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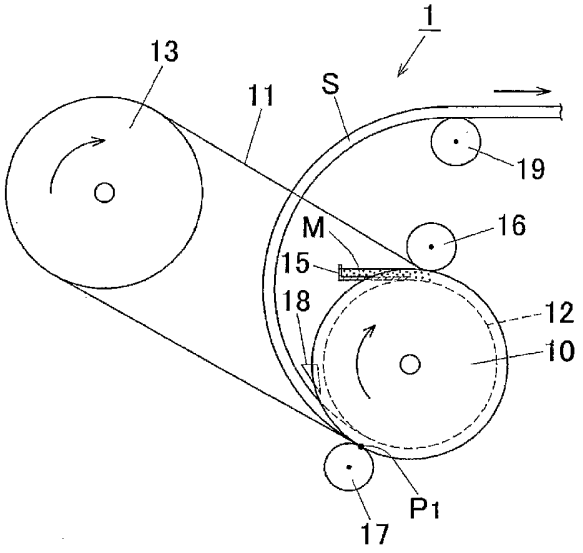
(54) **Title:** CONTINUOUS CASTING METHOD, CAST MATERIAL, METAL WORK PIECE AND CONTINUOUS CASTING APPARATUS



(57) **Abstract:** In a continuous casting method using a casting wheel and a continuous belt, the cooling performance of a cast material is improved without deteriorating the durability of the continuous belt and the freedom of the casting conditions. In the method, a cast material is cast by rotating a casting wheel (12) anda continuous belt (11) while continuously supplying molten metal into a casting space (14) formed by closing a concave groove (12) on an external peripheral surface of the casting wheel (10) with the continuous belt (11) put on the external peripheral surface of the casting wheel (12) and an external peripheral surface of a tension adjusting wheel (13). One or a plurality of pressing rollers (17) press the continuous belt (11) at a casting side of the casting wheel (10) against the casting wheel (10).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

CONTINUOUS CASTING METHOD, CAST MATERIAL, METAL WORK PIECE AND CONTINUOUS CASTING APPARATUS

This application claims priority to Japanese Patent Application No. 2004-312428 filed on October 27, 2004 and U.S. Provisional Application S.N. 60/624,178 filed on November 3, 2004, the entire disclosures of which are incorporated herein by reference in their entireties.

Cross Reference to Related Applications

This application is an application filed under 35 U.S.C. §111(a) claiming the benefit pursuant to 35 U.S.C. §119(e)(1) of the filing date of U.S. Provisional Application S.N. 60/624,178 filed on November 3, 2004, pursuant to 35 U.S.C. §111(b).

Technical Field

The present invention relates to a metal continuous casting method, a cast material manufactured by the continuous casting method, a metal work piece manufactured from this cast material, and a continuous casting apparatus for executing the continuous casting method.

In this disclosure, a casting direction in which a cast material advances may be referred to as a "rear" or "rear stage," and a direction opposite to the casting direction may be referred to as a "forward."

Background Art

The following description sets forth the inventor's knowledge of related art and problems therein and should not be construed as an admission of knowledge in the prior art.

As one of metal continuous casting methods, the following method is known. In this method, a casting space is defined by combining a casting wheel having a concave groove on its external peripheral portion and an endless belt for closing the concave groove. By rotating the casting wheel and the endless belt while supplying molten metal to the casting space, a cast material can be continuously manufactured. At a rear stage of the casting step, a rolling mill is arranged so that the cast material can be rolled continuously into a desired configuration.

In the continuous casting apparatus 3 shown in Fig. 5, the casting wheel 10 is provided with a concave groove 12 on its external peripheral surface. The continuous belt 11 is a loop-shaped endless belt 11 put on the casting wheel 10 and the tension adjusting wheel 13. In this state, the endless belt 11 closes the concave groove

12 of the casting wheel 10 to form a casting space 14 therebetween. This casting space 14 is cooled by cooling water from the internal peripheral surface portion of the casting wheel 10 and the external portion of the belt 11.

In the continuous casting apparatus 3, the molten metal M supplied to the casting space 14 from the tundish 15 is cooled by the casting wheel 10 and the belt 11 and formed into a cast material S continuously in accordance with the rotational driving of the casting wheel 10 and the belt 11. When the tip end portion of the cast material S passes the position P4 of the cooling area where the casting wheel 10 and the belt 11 are detached, the cast member S is detached with the scraper 18 from the casting wheel 10, and then continuously detached away from the casting wheel 10 by the bending moment applied to the cast material S after passing through the dancer roll 19 provided at the rear stage.

However, as shown in Fig. 6, the cast material S which is supposed to be cooled until it reaches the position P4 pushes the belt 11 outwardly by the moment applied to the cast material S for straitening it after passing the dancer roll 19, which may sometimes result in detachment of the cast material S from the casting wheel 10 at the position P5 which is ahead of the position P4. Such early detachment of the cast material S causes heavy deterioration of the thermal transmission, which in turn may cause cast defects such as cracks due to the remained liquid phase in

the cast material.

In order to prevent such early detachment in the cooling area, a method of increasing the tension of the belt can be employed. However, the belt is used under severe environments in which the belt comes into contact with high temperature molten metal, and therefore the increased tension causes a deterioration of the life.

In order to solve the above mentioned problems, there are proposals. For example, Japanese Unexamined Laid-open Patent Publication No. 59-193737 (Patent document 1) proposes a method in which the material of the belt is controlled and the thickness of the belt is set in considering of the molten metal temperature to enhance the contact between the casting mold and the cast material. Japanese Unexamined Laid-open Patent Publication No. 63-112044 (Patent Document 2) proposes a method in which the surface of the belt is coated with copper or aluminum to prevent generation of cracks to thereby enhance the durability of the belt.

In the method described in the aforementioned Patent Document 1, however, the belt is large in restriction, which harms the freedom of casting conditions. On the other hand, in the method described in the aforementioned Patent Document 2, sufficient durability against high belt tension cannot be obtained by the surface treatment of the belt.

The description herein of advantages and disadvantages of various features, embodiments, methods, and apparatus disclosed in other publications is in no way intended to limit the present invention. Indeed, certain features of the invention may be capable of overcoming certain disadvantages, while still retaining some or all of the features, embodiments, methods, and apparatus disclosed therein.

Other objects and advantages of the present invention will be apparent from the following preferred embodiments.

Disclosure of Invention

The preferred embodiments of the present invention have been developed in view of the above-mentioned and/or other problems in the related art. The preferred embodiments of the present invention can significantly improve upon existing methods and/or apparatuses.

The present invention has been made based on the aforementioned background technique, and aims to provide a continuous casting method capable of improving the cooling performance of a cast material without deteriorating durability of the belt and freedom of the casting conditions. Furthermore, the present invention aims to provide a cast material manufactured by the method, a metal work piece made of the cast material, and

a continuous casting apparatus for performing the continuous casting method.

To attain the aforementioned objects, the continuous casting method according to the present invention has the following structures [1] to [11].

[1] A continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel,

wherein one or a plurality of pressing rollers press the continuous belt at a casting side of the casting wheel against the casting wheel.

[2] The continuous casting method as recited in the aforementioned Item 1, wherein the one or a plurality of pressing rollers are pressed against the casting wheel with driving force.

[3] The continuous casting method as recited in the aforementioned Item 1, wherein the pressing roller is disposed at a second reference position (P2) on the external peripheral surface of the casting wheel or at a rear stage of the second reference

position (P2), wherein the second reference position (P2) is defined as a position away from a first reference position (P1) on the external peripheral surface of the casting wheel by a central angle of 45 degrees of the casting wheel toward a direction opposite to a casting direction, the first reference position (P1) being defined as a position where the continuous belt is detached from the pressing roller at a time of non-casting with no pressing roller.

