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(71) Applicants:
• **IHI Corporation**
Tokyo 135-8710 (JP)
• **IHI Metaltech Co., Ltd.**
Tokyo 105-0004 (JP)
• **Sumitomo Metal Industries, Ltd.**
Osaka 541-0041 (JP)

(72) Inventors:
• **DODO, Yasushi**
Tokyo 105-0004 (JP)
• **IDE, Kenichi**
Tokyo 105-0004 (JP)
• **MURAKAMI, Toshihiko**
Osaka-shi
Osaka 541-0041 (JP)
• **ITOU, Yoshiki**
Kitakyushu-shi
Fukuoka 802-8686 (JP)

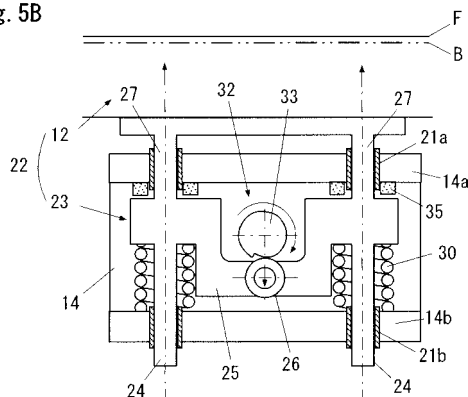
(74) Representative: **Grünecker, Kinkeldey, Stockmair & Schwanhäusser**
Anwaltssozietät
Leopoldstrasse 4
80802 München (DE)

(54) **CONTINUOUS HAMMERING DEVICE FOR CONTINUOUSLY MANUFACTURING CAST PIECES**

(57) A continuous hammering device for continuous casting includes a hammering member 22 for hammering a cast 1, a compression spring 30 which pushes the hammering member toward the cast, a cam mechanism 32 which compresses the compression spring by moving the hammering member away from the cast and then allows the hammering member to freely move, and a main body 14 which supports the hammering member,

the compression spring, and the cam mechanism. At the time of hammering, the cam mechanism 32 leaves the hammering member 22 to allow the hammering member to freely accelerate so as to convert compression energy of the compression spring 30 into kinetic energy of the hammering member 22, and the hammering member 22 collides with the cast 1, thereby applying predetermined hammering energy to the cast.

Fig. 5B



Description**BACKGROUND OF THE INVENTION**5 Technical Field of the Invention

[0001] The present invention relates to a continuous hammering device for continuous casting which improves center segregation or the like by applying a hammering vibration to a narrow side surface of a cast.

10 Description of the Related Art

[0002] In a cast produced by continuous casting, a central part of the thickness of the cast and a neighborhood thereof tend to develop an internal defect known as macro segregation, such as center segregation or V segregation.

15 The center segregation is an internal defect in which easily segregatable solute components, such as C, S, P and Mn, (hereinafter referred to as "the segregation components") incrassate and appear in the vicinity of a final solidifying portion of the cast. The V segregation is an internal defect in which the segregation components incrassate and appear in a V shape in the vicinity of a final solidifying portion of the cast.

[0003] A product made by hot working a cast having the aforesaid macro-segregation easily develops deterioration in toughness or hydrogen-induced cracking. Further, if the product is subjected to cold working for finishing, then the product is prone to crack.

[0004] The segregation occurring mechanism in a cast is considered as described below.

20 The segregation components incrassate in an interdendritic region of a column crystal, which is a solidification structure, as the solidification proceeds. Molten steel resulting from the incrassated segregation components flows out from the interdendritic region of the column crystal due to the contraction of the cast at the time of solidification or the bulging of the cast. The incrassated molten steel moves toward a solidification completion point of the final solidified portion, and solidifies there, thus forming an incrassated zone of the segregation components. The incrassated zone of the segregation components formed as described above refers to the segregation.

[0005] The aforesaid segregation of the cast can be effectively prevented by preventing the movement of the incrassated molten steel of the segregation components left in the interdendritic region of the column crystal and by preventing the incrassated molten steel from being locally built up. The applicant of the present invention has already proposed methods disclosed in patent documents 1 and 2.

[0006] The continuous casting method disclosed in patent document 1 is adapted to hammer a cast so as to prevent the occurrence of segregation, such as the center segregation or the V segregation, thereby obtaining a cast with good internal quality.

35 According to the method, to cast a cast having a rectangular transverse plane, at least one location of a narrow side surface of the cast, including an unsolidified portion, is continuously hammered, thus implementing the casting while applying vibrations to the cast. Hammering energy that satisfies a relationship expressed by $E \geq 0.0065 \times W$ is applied to the cast, where E denotes the hammering energy (J) per hammering hit applied to the cast, and W denotes the long side width in millimeters of the cast.

[0007] "The method for continuously casting steel and hammering vibrator" disclosed in patent document 2 aims at effectively preventing the occurrence of segregation even in a wide cast by effectively hammering a surface of the cast that includes an unsolidified portion.

40 For that purpose, the method is a continuous casting method in which a cast 1 having a rectangular transverse plane is cast by subjecting a thickness central area of the cast wherein a central solid phase rate f_s is at least 0.1 to 0.9 to continuous soft reduction in the direction of the thickness of the cast 1 such that the rolling reduction per meter remains within 1%. Further, in at least one place within the area wherein the central solid phase rate f_s is 0.1 to 0.9, opposing narrow side surfaces on both sides of the cast 1 are continuously hammered in the direction of the width of the cast. According to the method, the hammering is performed at a hammering vibration frequency of 4 to 12 Hz and with vibration energy of 30 to 150J.

50 **[0008]**

[Patent document 1]

Japanese Patent Application Laid-Open No. 2006-110620, "Continuously Casting Method"

[Patent document 2]

55 Japanese Patent Application Laid-Open No. 2007-229748, "Method for continuously casting steel and hammering vibrator"

[0009] The method for continuously casting steel disclosed in patent document 2 can be implemented by using a

hammering vibrator having a die 53 or the like in a segment 52 in the middle of drawing the cast 51, which has been solidified and cast in a die, toward a downstream side of a casting direction while guiding the cast 51 by a plurality of guide rolls 52a of a segment 52, as illustrated in Fig. 1.

[0010] In Fig. 1, reference numeral 53 denotes a die for hammering a narrow side surface of the cast 51. The die 53 has a hammering plate 53a capable of continuous hammering in a single segment so as to hammer the whole narrow side surface of the cast 51 in at least one segment 52 constituted of the plurality of guide rolls 52a.

[0011] The segment 52 is generally divided into upper and lower blocks. The reduction gradient of an upper segment 52b can be adjusted so as not to implement soft reduction. In the segment 52 illustrated in Fig. 1, the upper segment 52b is set in parallel with a lower segment 52c, with no reduction gradient, thus providing a regular pair of guide rolls applying no reduction to the cast 51.

[0012] A hammering device denoted by reference numeral 54 has the die 53 attached to the distal end portion thereof, and generates periodical vibrations then transmits the vibrations to the die 53. The hammering device 54 uses, for example, an air cylinder. The hammering device 54 is disposed at, for example, two locations on both narrow side surfaces of the cast 51 which includes an unsolidified portion.

[0013] A hammering position determining device denoted by reference numeral 55 presses the die 53 against a narrow side surface of the cast 51 from a standby position shown in Fig. 2A (refer to Fig. 2B), detects the pressed-against position, and then sets an interval L between the distal end surface of the die 53 and the narrow side surface of the cast 1 (hammering amplitude: about 8 mm) at a retreated position of the die 53 (refer to Fig. 2C).

