being **characterized in that**
   the surface portion includes 400 or more recesses (15) per centimeter.

Fig.1A

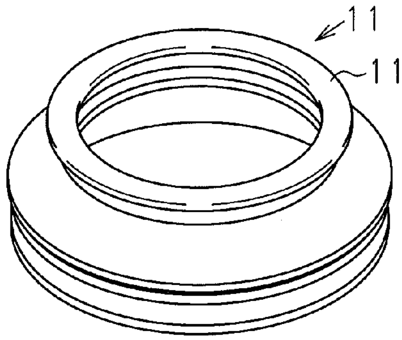


Fig.1B

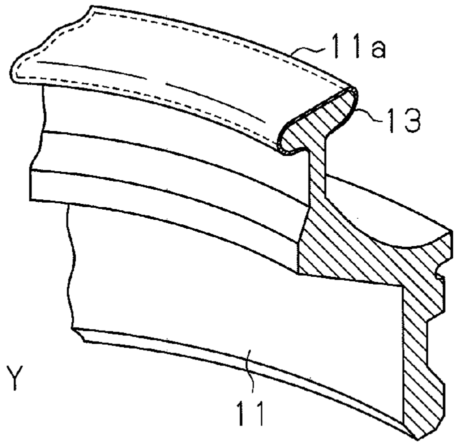


Fig.1C

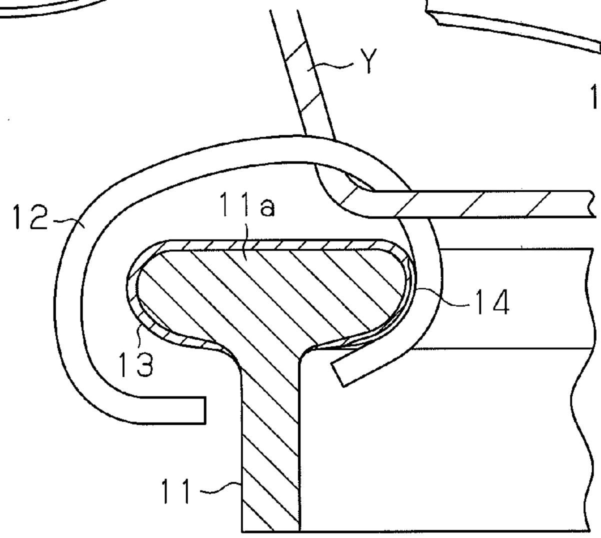


Fig.2