[4] The continuous casting method as recited in the aforementioned Item 2, wherein the pressing roller is disposed at a second reference position (P2) on the external peripheral surface of the casting wheel or at a rear stage of the second reference position (P2), wherein the second reference position (P2) is defined as a position away from a first reference position (P1) on the external peripheral surface of the casting wheel by a central angle of 45 degrees of the casting wheel toward a direction opposite to a casting direction, the first reference position (P1) being defined as a position where the continuous belt is detached from the pressing roller at a time of non-casting with no pressing roller.

[5] The continuous casting method as recited in the aforementioned Item 3, wherein the pressing roller is disposed at the first reference position (P1).

[6] The continuous casting method as recited in the aforementioned Item 4, wherein the pressing roller is disposed

at the first reference position (P1).

[7] The continuous casting method as recited in the aforementioned Item 3, wherein the pressing roller is disposed at a rear stage of the first reference position (P1).

[8] The continuous casting method as recited in the aforementioned Item 4, wherein the pressing roller is disposed at a rear stage of the first reference position (P1).

[9] The continuous casting method as recited in the aforementioned Item 7 or 8, wherein the pressing roller is disposed within a range from the first reference position P1 to a position away from the first reference position (P1) rearward by the central angle of 90 degrees.

[10] The continuous casting method as recited in any one of the aforementioned Items 1 to 8, wherein the casting wheel is cooled and the continuous belt is heated.

[11] The continuous casting method as recited in any one of the aforementioned Items 1 to 8, wherein the metal is aluminum or aluminum alloy.

A cast material according to the present invention has the following structure [12].

[12] A cast material manufactured by a continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel, wherein the cast material is continuously cast by pressing the continuous belt against the casting wheel with one or a plurality of pressing rollers disposed at a casting side of the casting wheel against the casting wheel.

A metal work piece according to the present invention has the following structure [13] and [14].

[13] A metal work piece obtained by performing plastic working to a cast material, wherein the cast material is manufactured by a continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel, wherein the cast material is continuously cast by pressing the continuous belt against the casting wheel with one or a plurality of pressing rollers disposed at a casting side of the casting wheel

against the casting wheel.

[14] A metal work piece obtained by performing cutting working to a cast material, wherein the cast material is manufactured by a continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel, wherein the cast material is continuously cast by pressing the continuous belt against the casting wheel with one or a plurality of pressing rollers disposed at a casting side of the casting wheel against the casting wheel.

A continuous casting apparatus according to the present invention has the following structure [15].

[15] A continuous casting apparatus, comprising:

a casting wheel rotatably driven, the casting wheel being provided with a concave groove on an external peripheral surface thereof;

a circular continuous belt put on the external surface of the casting wheel to form a casting space by closing the concave groove;

a tension adjusting wheel disposed at an inside of the

continuous belt for adjusting a tension of the continuous belt; and

a pressing roller for pressing the continuous belt at a casting side of the casting wheel.

Effects of the Invention

According to the continuous casting method of the invention as recited in the aforementioned Item [1], early detachment of the cast material from the casting wheel can be prevented, resulting in sufficient cooling of the casting material. Thus, no hot tear will be generated, which in turn can manufacture a cast material excellent in cast quality. Since the method can be performed by simply adding the pressing roller, the conventional casting wheel and continuous belt can be used. Thus, the durability of the continuous belt and the freedom of the casting conditions will not be deteriorated. Furthermore, sufficient cooling can be attained, which makes it possible to increase the casting rate, resulting in improved productivity.

According to the invention as recited in the aforementioned Item [2], early detachment of the cast material can be prevented assuredly.

According to the invention as recited in the aforementioned Item [3] and [4], early detachment of the cast material can be

prevented assuredly.

According to the invention as recited in the aforementioned Item [5] and [6], early detachment of the cast material can be prevented more assuredly.

According to the invention as recited in the aforementioned Item [7] and [8], a cooling area can be increased.

According to the invention as recited in the aforementioned Item [9], a cooling area can be maximized.

According to the invention as recited in the aforementioned Item [10], a continuous cast material in which a final solidification portion exists near the continuous belt side surface can be manufactured. In such a continuous cast material, even if cast defects are generated in the final solidification portion, such defects can be eliminated by removing the surface portion or will vanish or decrease by the subsequent plastic working. Thus, cast defects will not be carried over the work piece.

According to the invention as recited in the aforementioned Item [11], an aluminum cast material excellent in cast quality can be manufactured.

The cast material according to the invention as recited in

the aforementioned Item [12] is a high quality material with no cast crack due to sufficient cooling.

Since the metal work piece according to the invention as recited in the aforementioned Item [13] is obtained by subjecting the cast material of the present invention to plastic working, the metal work piece does not carry over cast defects, and is high in quality.

Since the metal work piece according to the invention as recited in the aforementioned Item [14] is obtained by subjecting the cast material of the present invention to cutting work, the metal work piece does not carry over cast defects, and is high in quality.

According to the continuous casting apparatus of the invention as recited in the aforementioned Item [15], the continuous casting method of the present invention can be carried out to manufacture a high quality cast material with no cast crack.

The above and/or other aspects, features and/or advantages of various embodiments will be further appreciated in view of the following description in conjunction with the accompanying figures. Various embodiments can include and/or exclude different aspects, features and/or advantages where applicable. In addition, various embodiments can combine one or more aspect

or feature of other embodiments where applicable. The descriptions of aspects, features and/or advantages of particular embodiments should not be construed as limiting other embodiments or the claims.

Brief Description of Drawings

The preferred embodiments of the present invention are shown by way of example, and not limitation, in the accompanying figures, in which:

Fig. 1 is a schematic view showing a structure of a continuous casting apparatus for executing the continuous casting method of the present invention;

Fig. 2 is a schematic view showing a casting space in the continuous casting apparatus shown in Fig. 1;

Fig. 3 is a schematic view showing a structure of another continuous casting apparatus for executing the continuous casting method of the present invention;

Fig. 4A is a schematic view showing another arrangement of the pressing roller in the continuous casting apparatus shown in Fig. 3;

Fig. 4B is a schematic view showing still another arrangement of the pressing roller in the continuous casting apparatus shown in Fig. 3;

Fig. 4C is a schematic view showing a position of the pressing roller in an example of the continuous casting apparatus shown in Fig. 3;

Fig. 5 is a schematic view showing a structure of a continuous casting apparatus for executing a conventional continuous casting method;

Fig. 6 is an explanatory view showing the state in which the continuous casting is executed using the continuous casting method shown in Fig. 5, and

Fig. 7 is a schematic view showing a structure of a continuous casting apparatus by an SCR method.

Best Mode for Carrying Out the Invention

In the following paragraphs, some preferred embodiments of the invention will be described by way of example and not limitation. It should be understood based on this disclosure that various other modifications can be made by those in the art based on these illustrated embodiments.

The continuous casting method of the present invention is designed to assuredly cool a cast material in a prescribed cooling region by preventing early detachment of the continuous belt from a casting wheel. Hereinafter, the present invention will be detailed with reference to a concrete continuous casting method and a continuous casting apparatus for executing the method.

In Figs. 1 and 2, a continuous casting apparatus 1 for executing the continuous casting method of the present invention is schematically illustrated.

