

DESCRIPTION

TITLE OF INVENTION: LAMINATED CORE MANUFACTURING
METHOD AND LAMINATED CORE MANUFACTURING APPARATUS

TECHNICAL FIELD

[0001] The present disclosure relates to a laminated core manufacturing method and a laminated core manufacturing apparatus. This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2024-059073, filed on April 1, 2024, the entire contents of which are incorporated herein by reference.

BACKGROUND ART

[0002] A laminated core is known as a core used for a rotary electric machine. The laminated core is configured by laminating a plurality of soft magnetic sheets. In the laminated core, it is necessary to fix the plurality of laminated soft magnetic sheets. As a technique for fixing the soft magnetic sheets, there is a technique for causing the soft magnetic sheets to adhere to each other by utilizing adhesion performance exhibited on the sheet surfaces of the soft magnetic sheet. As such a technique, there is a technique described in Patent Literature 1.

[0003] In the technique described in Patent Literature 1, the following processes are performed: forming a laminar member by performing a piercing process on a steel sheet having an adhesive layer formed on a surface thereof; applying an adhesive to the laminar member; and performing blanking on the

laminar member to which the adhesive has been applied. At this time, the adhesive is not applied to a specific laminar member. The blanked laminar members are laminated within a squeeze ring. The plurality of laminated laminar members move below the squeeze ring and are heated below the squeeze ring. The heating temperature at this time is a temperature at which the adhesive applied to the laminar member cures, and is a temperature lower than a temperature at which the adhesive layer formed on the surface of the laminar member cures. A laminated core composed of the plurality of laminar members that have adhered to each other in this manner is discharged from a die assembly. Then, the laminated core discharged from the die assembly is heated at a high temperature to cure the adhesive layer formed on the laminar member.

CITATION LIST

PATENT LITERATURE

[0004] Patent Literature 1: Translated National Publication of Patent Application No. 2024-519226

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] However, in the technique described in Patent Literature 1, there is no explanation regarding the relationship between the adhesion force provided by the adhesive and the adhesion force provided by the adhesive layer. In the technique described in Patent Literature 1, within a region of the surface of the steel sheet, the adhesive is applied to a region to

be formed as the laminar member by blanking. Therefore, the plurality of laminar members constituting the laminated core should sufficiently adhere to each other by the adhesive. For this reason, in the technique described in Patent Literature 1, the technical significance of performing adhesion by the adhesive layer is unclear. That is, in the technique described in Patent Literature 1, the adhesion by the adhesive layer may be a redundant step.

[0006] Furthermore, in the technique described in Patent Literature 1, a step for applying an adhesive needs to be added between the piercing process and the blanking step. Therefore, in the technique described in Patent Literature 1, the number of steps within the die assembly increases.

[0007] Furthermore, in the technique described in Patent Literature 1, the adhesive to be applied to the laminar member is an adhesive that cures at a low temperature. When the adhesive that cures at a low temperature is applied to a region to be formed as the laminar member by blanking, there is a concern that the time required for the entire adhesive to cure may become long. Therefore, in the technique described in Patent Literature 1, it may become necessary to adjust the punching speed of the steel sheet (the number of punching operations per unit time). In particular, when the size (at least one of a width, a depth, and a height) of the laminated core

is large, the time required for adhesion of the laminated core becomes long. Therefore, in the technique described in Patent Literature 1, it may be necessary to reduce the punching speed of the steel sheet.

[0008] The present disclosure has been made in view of the above problems, and an object thereof is to efficiently manufacture a laminated core for a rotary electric machine.

SOLUTION TO PROBLEM

[0009] A laminated core manufacturing method of the present disclosure is a laminated core manufacturing method for manufacturing a laminated core for a rotary electric machine using a soft magnetic sheet as a base material, the method including: a punching step of sequentially punching out first soft magnetic sheets from the base material using a die assembly; a temporary adhesion step of heating a plurality of the first soft magnetic sheets punched out in the punching step within a lower die of the die assembly, thereby causing the plurality of first soft magnetic sheets to temporarily adhere to each other; a separating step of separating a laminated body from a laminated body subsequent to the laminated body after the temporary adhesion step; and a permanent adhesion step of heating the plurality of first soft magnetic sheets constituting the laminated body outside the die assembly, thereby causing the plurality of first soft magnetic sheets to permanently adhere to each

other, in which an insulating material that exhibits adhesion performance through heating is formed on at least one of two sheet surfaces of the soft magnetic sheet, within the lower die, the plurality of first soft magnetic sheets move downward in response to punching in the punching step while at least partial regions of outer-peripheral-side ends thereof are supported, and the laminated body is configured by laminating a number of the first soft magnetic sheets corresponding to a height of the one laminated core.