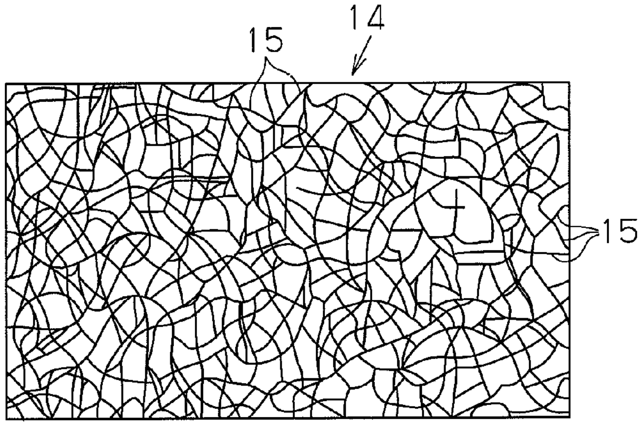


Fig.3

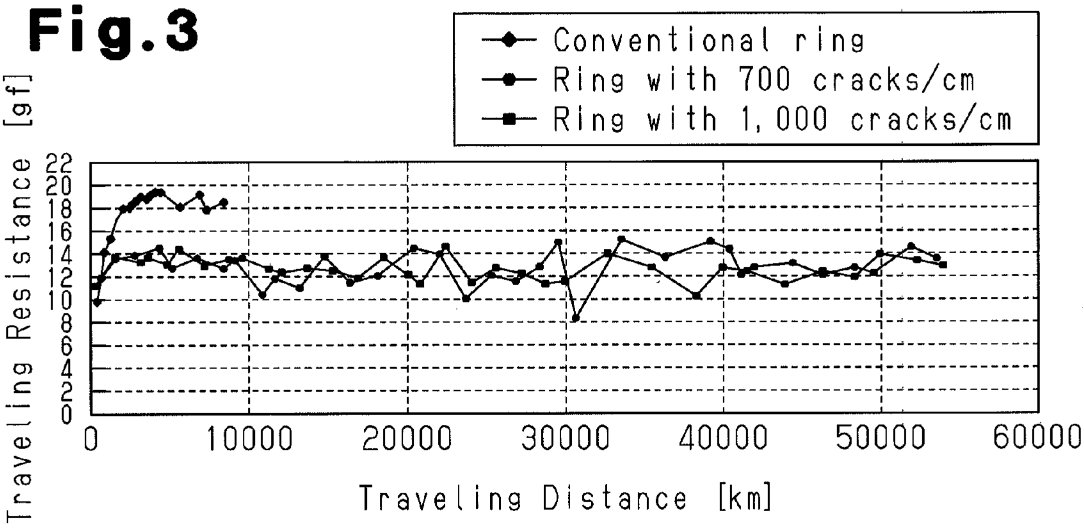


Fig.4A

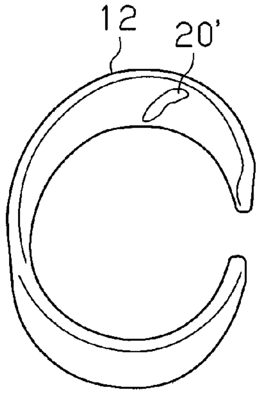


Fig.4B

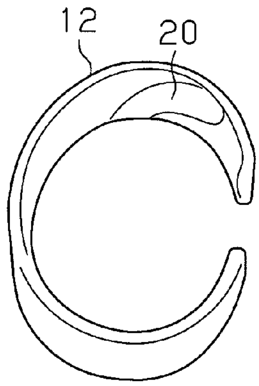


Fig.5

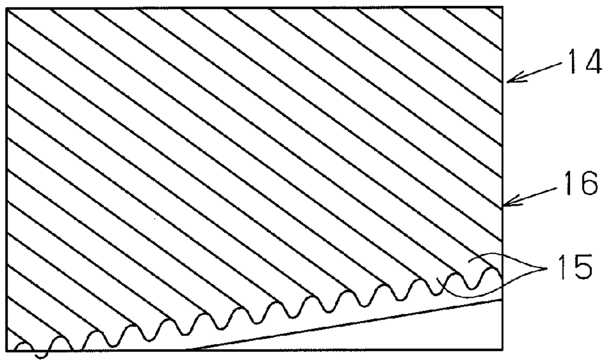


Fig.6

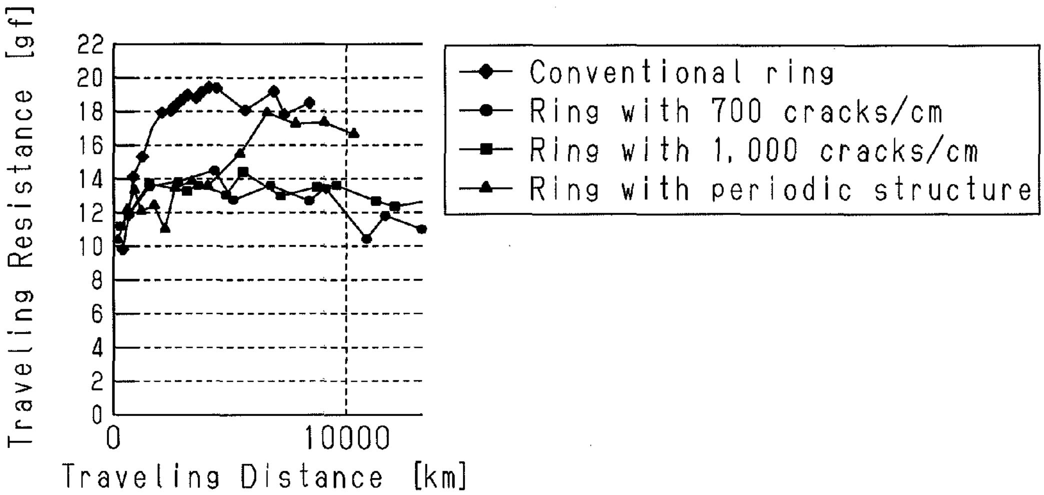