The continuous casting apparatus 1 is provided with a casting wheel 10 and a continuous belt 11 as rotational molting members.

The casting wheel 10 is provided with a concave groove 12 on the external peripheral surface, and can be cooled by supplying cooling water via a nozzle (not shown) provided in the wheel. On the other hand, the continuous belt 11 is a circular endless belt put on the casting wheel 10 and the tension adjusting wheel 13, so that a casting space 14 is formed by closing the concave groove 12 of the casting wheel 10. The continuous belt 11 is designed to be cooled by cooling water (not shown) supplied from outside within a region in which the belt comes into contact with the casting wheel 10.

The reference numeral "15" denotes a tundish for supplying molten metal M to the casting space 14, and the reference numeral "16" denoted a pinch roller for causing the continuous belt 11 to be in close contact with the casting wheel 10 at the molten metal inlet side of the casting wheel 10. On the other hand, at the casting outlet side, a pressing roller 17 for pressing the continuous belt 11 against the casting wheel 10 is disposed.

In this continuous casting apparatus 1, the molten metal M supplied to the casting space 14 from the tundish 15 is solidified from the contact surface of the molten metal M in contact with the casting wheel 10 and the continuous belt 11 toward the inside thereof while being cooled to be continuously formed into a cast material S in accordance with the rotational movement of the casting wheel 10 and the continuous belt 11. When the leading end portion of the cast material S passes the cooling region in which the casting wheel 10 and the continuous belt 11 are in contact with each other, the cast material S is detached from the casting wheel 10 with the scraper 18. After passing the dancer roller 19, the cast material S is further detached continuously from the casting wheel 10 by the bending moment to be applied to the cast material S. At this time, even if the cast material S received a moment in the unbending direction after passing the dancer roller 19, the cast material S will not be detached from the casting wheel 10 at the rear side of the pressing roller 17 since the continuous belt 11 is kept pressed against the casting wheel 10 with the pressing

roller 17. Thus, the cast material S is cooled sufficiently within the cooling region.

The continuous casting method of the present invention includes various modifications so long as the continuous belt is put on the external peripheral surface of the casting wheel and that of the tension adjusting wheel so as to close the concave groove and the pressing roller presses the continuous belt against the casting wheel at the cast material outlet side of the casting wheel. For example, rollers can be added so as to change the introducing direction of the continuous belt to the casting wheel and the detaching direction of the continuous belt from the casting wheel.

In the continuous casting apparatus 2 illustrated in Fig. 3, an additional roller 20 is disposed at the rear stage of the casting wheel 10 to change the detaching direction and position of the continuous belt 11 from the casting wheel 10.

In the aforementioned continuous casting apparatuses 1 and 2, the pressing roller 17 is disposed at a position P1 on the external peripheral surface of the casting wheel 10 (hereinafter referred to as "first reference position") where the continuous belt 11 detaches from the casting wheel 10 at the time of non-casting when no pressing roller 17 exists. This assuredly prevents the early detachment of the cast material S within the prescribed cooling

region.

At the time of casting, generally, the position where the continuous belt 11 is detached from the casting wheel 10 slightly moves forward from the first reference position P1 due to the moment of the cast material S. The cast material S is not always required to be kept in the concave groove 12 until it reaches the first reference position P1 so long as it is sufficiently cooled. Furthermore, since the pressing force is applied to the cast material S even at the rear stage of the pressing roller 17, the cost material S would not be detached from the casting wheel 10 for a while. As a result, the cast material S can be sufficiently cooled on the external peripheral surface of the casting wheel 10 even if the pressing roll 17 is moved from the first reference position P1 in a direction opposite to the casting direction.

Therefore, as shown in Fig. 4A, the present invention allows the pressing roller 17 to be positioned at the casting side or a rear stage of a second reference position P2, wherein the second reference position P2 is defined as a position away from the first reference position P1 by a certain distance in a direction opposite to the casting direction or in the forward direction. The pressing roll 17 can be disposed at the second reference position P2 or at any rearward position of the second reference position P2. As a concrete second reference position P2, it is recommended that the second reference position P2 is a position away from the first

reference position P1 by the central angle a1 of 45 degrees of the casting wheel 10 because the cast material S can be sufficiently cooled by preventing the early detachment of the cast material S when the second reference position P2 is away from the first reference position P1 in a direction opposite to the casting direction by 45 degrees or less. The upper limit of the preferable moving distance in the direction opposite to the casting direction can be represented by 35 degrees in central angel a1.

In order to secure a sufficient cooling region, it is preferable that the second reference position P2 is set to a position away from the cooling initiation position (i.e., the position of the pinch roller 16) by 160 degrees in central angle a2 or more, more preferably 170 degrees in central angle a2 or more (see Fig. 4A).

As shown in Fig. 4B, the pressing roller 17 can be moved rearward beyond the first reference position P1 to increase the cooling region. The rearward moving amount of the pressing roller 17 is not specifically limited so long as the pressing roller 17 does not interfere with the casting apparatus and the traveling of the cast material S. If the rearward moving amount of the pressing roller 17 is 90 degrees or less in central angle a3, there will be no arrangement problem. Thus, the cooling region can be maximized.

As shown in Fig. 4B, a plurality of pressing rollers 17 and 21 can be disposed in series along the peripheral direction of the casting wheel 10. Such arrangement of a plurality of pressing rollers 17 and 21 can enhance the detachment prevention effect of the cast material S. In the case of disposing a plurality of pressing rollers 17 and 21, the rearmost side (casting side) pressing roller 17 is disposed at a position defined by the first and second reference positions P1 and P2. The number of pressing rollers 17 and the positions of pressing rollers 17 other than the rearmost side pressing roller can be set arbitrarily.

In Figs. 4A and 4B, the scraper, the tundish and the concave groove are not illustrated for convenience of explanation.

In the continuous casting apparatus 1 shown in Fig. 1 too, in the same manner as in the continuous casting apparatus 2, a second reference position P2 and a rearward position P3 can be defined, and the pressing roller 17 can be disposed at any position at the rearward of the second reference position P2.

The pressing roller 17 causes an effect of preventing detachment of the cast material S by simply disposing so as to come in contact with the continuous belt 11. However, it is preferable that the pressing roller 17 assuredly presses the continuous belt 11 against the casting wheel 10 by applying a pressing force. It is sufficient to apply the pressing force capable of

bending the cast material S. The preferable pressing force is 0.5 kN or larger though it depends on the configuration of the cast material S. However, excessive pressing force causes a deformation of the casting wheel 10 and/or the continuous belt 11, and therefore it is preferable that the pressing force is 10 kN or less. The means for applying the pressing force is not specifically limited. Examples of such means include, e.g., a combination of compressed air/oil pressure and an actuator such as a cylinder or a vane pump, or an electric motor. The pressing roller 17 according to the present invention is not limited to a roller for pressing the continuous belt 11 against the casting wheel 10 with a driving force, but also includes a roller capable of freely rotating in a rotation direction with a central axis thereof fixed to a certain position to prevent the early detachment of the cast material S. The material of the pressing roller 17 is not specifically limited, and can be steel, copper, stainless or other metals. From the viewpoint of cost and workability, carbon steel can be recommended. It is preferable to execute a surface treatment such as Cr plating or nitriding treatment on the external peripheral surface of the roller 17 to give abrasion resistance. As for the roller diameter, although it is also not specifically limited, it is recommended that the diameter falls within the range of from 50 to 750 mm in view of strength, weight, interference with other structures in the continuous casting apparatus.