[0010] A laminated core manufacturing apparatus of the present disclosure is a laminated core manufacturing apparatus that manufactures a laminated core for a rotary electric machine using a soft magnetic sheet as a base material, the apparatus including: a die assembly for sequentially punching out first soft magnetic sheets from the base material; a first heating device for performing local heating to cause a plurality of the first soft magnetic sheets punched out by the die assembly to temporarily adhere to each other within a lower die of the die assembly; a separating means for separating a laminated body from a laminated body subsequent to the laminated body after heating by the first heating device is performed; and a second heating device for performing heating to cause the plurality of first soft magnetic sheets constituting the laminated body to permanently adhere to each other outside the die assembly, in which an

insulating material that exhibits adhesion performance through heating is formed on at least one of two sheet surfaces of the soft magnetic sheet, within the lower die, the plurality of first soft magnetic sheets move downward in response to punching by the die assembly while at least partial regions of outer-peripheral-side ends thereof are supported, and the laminated body is configured by laminating a number of the first soft magnetic sheets corresponding to a height of the one laminated core.

ADVANTAGEOUS EFFECTS OF INVENTION

[0011] According to the present disclosure, it is possible to efficiently manufacture a laminated core for a rotary electric machine.

BRIEF DESCRIPTION OF DRAWINGS

[0012] [Fig. 1] Fig. 1 is a view illustrating a first example of a configuration of a press apparatus.

[Fig. 2A] Fig. 2A is a view illustrating an example of a region to be punched out from an electrical steel sheet by a first punch and a first die.

[Fig. 2B] Fig. 2B is a view illustrating an example of a region to be punched out from the electrical steel sheet by a second punch and a second die.

[Fig. 2C] Fig. 2C is a view illustrating an example of a region to be punched out by a third punch and a third die after punching by the first punch and the first die is performed, without

punching by the second punch and the second die being performed.

[Fig. 2D] Fig. 2D is a view illustrating an example of a region to be punched out by the third punch and the third die after punching by the first punch and the first die and punching by the second punch and the second die are performed.

[Fig. 2E] Fig. 2E is a view illustrating a modified example of the region to be punched out by the third punch and the third die after punching by the first punch and the first die and punching by the second punch and the second die are performed.

[Fig. 3] Fig. 3 is a view explaining a specific example of a configuration of a guide ring and a first heating device.

[Fig. 4] Fig. 4 is a view illustrating an example of the relationship between a temperature of a first electrical steel sheet and time.

[Fig. 5] Fig. 5 is a view explaining an example of steps performed on a laminated body discharged from a lower die.

[Fig. 6] Fig. 6 is a view illustrating a first example of a configuration of a press apparatus and a nozzle.

[Fig. 7] Fig. 7 is a view illustrating a second example of the configuration of the press apparatus and the nozzle.

DESCRIPTION OF EMBODIMENTS

[0013] Embodiments will be explained below with

reference to the drawings. Note that the fact that targets to be compared such as length, position, size, and interval are the same includes not only the case where they are strictly the same but also the case where they are different within a range that does not depart from the spirit of the present disclosure (for example, the case where they are different within a range of tolerance determined at the time of design). Further, x-y-z coordinates illustrated in each drawing are coordinates for indicating the relationship of orientations in each drawing. In the x-y-z coordinates, a symbol in which a black circle (●) is provided inside a white circle (○) is a symbol indicating an arrow line directed from a far side toward a near side of the paper sheet. In the x-y-z coordinates, a symbol in which a cross mark (×) is provided inside a white circle (○) is a symbol indicating an arrow line directed from the near side toward the far side of the paper sheet. Further, in each drawing, for convenience of explanation and notation, only configurations necessary for the explanation are simplified and illustrated as necessary.

[0014] (First embodiment)

First, a first embodiment is explained.

Fig. 1 is a view illustrating an example of a configuration of a press apparatus 100.

This embodiment explains, as an example, the case where manufacturing a laminated core for a rotary

electric machine by using soft magnetic sheets as a base material is implemented by using the press apparatus 100. An insulating material that exhibits adhesion performance through heating is formed on at least one of two sheet surfaces of the soft magnetic sheet being the base material. Incidentally, the two sheet surfaces of the soft magnetic sheet are a front surface and a rear surface of the soft magnetic sheet. In the following explanation, when the insulating material is formed, the two sheet surfaces (front surface and rear surface) of the soft magnetic sheet are set to be a front surface and a rear surface of the insulating material. Further, in the following explanation, the sheet surface of the soft magnetic sheet in the middle of manufacture of the laminated core refers to both or one of the front surface and the rear surface of the soft magnetic sheet at a time point in the middle of the manufacture.

[0015] This embodiment explains, as an example, the case where the rotary electric machine is an inner-rotor type IPM (Interior Permanent Magnet) motor. However, the rotary electric machine is not limited to the IPM motor. For example, the rotary electric machine may be a motor other than the IPM motor. Further, the rotary electric machine may be a generator. Further, the rotary electric machine may be an outer-rotor type rotary electric machine.

[0016] Cores included in the rotary electric machine are a rotor core and a stator core. This embodiment

explains, as an example, the case where both the rotor core and the stator core are manufactured. However, only one of the rotor core and the stator core may be manufactured. Further, this embodiment explains, as an example, the case where the rotor core is constituted by one laminated core. Similarly, this embodiment explains, as an example, the case where the stator core is constituted by one laminated core. However, one rotor core may be configured by stacking a plurality of laminated cores in a lamination direction of the soft magnetic sheets. Similarly, one stator core may be configured by stacking a plurality of laminated cores in the lamination direction of the soft magnetic sheets. For example, when stacking a plurality of laminated cores, a skew may be provided.