Fig.7

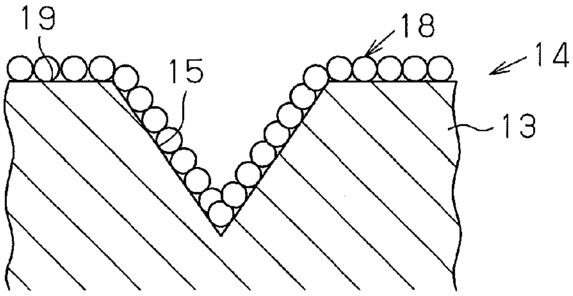


Fig.8

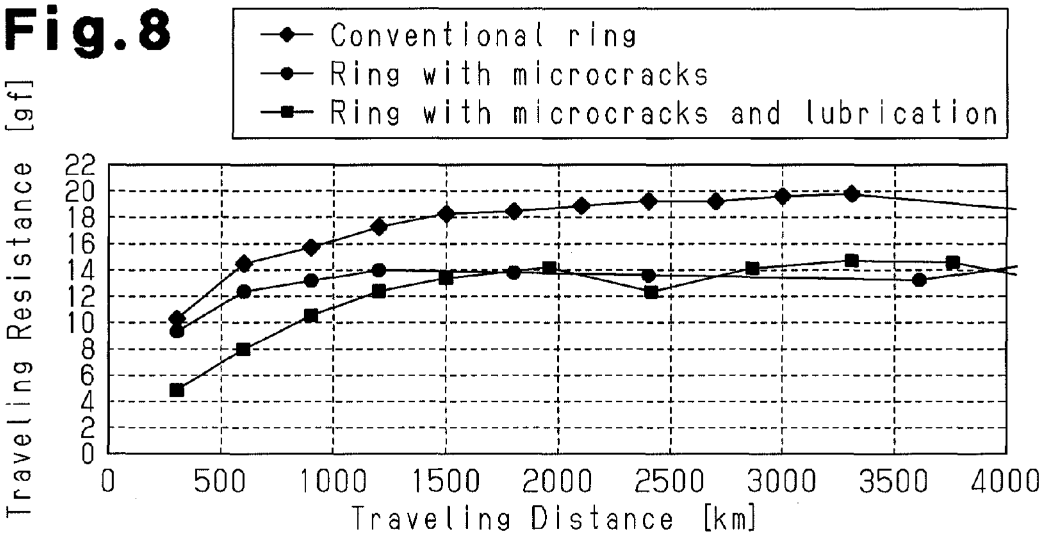


Fig.9A

Fig.9B

Fig.9C

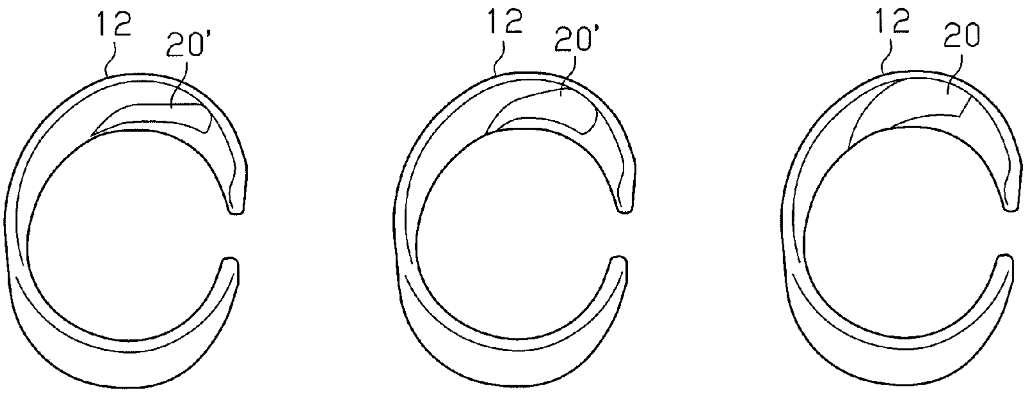


Fig.10

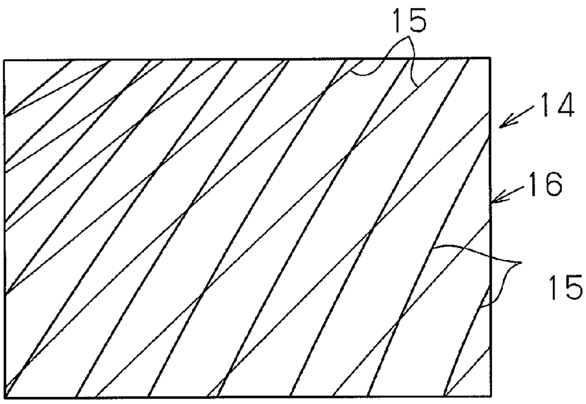


Fig.11

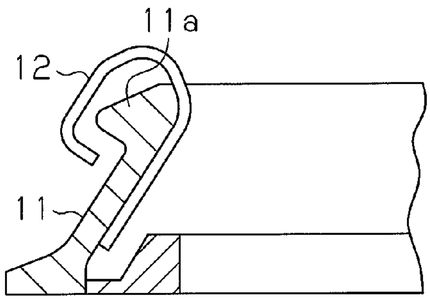