Although the continuous belt 11 is not specifically limited,

a belt made of soft steel with a thickness of 2 to 5 mm can be used. An example of the continuous belt 11 is about 2.3 mm or about 3.2 mm in thickness and has a width capable of sufficiently covering the external peripheral surface portion of the casting wheel 10. The tensile force of the continuous belt 11 should be adjusted depending on the thickness and the width of the continuous belt 11, and should be set so as not to reach the breakdown point of the material of the continuous belt 11 when the temperature of the continuous belt 11 rises by the contact with the molten metal M.

The size, the configuration and the driving conditions of the casting wheel 10 are not also specifically limited, but can be recommended as follows. Taking account of the layout of the continuous casting apparatus and the problems on manufacturing the casting wheel, the diameter of the casting wheel 10 preferably falls within the range of from 500 to 2,000 mm. Further, taking account of the rolling to be executed after the casting, the cross-sectional area of the concave groove 12 preferably falls within the range of from 500 to 100,000 mm^2. As for the configuration of the concave groove 12, taking account of easy detachment of the cast material S, it is preferable to form a cone angle θ of 2 to 45° (see Fig. 2) because of the following reasons. If the cone angle θ is less than 2°, it becomes difficult to pull out the cast material S from the concave groove 12. On the other hand, it exceeds 45°, the cross-sectional area of the cast material S

decreases. As for the revolution speed of the casting wheel 10, although it differs depending on various factors such as the metal or alloy to be cast or the diameter of the casting wheel 10 and a temperature at which the casting material is to be cast, it is recommended that the revolution speed falls within the range of from 0.1 to 10 rpm.

The casting temperature (the temperature at the end of the casting) is not specifically limited. However, in cases where rolling is executed at a subsequent step, it is preferable to set the casting temperature to a temperature of [the solidus temperature of the metal x 0.95] or less. If it exceeds the temperature, there is a possibility that the cast material is re-melted by the working heat generated at the time of the rolling. The lower limit of the casting temperature is not limited at all, and the temperature can be a room temperature or a temperature lower than the freezing point.

The continuous casting method of the present invention can be applied to various metal continuous casting. It is recommended that the method is applied to continuous casting for aluminum, aluminum alloy, copper or copper alloy, especially to a continuous casting for aluminum or aluminum alloy. As such aluminum or aluminum alloy, pure aluminum, Al-Cu series alloy, Al-Si series alloy, Al-Mg series alloy, Al-Mg-Si series alloy and Al-Zn-Mg series alloy can be exemplified.

According to the continuous casting method of the invention, early detachment of the cast material from the casting wheel can be prevented, resulting in sufficient cooling of the casting material. Thus, no hot tear will be generated due to a remained liquid phase immediately after the casting, which in turn can manufacture a cast material excellent in cast quality. Furthermore, since the method can be performed by simply adding the pressing roller, the conventional casting wheel and continuous belt can be used as it is. Thus, the durability of the continuous belt and the freedom of the casting conditions will not be deteriorated. Furthermore, sufficient cooling can be attained, which makes it possible to increase the casting rate, resulting in improved productivity. In addition to the above, since the continuous belt is pressed against the casting wheel by the pressing roller, even if the tension of the continuous belt decreases such as when the continuous belt is extended during the casting, the leak of the molten metal hardly occurs.

The continuous casting method of the present invention can be preferably used as a casting method (hereinafter "directional solidification" or "continuous casting method by directional solidification") for creating a final solidification portion in which cast defects are easily generated near the surface of the cast material by differentiating the solidification rate of the cast material between the casting wheel side and the continuous

belt side. Concretely, this is a continuous casting method in which the casting wheel is cooled while the continuous belt is heated so as to create the final solidification portion near the continuous belt side surface by delaying the solidification rate of the continuous belt side. In the continuous cast material in which a final solidification portion exists near the continuous belt side surface, even if cast defects are generated, such defects can be eliminated by removing the surface portion, or will vanish or decrease by the subsequent plastic working. Thus, cast defects will not be carried over the work piece.

In the continuous casting method by such directional solidification, the cooling is hardly performed from the continuous belt side and therefore the cooling is should be mainly performed by the casting wheel side. Thus, it is very important to enhance the heat transfer by increasing the contact area and the pressure between the casting wheel and the cast material as large as possible. Accordingly, it is of great significance to apply the present invention capable of preventing early detachment of the cast material from the casting wheel by disposing the pressing roller to the aforementioned continuous casting method.

As mentioned above, the continuous casting method of the present invention is to be applied to a casting apparatus in which a circular continuous belt 11 is put on the casting wheel 10 and the tension adjusting wheel 13 with both the casting wheel 10 and

the tension adjusting wheel 13 in contact with the inner side of the continuous belt 11. However, in some continuous casting apparatuses using a casting wheel and a continuous belt, a method of putting the continuous belt is different from that of the present invention. For example, in the apparatus shown in Fig. 7 for executing a casting method called an SCR method, the outside of the continuous belt 11 comes into contact with the casting wheel 10 while the inside of the continuous belt 11 comes into contact with the tension adjusting wheel 30, and the continuous belt 11 comes into close contact with the external peripheral surface of the casting wheel 10 with the pressing rollers 31 and 32 disposed at the molten metal inlet side and the cast material outlet side, respectively. The pressing roller 32 located at the cast outlet side in the SCR method is different from the pressing roller 17 of the present invention in function and effect.

In detail, in the continuous casting method of the present invention, the pressing roller 17 presses the continuous belt 11 to simply pinch the belt 11 between the pressing roller 17 and the casting wheel 10. Therefore, if the pressing roller 17 is moved toward the casting direction from the first reference position P1 and pressed toward the center of the casting wheel 10, the pressing roller 17 and the continuous belt 11 are slightly moved toward the casting wheel 10, increasing the tensile force of the continuous belt 11. Such tensile force increasing effect increases as the pressing roller 17 moves in the casting direction from the first

reference position P1. However, in the SCR method, the pressing roller 32 presses the continuous belt 11 against the casting wheel 12 in a state in which the continuous belt 11 is wound around the external peripheral surface of the pressing roller 32. Therefore, if the pinched portion 11a between the pressing roller 32 and the continuous belt 11 is slightly moved toward the casting wheel side, the portion 11b of the continuous belt 11 between the pressing roller 32 and the tension adjusting roller 30 comes loose slightly, resulting decreased tension. As a result, in order to maintain the tension of the continuous belt 11, the position of the tension adjusting wheel 30 should be adjusted.

In general, in the continuous casting using the casting wheel 10 and the continuous belt 11, it is important not to decrease the tension of the continuous belt 11. In the present invention, since it is to be applied to a continuous casting method in cases where the casting wheel 10 and the tension adjusting wheel 13 are disposed inside the continuous belt 11, the present invention is different from the aforementioned SCR method in that the tension of the continuous belt 11 does not decrease by the pressing roller 17 disposed at the cast outlet side of the casting wheel 10 and that the pressing force of the pressing roller 17 and the tension of the continuous belt 11 can be simultaneously adjusted by controlling the position of the pressing roller 17. Especially, in the continuous casting method by directional solidification, it is required to press the continuous belt 11 against the casting

wheel 10, and therefore the application of the present invention is of great significance.

The metal work piece of the present invention is manufactured by executing plastic working or cutting work to the cast material of the present invention. Therefore, the work piece has no carried over cast defect, and is high in quality. The plastic working method and the cutting work method are not limited. As a plastic working method, rolling, extruding, drawing, forging, bending and pressing can be exemplified. As a cutting work method, a method of cutting using a turning machine, a milling machine, or a drilling machine can be exemplified. The product configuration is not also limited.