[0014] The interval L between the die 53 and the cast 51 differs according to the width of the cast 51 to be cast. Hence, the interval L must be set, taking the narrow side surface of the cast 51 in a casting process as the reference. More specifically, the interval L influences the stroke of the hammering device 54, so that an insufficient stroke makes it impossible to secure hammering speed, failing to provide sufficient hammering vibration energy. Therefore, at the start of hammering, the positioning, that is, the relative positional adjustment, of the die 53 and the narrow side surface of the cast 51 is performed.

[0015] According to the method for continuously casting steel disclosed in patent document 2, the cast 51 having a rectangular transverse plane is cast by subjecting a thickness central area of the cast wherein a central solid phase rate f_s is at least 0.1 to 0.9 to continuous soft reduction in the direction of the thickness of the cast 51 such that the rolling reduction per meter remains within 1%. Further, in at least one place within the area wherein the central solid phase rate f_s is 0.1 to 0.9, opposing narrow side surfaces on both sides of the cast 51 are continuously hammered in the direction of the width of the cast by using the aforesaid hammering vibrator. According to the method, the hammering is performed at a hammering vibration frequency of 4 to 12 Hz and vibration energy of 30 to 150J.

[0016] However, the hammering vibrator described above has been posing the following problem.

The aforesaid hammering vibrator has been presenting a problem with durability, because the hammering vibrator is subjected to high impacts (30 to 150J) at high frequencies (4 to 12 Hz) while being exposed to high-temperature radiation heat (e.g., approximately 1200°C) from the cast 51, scales, water, and the like.

More specifically, when an air cylinder is used for the hammering device 54 and the hammering is carried out by electrical control of solenoid valves, the solenoid valves, the air cylinder, cables and the like are frequently damaged in the severe environment described above. Thus, continuous use of a few days or more has been impossible.

There has been another problem in that, when the interval L is set by the hammering position determining device 55 as illustrated in Fig. 1, the die 53 is dragged by the cast 51 in the process of continuous casting and subjected to a large force in the transverse direction (in the direction in which the cast 51 moves), causing the hammering device 54 and the hammering position determining device 55 to be easily damaged.

SUMMARY OF THE INVENTION

[0017] The present invention has been made to solve the problems described above. A first object of the present invention is to provide a continuous hammering device for continuous casting which is capable of continuously hammering opposing narrow side surfaces on both sides of a cast in a continuously casting process of steel in the direction of the width of the cast at a predetermined hammering vibration frequency (e.g., 4 to 12 Hz) and with predetermined hammering energy (e.g., 30 to 150J). The continuous hammering device has high durability that enables prolonged continuous use even when subjected to high impacts (30 to 150J) at high frequencies (4 to 12 Hz) while being exposed to high-temperature radiation heat (e.g., approximately 1200°C) from a cast, scales, water and the like.

[0018] A second object of the present invention is to provide a continuous hammering device for continuous casting which is capable of hammering with fixed hammering energy even when a hammering vibration frequency is changed.

A third object of the present invention is to provide a continuous hammering device for continuous casting which has high durability that enables prolonged continuous use even when idle hammering in the absence of cast is repeated.

A fourth object of the present invention is to provide a continuous hammering device for continuous casting which is capable of accurate positioning without being subjected to a large force in a lateral direction relative to a cast in a

continuous casting process and which is capable of hammering the cast with predetermined hammering energy.

[0019] The present invention provides a continuous hammering device for continuous casting, comprising:

a hammering member for hammering a cast;

a compression spring which pushes the hammering member toward the cast;

a cam mechanism which moves the hammering member away from the cast to compress the compression spring and then allows the hammering member to freely move; and

a main body which supports the hammering member, the compression spring, and the cam mechanism, wherein at the time of hammering, the cam mechanism leaves the hammering member to allow the hammering member to freely accelerate so as to convert compression energy of the compression spring into kinetic energy for the hammering member, and the hammering member collides with the cast, thereby imparting predetermined hammering energy to the cast.

[0020] According to a preferred embodiment of the present invention, the hammering member comprises:

a die which hammers a hit surface of the cast; and

a reciprocating member which has one end thereof fixed to the die and which is capable of reciprocating between a hammering position where contact to the hit surface is made and a storage position away from the hit surface by a predetermined distance; wherein

the compression spring which is held between the reciprocating member and the main body, retains predetermined compression energy at the storage position, and releases the kinetic energy at the hammering position, and the cam mechanism includes a rotating cam which is rotatably supported by the main body, moves the reciprocating member to the storage position at a predetermined cycle, and then allows the reciprocating member to freely move to the hammering position, and a rotative drive device which rotatively drives the rotating cam.

[0021] The cam curve of the rotating cam is preferably an Archimedes curve in which a rotational angle and a displacement have a proportional relationship.

[0022] The reciprocating member has a cam follower which freely rotates while in contact with the rotating cam.

[0023] The natural period of the compression spring is set to cause the rotating cam and the cam follower to come in contact with each other again at a compression position of the compression spring.

[0024] The continuous hammering device further includes a damper device which reduces the moving speed of the reciprocating member when the reciprocating member passes the hammering position and moves toward the cast.

[0025] The continuous hammering device further includes:

a moving device which moves the main body back and forth relative to the cast; and

a positioning mechanism which sets the main body at a predetermined position relative to the cast.

[0026] The positioning mechanism is constituted of a plurality of guide rollers which is rotatably installed to the main body and which freely rotates while in contact with the hit surface of the cast at a predetermined position.

[Effect of the Invention]

[0027] According to the arrangements of the present invention described above, the continuous hammering device has the hammering member, the compression spring, the cam mechanism, and the main body, wherein the cam mechanism moves the hammering member away from the cast to compress the compression spring, and then the cam mechanism moves away from the hammering member at the time of hammering to allow the hammering member to freely accelerate, thereby converting the compression energy of the compression spring into the kinetic energy for the hammering member. The hammering member collides with the cast to impart the predetermined hammering energy to the cast. Thus, a durable device which does not depend on electrical control can be provided.

More specifically, the continuous hammering device in accordance with the present invention is capable of continuously hammering the opposing narrow side surfaces on both sides of the cast in the width direction of the cast in the process of continuous casting of steel, and has high durability that enables prolonged continuous use even when subjected to a high impact (30 to 150J) at a high frequency (4 to 12 Hz) while being exposed to high-temperature radiation heat (e.g., approximately 1200°C) from a cast, scales, water and the like.

[0028] The compression spring held between the reciprocating member and the main body retains predetermined compression energy at the storage position, and releases the kinetic energy at the hammering position, and the cam mechanism includes a rotating cam which moves the reciprocating member to the storage position at a predetermined cycle, and then allows the reciprocating member to freely move to the hammering position, and a rotative drive device

which rotatively drives the rotating cam. This arrangement makes it possible to set the predetermined hammering vibration frequency (e.g., 4 to 12 Hz) by the rotational speed of the rotating cam of the rotative drive device and to set the predetermined compression energy of the compression spring to the predetermined hammering energy (e.g., 30 to 150J).

[0029] The cam curve of the rotating cam is the Archimedes curve in which a rotational angle and a displacement have a proportional relationship. This makes it easy for the cam mechanism to leave the hammering member at the time of hammering so as to allow the hammering member to freely accelerate.

[0030] The displacement (deformation amount) of the compression spring caused by the rotating cam at the storage position and the hammering position is constant. Hence, hammering can be accomplished at constant hammering energy even when the hammering vibration frequency is changed by changing the rotational speed of the rotating cam.