Fig.12A

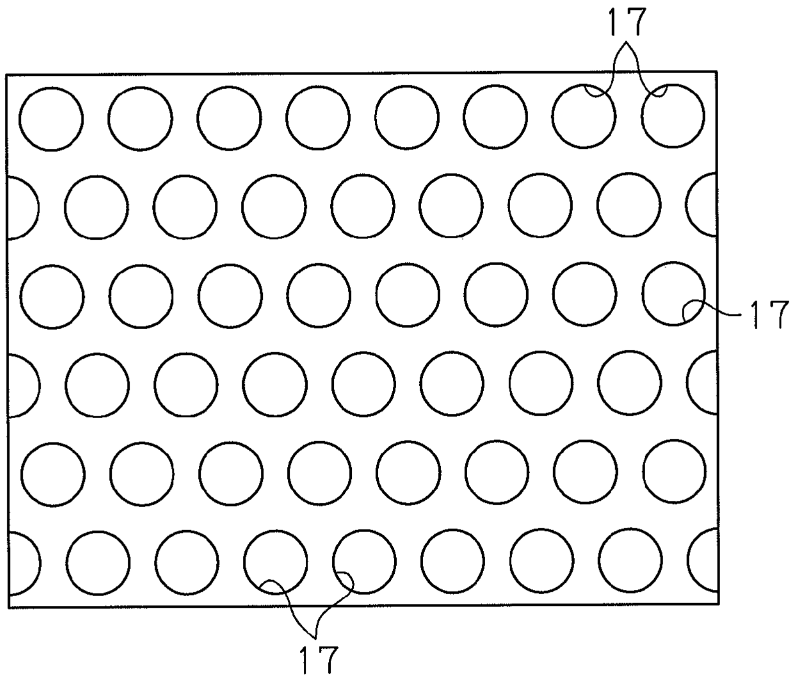
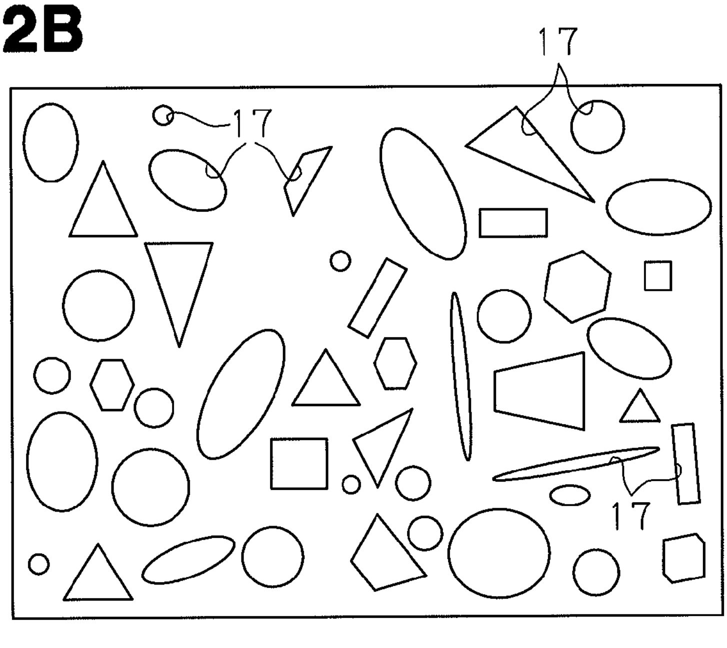


Fig.12B



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Patent documents cited in the description

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