In the continuous casting apparatus of the present invention, the molten metal supplying means, the cooling means, the transferring means of the cast material and other means are not limited in structure and can be any known means so long as the apparatus is provided with the aforementioned casting wheel, the continuous belt, the tensile adjusting wheel, and the pressing roller. Furthermore, a plastic working machine can be disposed at a rear side of the continuous casting apparatus to continuously execute the aforementioned plastic working subsequent to the continuous casting.

EXAMPLE

[CONTINUOUS CASTING EXAMPLE 1]

A continuous casting tests using JIS A6061 (Si: 0.6 mass%, Fe: 0.2 mass%, Cu: 0.32 mass%, Mg: 1 mass%, Cr: 0.2 mass%, the balance being Al and inevitable impurities) were executed while changing the position of the pressing roller 17 of the continuous casting apparatus 2 shown in Fig. 3. The casting wheel 10 was 1,400 mm in diameter, 2,200 mm^2 in cross-sectional area of the concave groove 11 (=cross-sectional area of the casting space 14). The cast material S was cooled by supplying cooling water from the inside of the casting wheel 10 and from the outside of the continuous belt 11.

The position of the pressing roller 17 in each example shown in Table 1 is represented by the central angle a of the casting wheel 10 as a moving distance from the first reference position P1 as shown in Fig. 4C. The direction opposite to the casting direction is shown as "-a," and the casting direction (rearward direction) is shown as "a." In the continuous casting apparatus 2 used in this Example, the first reference position P1 is located at the position away from the pinch roller 16 by the central angle a_4 of 205°. The continuous casting is executed by rotating the casting wheel 10 at 2.5 rpm while applying the pressing force of 3 kN.

As a comparative example, in the continuous casting apparatus 2 shown in Fig. 3, continuous casting is executed in a state in which the pressing roller 17 is removed.

In the continuous casting of each Example and Comparative Example, the temperature of the continuous cast material S was measured at the position away from the first reference position P1 by 500 mm toward the casting direction, and the quality of the cast material was observed. These results are also shown in Table 1.

Table 1

	Distance from the position P1 of the pressing roller ($\pm\alpha$)	Temperature of the cast material	Cast quality
Example 1	-60°	575°C	Fine cracks were generated on the cast material surface due to insufficient cooling
Example 2	-55°	570°C	No cast crack and defect
Example 3	-45°	570°C	No cast crack and defect
Example 4	-35°	563°C	No cast crack and defect
Example 5	-20°	552°C	No cast crack and defect
Example 6	0° (P1)	535°C	No cast crack and defect
Example 7	+30°	521°C	No cast crack and defect
Example 8	+60°	504°C	No cast crack and defect
Example 9	+90°	489°C	No cast crack and defect
Comparative Example	No Pressing roller	580°C	Hot tears were generated due to insufficient cooling, The continuous cast material was detached from the casting wheel at P1 by about 1 mm.

From the results shown in Table 1, it is confirmed that early detachment of the cast material can be prevented by disposing the pressing roller 17 to assuredly cool the cast member, and therefore a continuous cast material high in quality can be manufactured.

[CONTINUOUS CASTING EXAMPLE 2]

A continuous casting tests using Al-Si series alloy (Si: 11 mass%, Cu: 4.2 mass%, Mg: 0.6 mass%, the balance being Al and inevitable impurities) were executed using the continuous casting apparatus 2 shown Fig. 3 under the conditions shown in Table 2 in which the revolution speed of the casting wheel 10, the temperature of the continuous belt 11 and the pressing roller 17 or no pressing roller are combined.

In the case of cooling the continuous belt 11, cooling water was supplied from the outside as in the same manner as the aforementioned continuous casting Example 1. In the case of heating the continuous belt 11, no water cooling was executed, and the continuous belt 11 was heated with the burner 22 disposed at an upstream side of the pinch roller 17. In the case of using the pressing roller 17, pressing force of 3 kN was applied.

In each continuous casting, the temperature of the continuous cast material S was measured at the position away from the first reference position P1 by 500 mm toward the casting direction. These

results are also shown in Table 2.

Table 2

Revolution speed of the casting wheel	Temperature of the cast material			
	Pressing roller: used		Pressing roller: not used	
	Continuous belt Cooled	Continuous belt Heated	Continuous belt Cooled	Continuous belt Heated
1.1 rpm	-	441°C	-	453°C
1.3 rpm	439°C	462°C	450°C	480°C
1.5 rpm	453°C	-	471°C	-
1.7 rpm	498°C	-	520°C	-

From the results shown in Table 2, in the continuous casting method in which the casting wheel and the continuous belt are differentiated in temperature, it is confirmed that the cooling by the casting wheel can be performed assuredly by disposing the pressing roller. Furthermore, in the continuous cast material manufactured by using the pressing roller while heating the continuous belt, the final solidification portion was formed near the continuous belt side surface.

Industrial Applicability

The present invention is directed to a continuous casting method using a casting wheel and a continuous belt and can be utilized when manufacturing a metal cast material to be subjected to plastic working or cutting work.

While the present invention may be embodied in many different forms, a number of illustrative embodiments are described herein with the understanding that the present disclosure is to be considered as providing examples of the principles of the invention and such examples are not intended to limit the invention to preferred embodiments described herein and/or illustrated herein.

While illustrative embodiments of the invention have been described herein, the present invention is not limited to the various preferred embodiments described herein, but includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed in the claims and not limited to examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive. For example, in the present disclosure, the term "preferably" is non-exclusive and means "preferably, but not limited to." In this disclosure and during the prosecution of this application, means-plus-function or step-plus-function limitations will only be employed where for a specific claim limitation all of the following conditions are present in that limitation: a) "means for" or "step for" is expressly recited; b) a corresponding function is expressly recited; and c) structure, material or acts that support that

structure are not recited. In this disclosure and during the prosecution of this application, the terminology "present invention" or "invention" may be used as a reference to one or more aspect within the present disclosure. The language present invention or invention should not be improperly interpreted as an identification of criticality, should not be improperly interpreted as applying across all aspects or embodiments (i.e., it should be understood that the present invention has a number of aspects and embodiments), and should not be improperly interpreted as limiting the scope of the application or claims. In this disclosure and during the prosecution of this application, the terminology "embodiment" can be used to describe any aspect, feature, process or step, any combination thereof, and/or any portion thereof, etc. In some examples, various embodiments may include overlapping features. In this disclosure and during the prosecution of this case, the following abbreviated terminology may be employed: "e.g." which means "for example;" and "NB" which means "note well."

CLAIMS

1. A continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel,

wherein one or a plurality of pressing rollers press the continuous belt at a casting side of the casting wheel against the casting wheel.

2. The continuous casting method as recited in claim 1, wherein the one or a plurality of pressing rollers are pressed against the casting wheel with driving force.

3. The continuous casting method as recited in claim 1, wherein the pressing roller is disposed at a second reference position (P2) on the external peripheral surface of the casting wheel or at a rear stage of the second reference position (P2), wherein the second reference position (P2) is defined as a position away from a first reference position (P1) on the external peripheral surface of the casting wheel by a central angle of 45 degrees of the casting wheel toward a direction opposite to a casting direction, the first reference position (P1) being defined as a position where the

continuous belt is detached from the pressing roller at a time of non-casting with no pressing roller.