[0031] The natural period of the compression spring is set to cause the rotating cam and the cam follower to come in contact with each other again at the compression position of the compression spring. This arrangement makes it possible to reduce the colliding speed when the rotating cam comes in contact with the cam follower again, thus enabling higher durability of the rotating cam and the cam follower.

[0032] The damper device reduces the moving speed of the reciprocating member when the reciprocating member passes the hammering position and moves toward the cast. This makes it possible to prevent the collision between the cam follower and the rotating cam, thus permitting high durability that enables prolonged continuous use even when idle hammering repeated in the absence of the cast.

[0033] The continuous hammering device further includes the moving device which moves the main body back and forth relative to the cast and the positioning mechanism (e.g., the plurality of guide rollers) which sets the main body at a predetermined position relative to the cast. This arrangement makes it possible to achieve accurate positioning without being subjected to a large force in a lateral direction relative to a cast in a continuous casting process and hammer the cast with predetermined hammering energy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

Fig. 1 is a configuration diagram of equipment for continuously casting steel provided with a hammering vibrator disclosed in patent document 2;

Fig. 2A is a graphical illustration of the operation of the hammering vibrator disclosed in patent document 2;

Fig. 2B illustrates a state wherein a die 53 is pressed against a narrow side surface of a cast 51 from a standby position shown in Fig. 2A;

Fig. 2C illustrates a state wherein the die 53 has been drawn back from the state illustrated in Fig. 2B;

Fig. 3 is a general perspective view of a continuous hammering device for continuous casting in accordance with the present invention;

Fig. 4 is a general top plan view illustrating the relationship between a cast 1 and two continuous hammering devices 10;

Fig. 5A is a configuration diagram illustrating an essential section of the continuous hammering device 10, and also indicating the storage position;

Fig. 5B is a configuration diagram illustrating the essential section of the continuous hammering device 10, the hammering position being indicated;

Fig. 6 is another configuration diagram illustrating the essential section of the continuous hammering device 10;

Fig. 7A illustrates a positional relationship between a rotating cam 33 and a cam follower 26, showing a case where a die 12 does not collide with a cast 1;

Fig. 7B illustrates a positional relationship between the rotating cam 33 and the cam follower 26, showing a case where the die 12 collides with the cast 1; and

Fig. 8 is a comparative diagram comparing the equipment durability of the device in accordance with the present invention and a conventional type.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0035] The following will describe a preferred embodiment of the present invention with reference to the accompanying drawings. Like components in the drawings will be assigned like reference numerals and the same description thereof will be omitted.

[0036] Fig. 3 is a general perspective view of the continuous hammering device for continuous casting in accordance with the present invention.

In this figure, a total of two continuous hammering devices 10 in accordance with the present invention are installed on both sides so as to simultaneously or alternately hammer opposing narrow side surfaces 1a on both sides of a cast 1.

Reference numeral 12 denotes a die, reference numeral 14 denotes a main body, and reference numeral 16 denotes a moving device.

[0037] The cast 1 solidified and cast in a casting die by continuously casting steel has an approximately rectangular transverse plane and continuously moves in one direction.

In actual continuous casting, preferably, the cast 1 stretches in an arc shape and moves in a direction aslant downward at an angle of 45 to 54 degrees from perpendicular; however, the present invention is not limited to the inclination. The cast 1 may alternatively be moved horizontally or vertically.

The cast 1 at the position where the continuous hammering devices 10 are installed is a cast that includes an unsolidified portion. More specifically, a surface of the cast 1 has been solidified with a scale attached thereto, but the surface temperature thereof is high (e.g., approximately 1200°C), and its inside is still in the process of solidifying or half molten. The present invention is not limited to the cast 1 in such a state, and may be applied to the cast 1 in a different state.

[0038] In Fig. 3, the dies 12 are adapted to hammer opposing narrow side surfaces 1a (hereinafter referred to as "the hit surfaces") on both sides of the cast 1. Each of the dies 12 extends along the cast 1 in the direction in which the cast moves and has a height (thickness) that is smaller than the total height (the thickness in the height direction) of the hit surface 1a so as to hammer the central portion of the total height of the narrow side surface 1a (the hit surface).

[0039] The main body 14 mounted on a support base 15 is guided by a linear guide, which is not shown, so as to be able to linearly move in a direction orthogonal to the hit surface 1a (e.g., a horizontal direction).

The moving device 16 is constituted of a pneumatic or hydraulic direct-acting cylinder 17, a swinging shaft 18, links 19a, 19b and 19c in this example. The main body 14 is moved forward and backward relative to the cast 1 by the expansion and contraction of the direct-acting cylinder 17.

The construction of the moving device 16 is not limited to the example described above.

[0040] Fig. 4 is a general top plan view illustrating the relationship between the cast 1 and the two continuous hammering devices 10.

In this figure, reference numeral 20 denotes a positioning mechanism, which is, in this example, rotationally installed to the main body 14 and composed of a plurality of (three in the figure) guide rollers 20a that rotate in contact with the hit surface 1a of the cast 1 at a predetermined position.

With this arrangement, the main body 14 is moved forward relative to the cast 1 by the moving device 16 to bring the plurality of guide rollers 20a into contact with the hit surface 1a of the cast 1, causing the guide rollers 20a to freely rotate while in contact with the cast 1 in the process of continuous casting. Thus, the main body 14 can be set at a predetermined position relative to the cast 1 without being subjected to a large force in a transverse direction.

[0041] Fig. 5A and Fig. 5B are configuration diagrams of an essential section of the continuous hammering device 10, Fig. 5A indicating a storage position and Fig. 5B indicating a hammering position.

In these figures, the continuous hammering device 10 in accordance with the present invention has a hammering member 22, a compression spring 30, and a cam mechanism 32. These hammering member, the compression spring, and the cam mechanism are supported by the main body 14.

[0042] The hammering member 22 is constituted of the die 12 which hammers the hit surface 1a of the cast 1, and a reciprocating member 23. The reciprocating member 23 in this example is constituted of two slide portions 24, a cam follower base 25, a cam follower 26, and connecting portions 27 at two locations.

As illustrated in Fig. 6, the hammering member 22 is constituted of the die 12 and the reciprocating member 23. The same operation is provided when the reciprocating member 23 has the slide portion 24 at one location, the cam follower base 25, the cam follower 26, and the connecting portion 27 at one location. The following will describe a case where the reciprocating member 23 has the slide portions at two locations and the connecting portions at two locations.

[0043] Each of the two connecting portions 27 has one end (the upper end in the figure) thereof fixed to the die 12, extends in parallel to a direction orthogonal to the hit surface 1a, and is supported by a bearing 21a, which is fixed to a support plate 14a of the main body 14, such that the connecting portion 27 is allowed to reciprocate in a direction orthogonal to the hit surface 1a. Further, each of the slide portions 24 at the two locations extends in parallel to a direction orthogonal to the hit surface 1a and is supported by a bearing 21b, which is fixed to a support plate 14b of the main body 14, such that the slide portion 24 is allowed to reciprocate in a direction orthogonal to the hit surface 1a.

[0044] Both ends of the cam follower base 25 are fixed to the slide portions 24 at the two locations and the connecting portions 27 at the two locations, so that the cam follower base 25 can be reciprocated integrally with the slide portions 24 at the two locations and the connecting portions 27 at the two locations. In this example, the central portion of the cam follower base 25 is recessed in a direction away from the hit surface 1a; however, the present invention is not limited thereto. Alternatively, the central portion of the cam follower base 25 may be, for example, linearly shaped.