4. The continuous casting method as recited in claim 2, wherein the pressing roller is disposed at a second reference position (P2) on the external peripheral surface of the casting wheel or at a rear stage of the second reference position (P2), wherein the second reference position (P2) is defined as a position away from a first reference position (P1) on the external peripheral surface of the casting wheel by a central angle of 45 degrees of the casting wheel toward a direction opposite to a casting direction, the first reference position (P1) being defined as a position where the continuous belt is detached from the pressing roller at a time of non-casting with no pressing roller.

5. The continuous casting method as recited in claim 3, wherein the pressing roller is disposed at the first reference position (P1).

6. The continuous casting method as recited in claim 4, wherein the pressing roller is disposed at the first reference position (P1).

7. The continuous casting method as recited in claim 3, wherein the pressing roller is disposed at a rear stage of the first reference position (P1).

8. The continuous casting method as recited in claim 4, wherein the pressing roller is disposed at a rear stage of the first reference position (P1).

9. The continuous casting method as recited in claim 7 or 8, wherein the pressing roller is disposed within a range from the first reference position P1 to a position away from the first reference position (P1) rearward by the central angle of 90 degrees.

10. The continuous casting method as recited in any one of claims 1 to 8, wherein the casting wheel is cooled and the continuous belt is heated.

11. The continuous casting method as recited in any one of claims 1 to 8, wherein the metal is aluminum or aluminum alloy.

12. A cast material manufactured by a continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel, wherein the cast material is continuously cast by pressing the continuous belt against the casting wheel with one or a plurality of pressing

rollers disposed at a casting side of the casting wheel against the casting wheel.

13. A metal work piece obtained by performing plastic working to a cast material, wherein the cast material is manufactured by a continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel, wherein the cast material is continuously cast by pressing the continuous belt against the casting wheel with one or a plurality of pressing rollers disposed at a casting side of the casting wheel against the casting wheel.

14. A metal work piece obtained by performing cutting working to a cast material, wherein the cast material is manufactured by a continuous casting method for casting a cast material by rotating a casting wheel and a continuous belt while continuously supplying molten metal into a casting space formed by closing a concave groove on an external peripheral surface of the casting wheel with the continuous belt put on the external peripheral surface of the casting wheel and an external peripheral surface of a tension adjusting wheel, wherein the cast material is continuously cast by pressing the continuous belt against the casting wheel with one or a plurality

of pressing rollers disposed at a casting side of the casting wheel against the casting wheel.

15. A continuous casting apparatus, comprising:

a casting wheel rotatably driven, the casting wheel being provided with a concave groove on an external peripheral surface thereof;

a circular continuous belt put on the external surface of the casting wheel to form a casting space by closing the concave groove;

a tension adjusting wheel disposed at an inside of the continuous belt for adjusting a tension of the continuous belt; and

a pressing roller for pressing the continuous belt at a casting side of the casting wheel.