[0045] The cam follower 26 is freely rotatively installed to a middle portion of the cam follower base 25, so that the cam follower 26 freely rotates while in contact with a rotating cam 33, which will be discussed later. In the present invention, the cam follower 26 does not remain in constant contact with the rotating cam 33. Instead, the cam follower 26 comes in contact with the rotating cam 33 while the compression spring 30 is compressed by the rotating cam 33. At the time of hammering, the rotating cam 33 leaves the cam follower 26, allowing the reciprocating member 23 to

freely accelerate together with the cam follower 26.

[0046] This arrangement enables the reciprocating member 23 having one end thereof (the upper end in the figure) fixed to the die 12 to reciprocate between a hammering position (F) where the die 12 comes in contact with the hit surface 1a and a storage position (B) where the die 12 is away from the hit surface 1a by a predetermined distance.

The predetermined distance corresponds to a distance of compression of the compression spring 30 caused by the rotating cam 33.

[0047] The compression spring 30, which uses a coil spring in this example, is held between the reciprocating member 23 (the cam follower base 25 in this example) and the main body 14 (the support plate 14b in this example) in a compressed state. The compression spring 30 retains predetermined compression energy E1 at the storage position (the position indicated in Fig. 5A) and releases kinetic energy E2 at the hammering position (the position indicated in Fig. 5B).

The kinetic energy E2 is the difference in compression energy of the compression spring 30 between the storage position (the position indicated in Fig. 5A) and the hammering position (the position indicated in Fig. 5B). A relationship denoted by Kinetic energy $E2 \leq$ Compression energy E1 applies. The kinetic energy E2 can be increased by increasing the compression amount of the compression spring 30 at the hammering position (the position indicated in Fig. 5B) by a shim or the like.

[0048] The cam mechanism 32 is constituted of the rotating cam 33 rotatively supported by the main body 14 and the rotative drive device which rotatively drives the rotating cam 33.

The rotating cam 33 rotates while in contact with the cam follower 26 of the reciprocating member 23 to move the reciprocating member 23 (the cam follower base 25 in this example) to the storage position (the position indicated in Fig. 5A) at a predetermined cycle and then moves away from the cam follower 26 to allow the reciprocating member 23 to freely move to the hammering position (the position indicated in Fig. 5B).

In this example, the cam curve of the rotating cam 33 is the Archimedes curve in which a rotational angle and a displacement have a proportional relationship. However, the present invention is not limited to the Archimedes curve. The cam curve may be another type of curve as long as the curve enables the rotating cam 33 to move the reciprocating member 23 to the storage position (the position indicated in Fig. 5A) at a predetermined cycle to compress the compression spring 30, then leaves the cam follower 26 to allow the reciprocating member 23 to freely move to the hammering position (the position indicated in Fig. 5B).

[0049] The rotative drive device, which is not shown, may use any rotative drive device (e.g., a motor combined with a speed reducer) as long as the rotative drive device is capable of rotatively driving the rotating cam 33 at a predetermined speed.

The rotative drive device is preferably provided with a widely-known universal joint (e.g., a Schmitz coupling, a universal coupling or the like) installed at the middle thereof, so that a rotational motive force can be transmitted to the rotating cam 33 even when the main body 14 is moved back and forth relative to the cast 1 by the moving device 16.

[0050] According to the arrangement of the present invention described above, the continuous hammering device 10 has the hammering member 22, the compression spring 30, the cam mechanism 32, and the main body 14. The cam mechanism 32 moves the hammering member 22 in the direction away from the cast 1 to compress the compression spring 30 (Fig. 5A).

Subsequently, at the time of hammering, the cam mechanism 32 (the rotating cam 33) leaves the hammering member 22 (the cam follower 26) to allow the hammering member 22 to freely accelerate, thereby causing the compression energy E1 of the compression spring 30 to be converted into the kinetic energy E2 of the hammering member 22 (the die 12). Collision of the hammering member 22 against the cast 1 imparts the predetermined hammering energy (= the kinetic energy E2) to the cast 1 (Fig. 5B).

[0051] Thus, the continuous hammering device 10 in accordance with the present invention is a durable device which does not depend upon electrical control.

More specifically, the continuous hammering device 10 in accordance with the present invention is capable of continuously hammering opposing narrow side surfaces 1a on both sides of the cast 1 in continuous casing of steel in the direction of the width of the cast, and exhibits high durability that enables prolonged continuous use even when subjected to high impacts (30 to 150J) at high frequencies (4 to 12 Hz) while being exposed to high-temperature radiation heat (e.g., approximately 1200°C) from the cast 1, scales, water and the like.

[0052] Further, the compression spring 30 is held between the reciprocating member 23 (the cam follower base 25) and the main body 14 (the support plate 14b), retains the predetermined compression energy E1 at the storage position (the position indicated in Fig. 5A), then releases the kinetic energy E2 at the hammering position (the position indicated in Fig. 5B). The cam mechanism 32 includes the rotating cam 33, which moves the reciprocating member 23 to the storage position (the position indicated in Fig. 5A) at the predetermined cycle and then allows the reciprocating member 23 to freely move to the hammering position (the position indicated in Fig. 5B), and the rotative drive device, which rotatively drives the rotating cam 33. With this arrangement, a predetermined hammering vibration frequency (e.g., 4 to 12 Hz) can be freely set by the rotational speed of the rotating cam 33 driven by the rotative drive device, and the

predetermined compression energy E1 of the compression spring 30 can be converted into the predetermined hammering energy E2 (e.g., 30 to 150J).

[0053] The cam curve of the rotating cam 33 is the Archimedes curve in which a rotational angle and a displacement have a proportional relationship. This makes it easy for the cam mechanism 32 to leave the hammering member 22 at the time of hammering so as to allow the hammering member 22 to freely accelerate.

[0054] The displacement (deformation amount) of the compression spring 30 caused by the rotating cam 33 at the storage position (the position indicated in Fig. 5A) and the hammering position (the position indicated in Fig. 5B) is constant. Hence, hammering with constant hammering energy can be accomplished even when the hammering vibration frequency is changed by changing the rotational speed of the rotating cam 33.

[0055] Fig. 7A and Fig. 7B illustrate positional relationships between the rotating cam 33 and the cam follower 26, Fig. 7A illustrating a case where the die 12 does not collide with the cast 1, while Fig. 7B illustrating a case where the die 12 collides with the cast 1.

In Fig. 7A and Fig. 7B, an axis of abscissas θ indicates the rotational angle of the rotating cam 33, values of 0 to 2π being repeated for each rotation. An axis of ordinates y indicates the displacement of the cam follower 26.

[0056] In the figure, a cam curve 33a of the rotating cam 33 is an Archimedes curve in which a rotational angle θ and a displacement y have a proportional relationship. A polygonal line indicated by A-B-C in the figure is repeated for each rotation of the rotating cam 33. A straight line AB can be represented by expression (1) given below.

$$y = a\theta - y_3 \dots \text{Expression (1)}$$

where "a" denotes the inclination of the straight line AB ($= (y_1 + y_3) / 2\pi$).

[0057] As a trajectory 26a of the cam follower 26 and a cam curve 33a indicate in Fig. 7A and Fig. 7B, the cam follower 26 displaces while in contact with the rotating cam 33 according to the cam curve 33a during a period in which the rotational angle θ of the rotating cam 33 changes from an intermediate angle β between an angle α and 2π to the angle 2π . From an angle 0 to the angle β , the cam follower 26 freely moves due to a spring force while in no contact with the rotating cam 33.

[0058] In the case where the die 12 does not collide with the cast 1, the trajectory 26a of the cam follower 26 is represented by the curve denoted by a-b-c-d-e-f, as illustrated in Fig. 7A. More specifically, the storage position (the position indicated in Fig. 5A) corresponds to a point B, and the compression spring 30 is compressed by a distance y_1 from the initial position thereof and has the predetermined compression energy E1.

When the rotational angle θ of the rotating cam 33 exceeds zero, the cam follower 26 is accelerated by a spring force and draws a trajectory indicated by the curve a-b-c. In the trajectory, the curve a-b denotes an acceleration period during which the spring extends from a compressed state to zero deformation (the state of a natural length) and the curve b-c denotes a deceleration period during which the spring extends beyond the initial position thereof.

[0059] According to the present invention, a damper device 35 is provided to attenuate the moving speed of the reciprocating member 23 when the reciprocating member 23 passes the hammering position ($y=0$) and moves toward the cast, as illustrated in Fig. 5A and Fig. 5B. The damper device 35 is, for example, a hydraulic damper or a damper rubber. In the example illustrated in Fig. 5A and Fig. 5B, the damper device 35 is provided between the reciprocating member 23 and the main body 14 (the support plate 14a).

The damper device 35 operates only during the period defined by the curve b-c and sets the damping force such that the curve b-c-d does not collide with the cam curve 33a.

[0060] With this arrangement, when the reciprocating member 23 passes the hammering position ($y=0$) and moves toward the cast, the moving speed of the reciprocating member 23 is damped by the damper device 35, thereby preventing the collision between the cam follower 26 and the rotating cam 33. Further, even when idle hammering is repeated in the absence of the cast 1, high durability that enables prolonged continuous use can be provided.

[0061] In Fig. 7A, the curve c-d-e-f denotes the free vibration of the spring, which depends upon the natural period of the compression spring 30. The natural period is set such that the rotating cam 33 and the cam follower 26 come in contact again at the compression position (point f in the figure) of the compression spring 30.

This arrangement makes it possible to reduce the colliding speed when the rotating cam 33 comes in contact with the cam follower 26 again (at the point f in the figure), thus permitting higher durability of the rotating cam 33 and the cam follower 26.

[0062] In the case where the die 12 collides with the cast 1, the trajectory 26a of the cam follower 26 draws a curve that is midway between the curve a-b-g and the curve a-b-h-i-j-k, as illustrated in Fig. 7B.

More specifically, the storage position (the position indicated in Fig. 5A) corresponds to the point B, and the compression spring 30 is compressed by a distance y_1 from the initial position thereof and has the predetermined compression energy E1.

Then, as the rotational angle θ of the rotating cam 33 exceeds zero, the cam follower 26 is accelerated by a spring force and draws a trajectory indicated by the curve a-b. The curve a-b denotes an acceleration period during which the spring extends from a compressed state to zero deformation (the state of a natural length).

[0063] If the cast 1 exists at a predetermined position ($y=0$) and the restitution coefficient thereof is zero, that is, the cast 1 is a complete plastic body, then the cam follower 26 collides with the cast 1 and stops at that position, maintains a straight line g, comes in contact with the cam curve 33a at the angle α , and thereafter, the cam follower 26 is compressed to the point B along the cam curve 33a.

[0064] If the cast 1 exists at the predetermined position ($y=0$) and the restitution coefficient thereof is 1, then the cam follower 26 collides with the cast 1 and is bounced back at the same speed, traces the curve h-i-j-k and collides with the rotating cam 33 at a point k, and thereafter, the cam follower 26 is compressed along the cam curve 33a.

[0065] If the cast 1 exists at the predetermined position ($y=0$) and the restitution coefficient thereof is midway between 0 and 1, then the trajectory 26a of the cam follower 26 will be midway between the curve a-b-g and the curve a-b-h-i-j-k.

[0066] The natural period of the compression spring is set such that the rotating cam 33 and the cam follower 26 come in contact with each other again at the compression position (the point k in the figure) of the compression spring.

This arrangement makes it possible to reduce the colliding speed when the rotating cam 33 comes in contact with the cam follower 26 again (at the point k in the figure), thus permitting higher durability of the rotating cam 33 and the cam follower 26.

[Embodiment]

[0067] The continuous hammering device 10 having the construction described above has been actually fabricated and a test has been carried out using an actual cast 1.

The test result has proven that the continuous hammering device 10 in accordance with the present invention makes it possible to continuously hammer the opposing narrow side surfaces on both sides of the cast 1 in the process of continuous casting of steel in the direction of the width of the cast. The test result has also proven that the continuous hammering device 10 survives prolonged continuous use even when subjected to high impacts (30 to 150J) at high frequencies (4 to 12 Hz) while being exposed to high-temperature radiation heat (e.g., approximately 1200°C) from the cast 1, scales, water and the like.

Fig. 8 illustrates the result of comparison between the durability of conventional equipment which uses an air cylinder as the hammering device thereof and carries out hammering by electrical control using solenoid valves (maintenance carried out at the time of major failures) and the durability of the present invention.

A segment for continuous casting generally survives continuous use in a production line for about six months to about one year unless rolls wear or fail (damage to bearings, water leakage, or the like). The equipment durability assessment means that a continuous hammering device has been out of action for maintenance or removed from a production line for maintenance due to a major failure except when the service life of the segment expires. The continuous hammering device in accordance with the present invention enables prolonged continuous hammering, which is approximately 12 times longer than the conventional type.

[0068] It is obvious that the present invention is not limited to the embodiments described above, but may be modified in a variety of forms without departing from the spirit or essential characteristics thereof.

Claims

1. A continuous hammering device for continuous casting, comprising:

- a hammering member for hammering a cast;
- a compression spring which pushes the hammering member toward the cast;
- a cam mechanism which compresses the compression spring by moving the hammering member away from the cast and then allows the hammering member to freely move; and
- a main body which supports the hammering member, the compression spring, and the cam mechanism, wherein at the time of hammering, the cam mechanism leaves the hammering member to allow the hammering member to freely accelerate so as to convert compression energy of the compression spring into kinetic energy of the hammering member, and the hammering member collides with the cast, thereby imparting predetermined hammering energy to the cast.

2. The continuous hammering device for continuous casting according to claim 1, wherein the hammering member comprises:

a die which hammers a hit surface of the cast; and
a reciprocating member which has one end thereof fixed to the die and which is capable of reciprocating between
a hammering position where contact to the hit surface is made and a storage position away from the hit surface
by a predetermined distance,
5 the compression spring which is held between the reciprocating member and the main body, retains predetermined
compression energy at the storage position, and releases the kinetic energy at the hammering position,
and
the cam mechanism includes a rotating cam which is rotatably supported by the main body, moves the recip-
roating member to the storage position at a predetermined cycle, and then allows the reciprocating member
10 to freely move to the hammering position, and a rotative drive device which rotatively drives the rotating cam.

3. The continuous hammering device for continuous casting according to claim 2, wherein the cam curve of the rotating
cam is an Archimedes curve in which a rotational angle and a displacement have a proportional relationship.

15 4. The continuous hammering device for continuous casting according to claim 2, wherein the reciprocating member
has a cam follower which freely rotates while in contact with the rotating cam.

5. The continuous hammering device for continuous casting according to claim 4, wherein a natural period of the
compression spring is set to cause the rotating cam and the cam follower to come in contact with each other again
20 at a compression position of the compression spring.

6. The continuous hammering device for continuous casting according to claim 2, further comprising a damper device
which reduces the moving speed of the reciprocating member when the reciprocating member passes the hammering
position and moves toward the cast.

25 7. The continuous hammering device for continuous casting according to claim 1, further comprising:

a moving device which moves the main body back and forth relative to the cast; and
a positioning mechanism which sets the main body at a predetermined position relative to the cast.