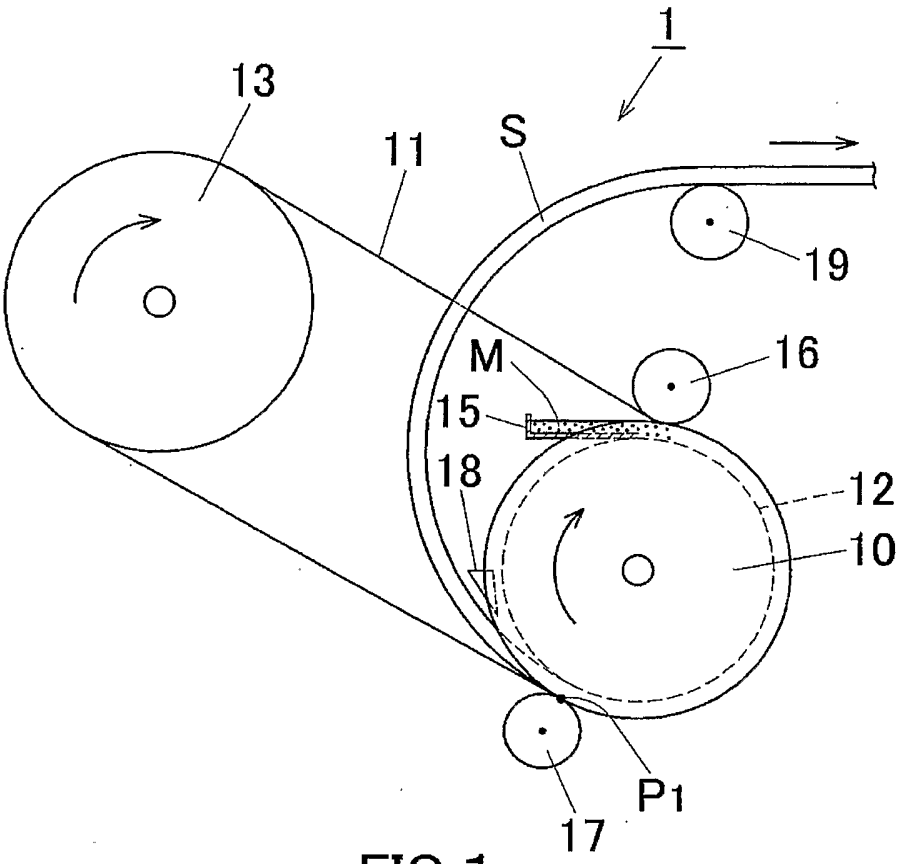

FIG.1

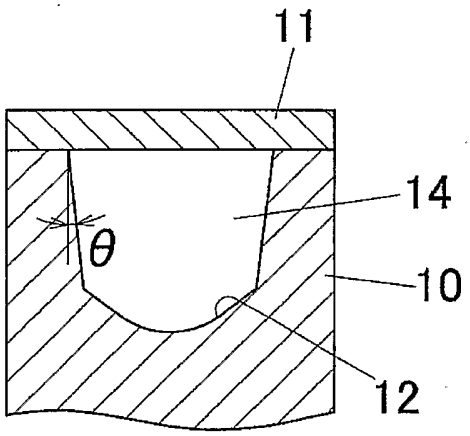

FIG.2

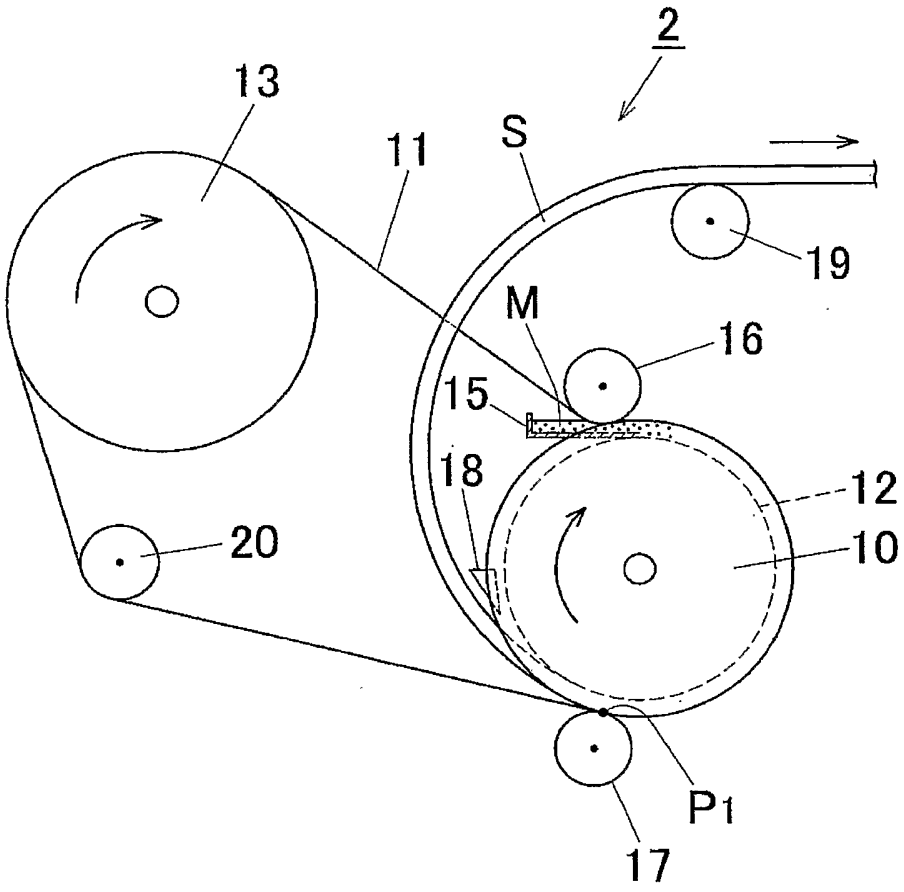

FIG.3

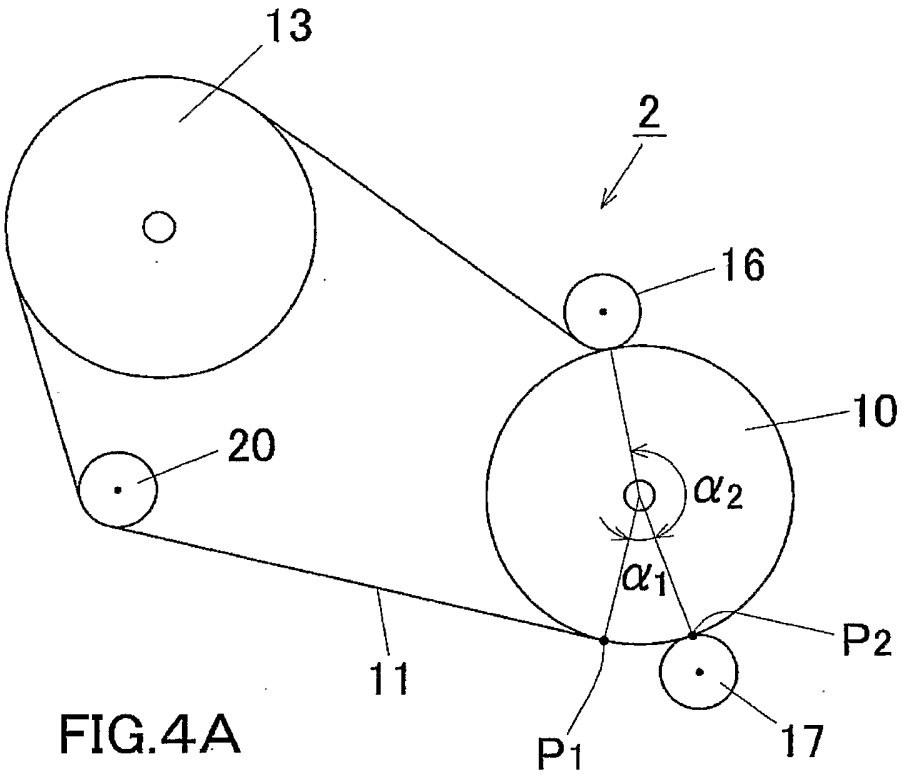
13
2
16
10
20
α_2
α_1
P2
11
P1
17

FIG.4A

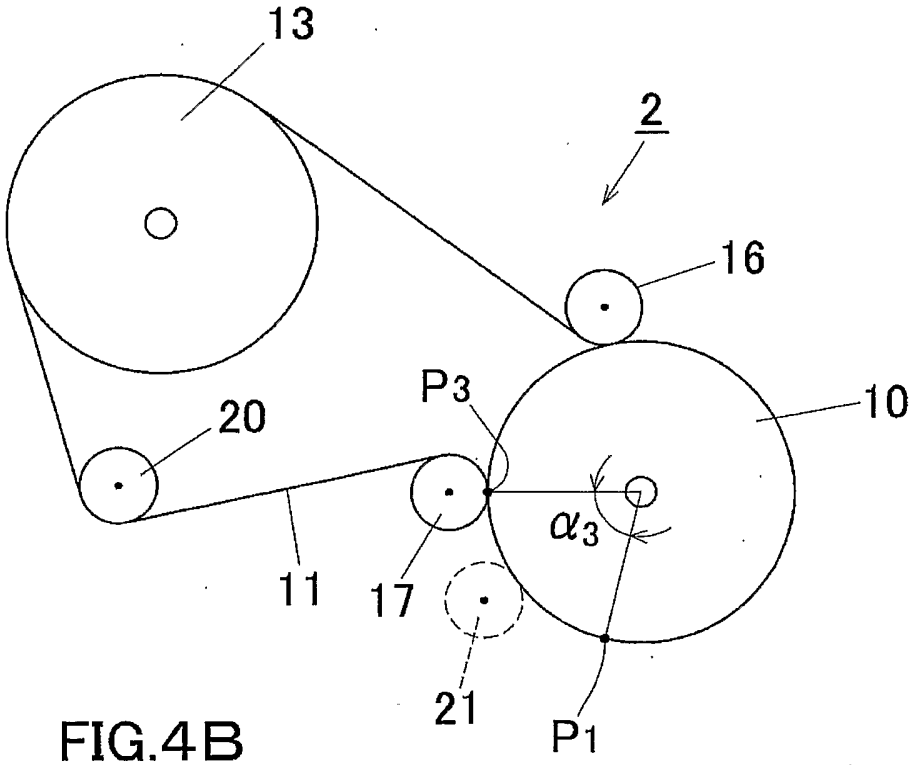
13
2
16
P3
10
20
α_3
11
17
21
P1

FIG.4B

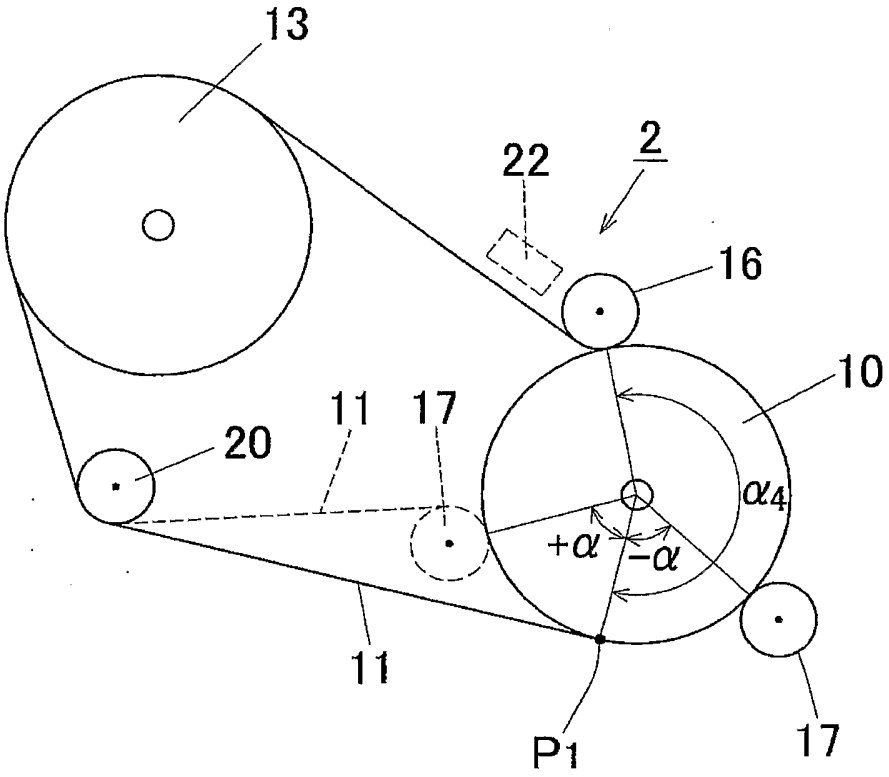

FIG.4C

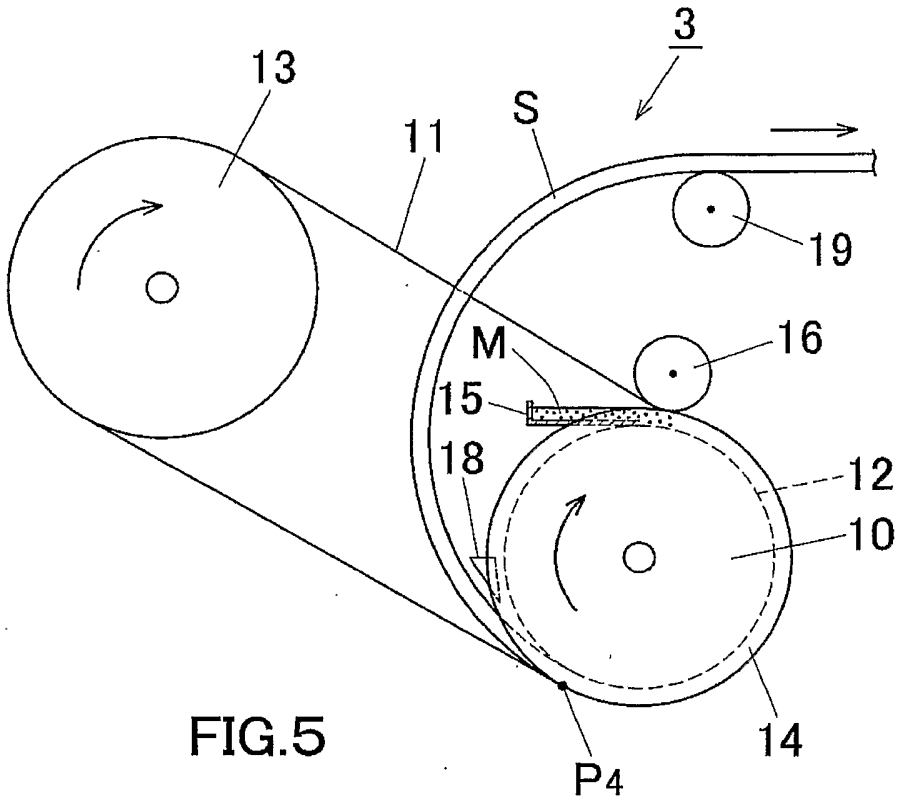

FIG.5

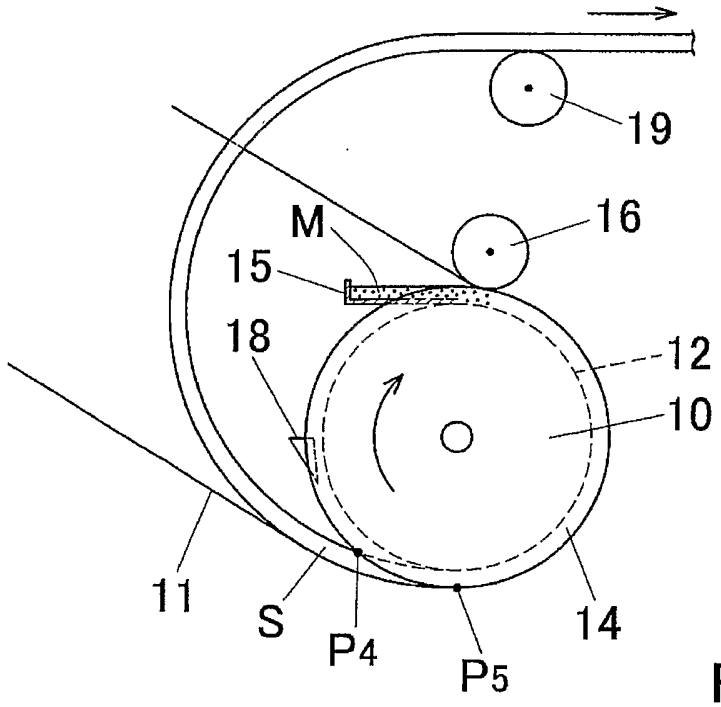

FIG.6

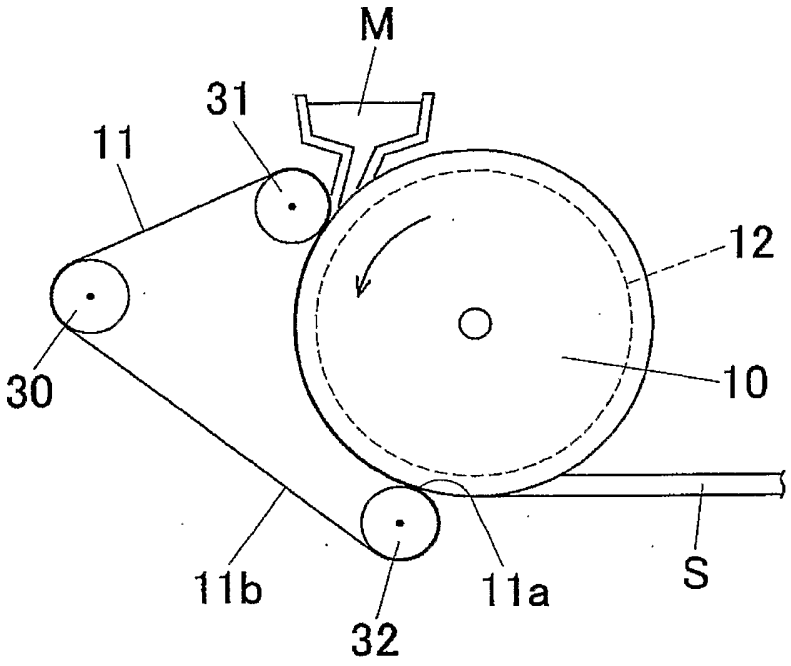

FIG.7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/020171

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. *B22D11/06(2006.01)*

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)

Int.Cl. *B22D11/06(2006.01)*

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2006
Registered utility model specifications of Japan 1996-2006
Published registered utility model applications of Japan 1994-2006

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.
X Y	JP 60-064755 A (FURUKAWA ELECTRIC CO.,LTD.) 1985.04.13, Page1,Fig.1 Family none	1-9,11-15 10
X Y	JP 03-036345 U (NIKKEI GIKEN K.K.) 1991.04.09, Page7,Fig.3 Family none	1-9,11-15 10
X Y	JP 04-071756 A (NIPPON KEIKINZOKU K.K.) 1992.03.06, Page3,Fig.2 Family none	1-9,11-15 10
Y	JP 61-286043 A (SUMITOMO METAL IND .,LTD.) 1986.12.16, Page1 Family none	10

☐ 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	Date of mailing of the international search report
01.03.2006	14.03.2006

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	KENGO KOYANAGI 4E 3232 Telephone No. +81-3-3581-1101 Ext. 3425

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