30 8. The continuous hammering device for continuous casting according to claim 7, wherein the positioning mechanism
comprises a plurality of guide rollers which is rotatably installed to the main body and which freely rotates while in
contact with the hit surface of the cast at a predetermined position.

Fig. 1
Prior Art

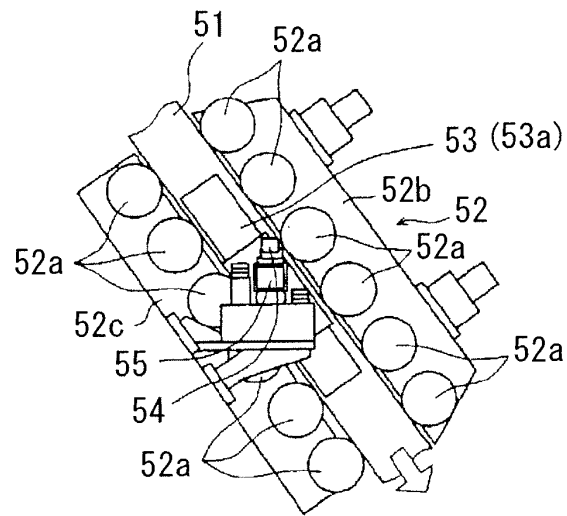


Fig. 2A
Prior Art

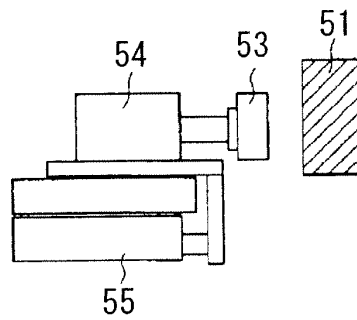


Fig. 2B
Prior Art

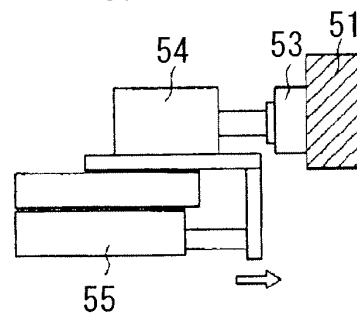


Fig. 2C
Prior Art

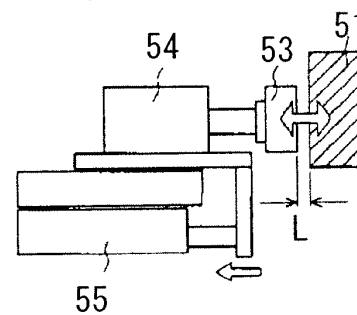


Fig. 3

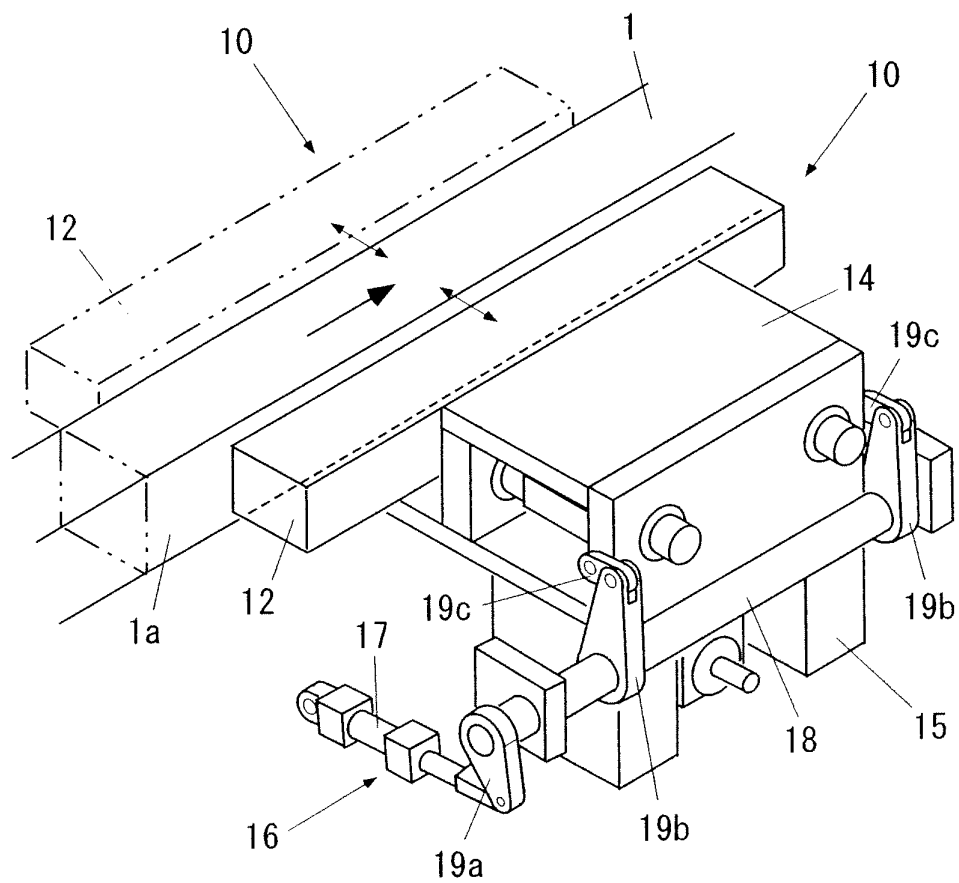


Fig. 4

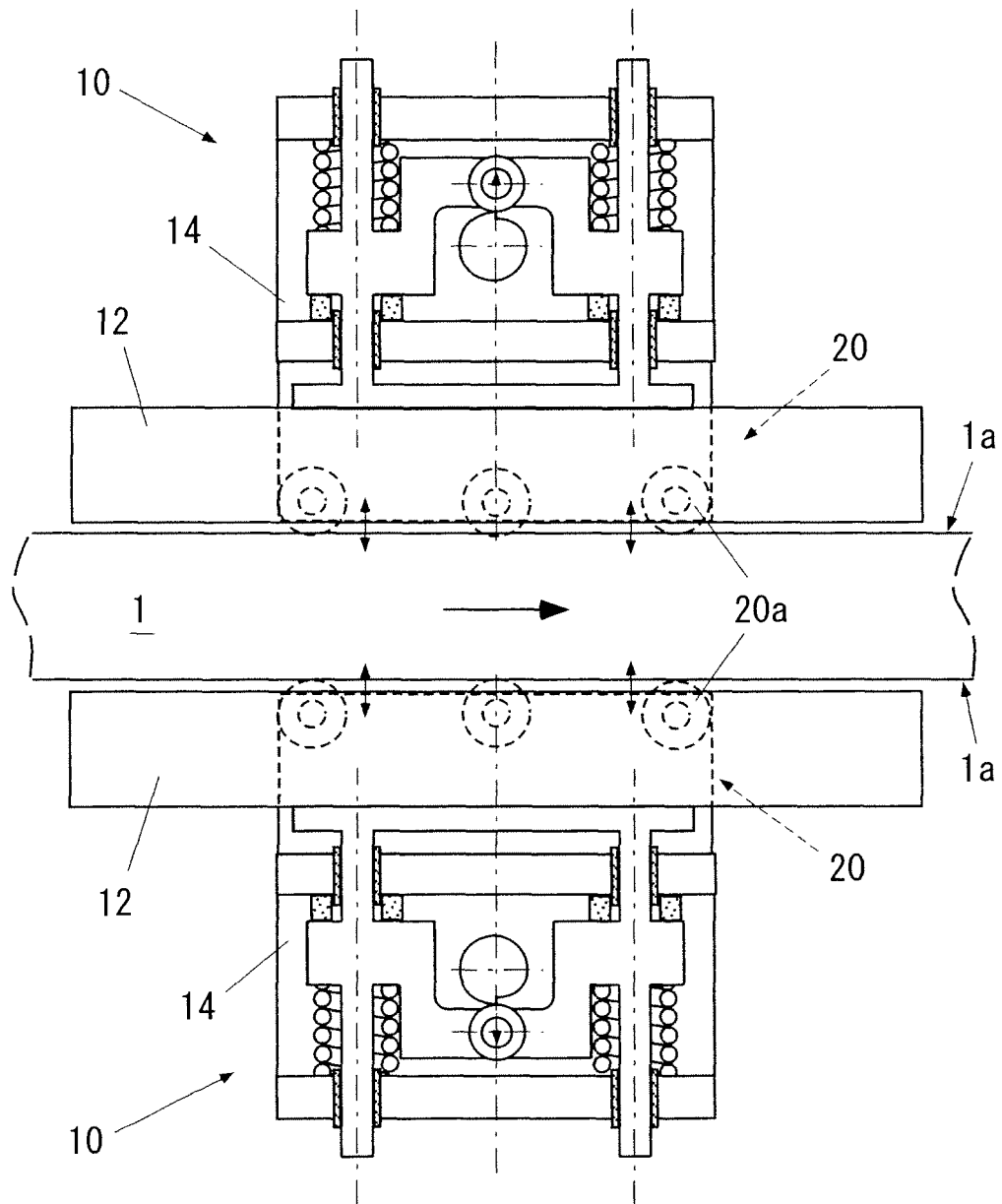


Fig. 5A

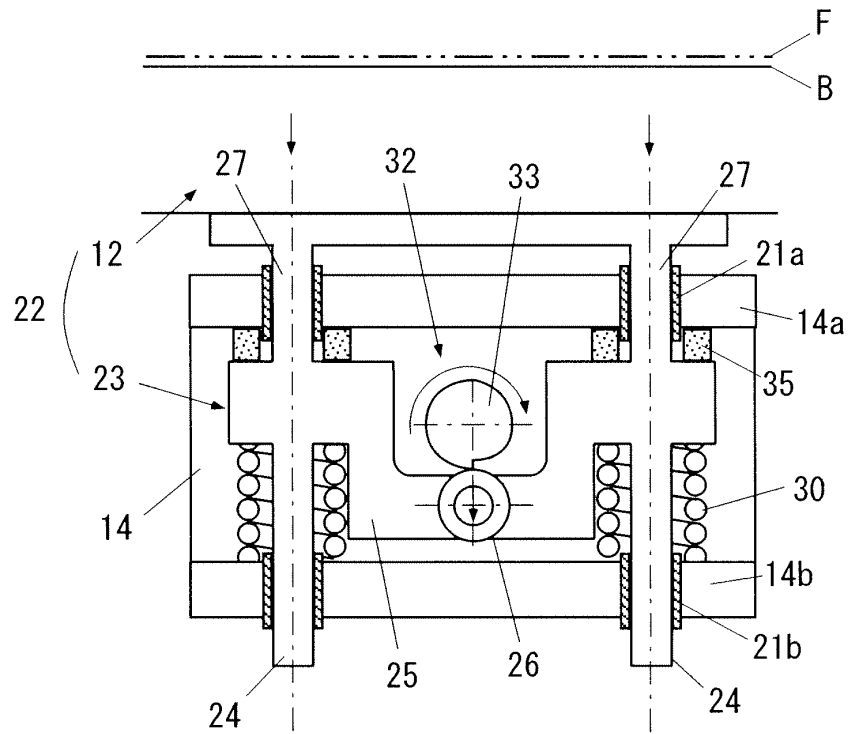


Fig. 5B

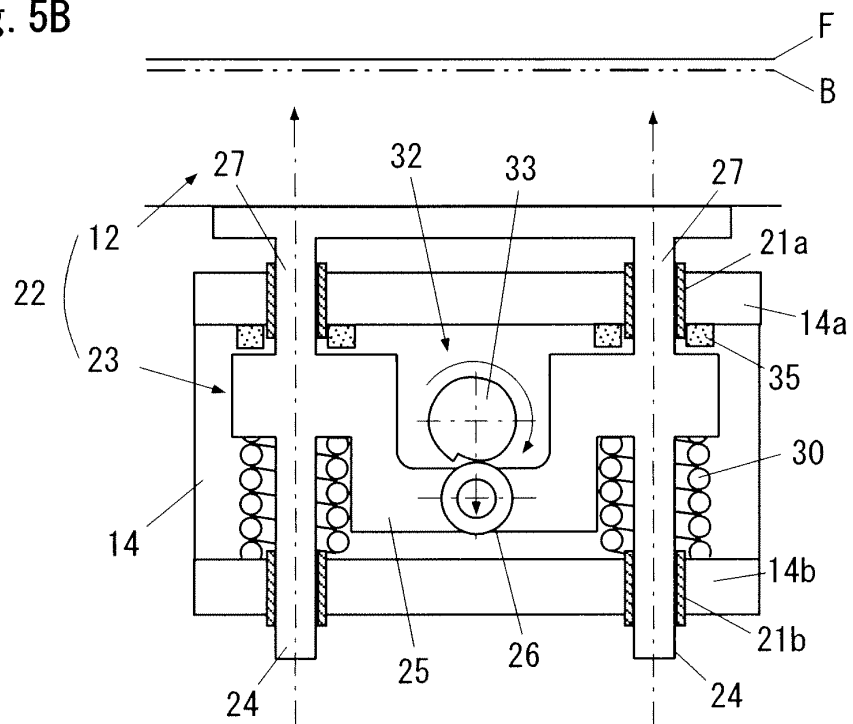


Fig. 6

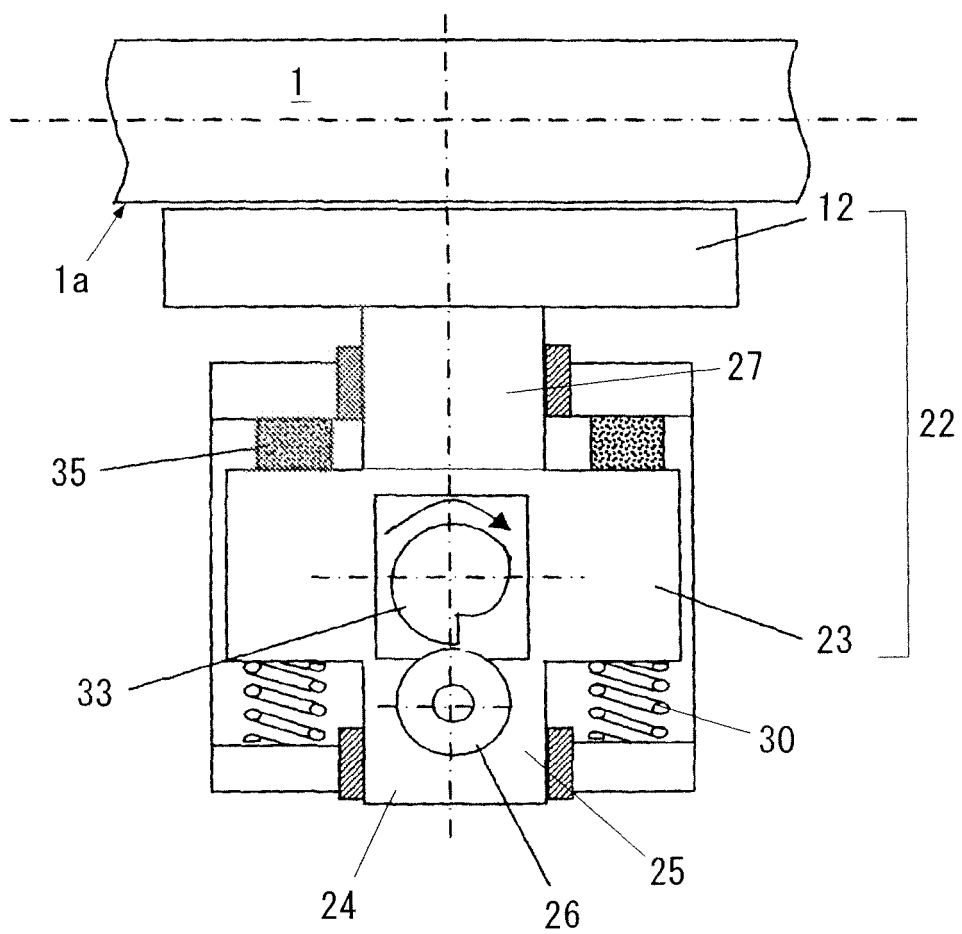


Fig. 7A

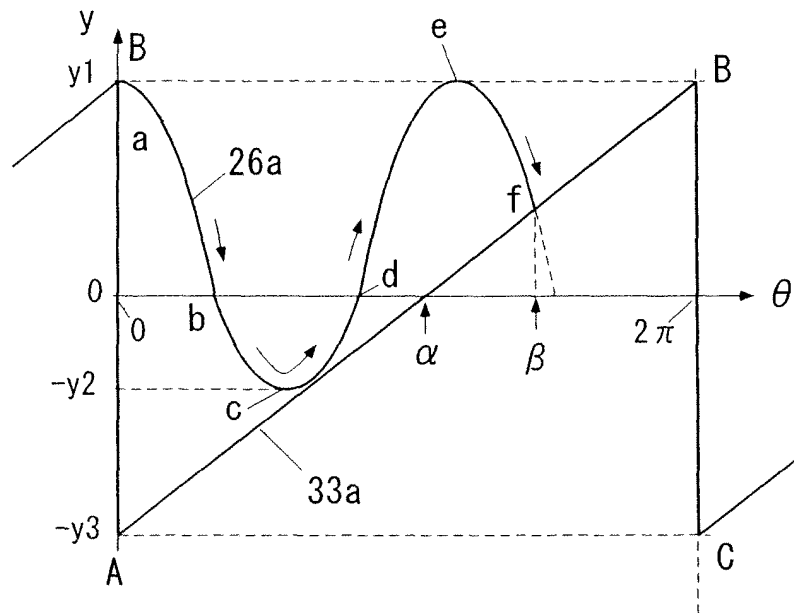


Fig. 7B

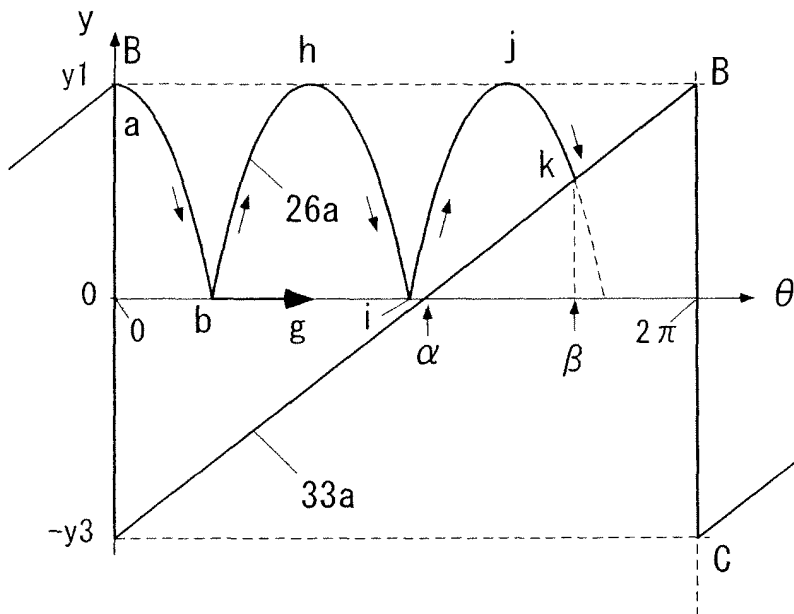
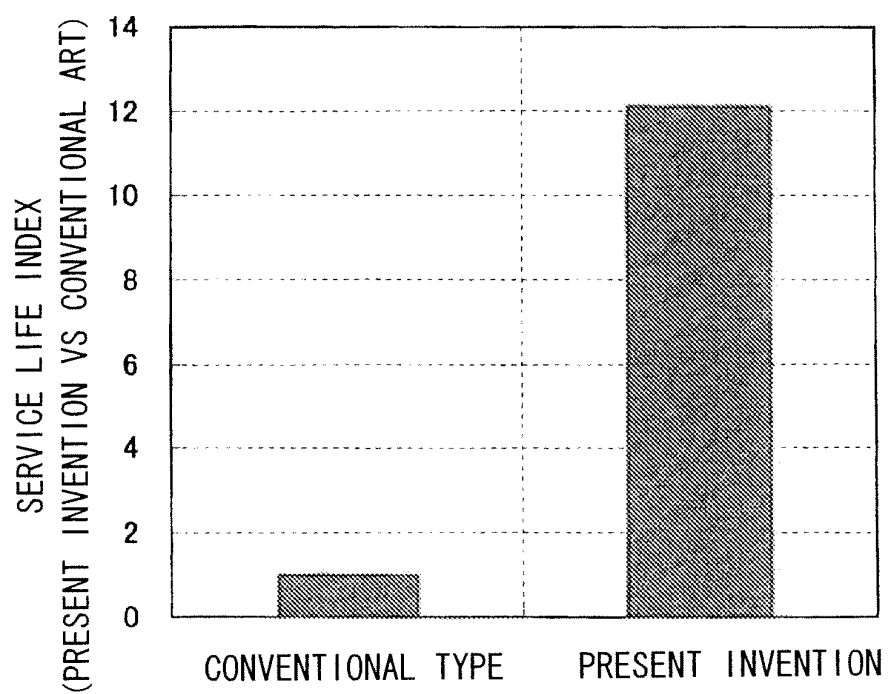


Fig. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/054485

A. CLASSIFICATION OF SUBJECT MATTER B22D11/128(2006.01) i, B22D27/20(2006.01) i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) B22D11/128, B22D27/20		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2009 Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2007-229748 A (Sumitomo Metal Industries, Ltd.), 13 September, 2007 (13.09.07), Claims; Par. Nos. [0028] to [0033], [0063]; Figs. 1 to 3 (Family: none)	1-4, 7 5-6, 8
Y A	JP 35-2265 Y1 (Yoshio HAKAMADA), 10 February, 1960 (10.02.60), Page 1, right column, lines 4 to 9; Figs. 1 to 5 (Family: none)	1-4, 7 5-6, 8
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 15 June, 2009 (15.06.09)		Date of mailing of the international search report 23 June, 2009 (23.06.09)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/054485

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 175051/1984 (Laid-open No. 91143/1986) (Mitsubishi Heavy Industries, Ltd.), 13 June, 1986 (13.06.86), Claims (Family: none)	1-4, 7 5-6, 8

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2006110620 A [0008]
- JP 2007229748 A [0008]