[0017] Further, this embodiment explains, as an example, the case where the soft magnetic sheet (base material) is a non-oriented electrical steel sheet. However, the soft magnetic sheet (base material) is not limited to the non-oriented electrical steel sheet. For example, the soft magnetic sheet (base material) may be a grain-oriented electrical steel sheet. For example, when manufacturing a split core, the soft magnetic sheet (base material) may be a grain-oriented electrical steel sheet. Incidentally, the stator core is configured by using a plurality of split cores. A planar shape of the split core is, for example, a planar shape of one of p parts (p is

an integer of 2 or more). The p parts are parts obtained by dividing the stator core into p parts so as to have a p -fold symmetrical relationship with a center line of the stator core as a rotational symmetry axis.

[0018] Further, the soft magnetic sheet is not limited to the non-oriented electrical steel sheet or the grain-oriented electrical steel sheet. The soft magnetic sheet may be, for example, any one of an amorphous alloy thin sheet, a nanocrystalline alloy thin sheet, a permendur sheet, and a permalloy sheet. In this case, in the following explanation, the electrical steel sheet is replaced with these soft magnetic sheets.

[0019] The insulating material that exhibits adhesion performance through heating changes, by heating, from a state where it cannot adhere to an adherend to a state where it can adhere to the adherend. In the following explanation, the insulating material that exhibits adhesion performance through heating is abbreviated as an insulating material as necessary. Incidentally, the insulating material is formed so as to cover the whole or a part of the sheet surface of the soft magnetic sheet (base material). For example, the insulating material may be formed in a region of 50% or more, preferably a region of 70% or more, more preferably a region of 90% or more, and most preferably a region of 100% of the total area of the

sheet surface of the soft magnetic sheet.

[0020] As described above, this embodiment explains, as an example, the case where the soft magnetic sheet (base material) is a non-oriented electrical steel sheet. In the following explanation, the non-oriented electrical steel sheet is abbreviated as an electrical steel sheet as necessary.

[0021] In a manufacturing line such as a finish annealing line (a manufacturing line in a step upstream of the step performed by the press apparatus 100), an insulating coating is continuously formed on the sheet surface of an electrical steel sheet (base material) moving through the manufacturing line. For example, an insulating material may be achieved by containing a thermosetting resin in the insulating coating. In this case, the insulating coating formed on the sheet surface of the electrical steel sheet (base material) is the insulating material.

Incidentally, the insulating coating formed on the sheet surface of the electrical steel sheet (base material) has a function of electrically insulating the electrical steel sheet from an object coming into contact with the sheet surface of the electrical steel sheet. As above, the insulating material may fulfill a role other than the role as an adhesive. However, the insulating material may fulfill only the role as an adhesive.

[0022] Further, the insulating coating continuously formed on the sheet surface of the electrical steel

sheet (base material) in the manufacturing line such as a finish annealing line does not have to exhibit adhesion performance through heating. In this case, an adhesive that exhibits adhesion performance through heating may be applied onto the insulating coating that does not exhibit adhesion performance through heating. In this case, the adhesive applied onto the insulating coating that does not exhibit adhesion performance through heating is the insulating material. The adhesive contains, for example, a thermosetting resin.

[0023] For example, the adhesive may be continuously formed on the sheet surface of the electrical steel sheet (base material) (on the insulating coating that does not exhibit adhesion performance through heating) moving through the manufacturing line in a step upstream of the step performed by the press apparatus 100. The formation of the adhesive is achieved, for example, by baking the adhesive onto the insulating coating formed on the sheet surface of the electrical steel sheet. Incidentally, the movement of the electrical steel sheet (base material) in the manufacturing line is performed as follows, for example. First, a coil (a coiled electrical steel sheet) is set on an uncoiler installed on an upstream side of the manufacturing line. Then, the coil (electrical steel sheet) is unwound from the uncoiler and the electrical steel sheet is moved from the upstream side to a downstream

side of the manufacturing line. During the movement of the electrical steel sheet, the adhesive is continuously applied onto the sheet surface of the electrical steel sheet. Then, the electrical steel sheet on which the adhesive has been formed is wound into a coil shape by a coiler installed on the downstream side of the manufacturing line. The electrical steel sheet (coil) wound into a coil shape in this manner may be used as the base material.

[0024] As described above, this embodiment explains, as an example, the case where the insulating material that exhibits adhesion performance through heating is formed on the sheet surface of the electrical steel sheet (base material) before the electrical steel sheet (base material) enters the press apparatus 100 (a die assembly (an upper die 110 and a lower die 120)). Further, this embodiment explains, as an example, the case where the insulating material that exhibits adhesion performance through heating is not formed on the sheet surface of the electrical steel sheet (base material) after the electrical steel sheet (base material) enters the press apparatus 100 (the die assembly (the upper die 110 and the lower die 120)). Further, this embodiment explains, as an example, the case where the insulating material (insulating material that exhibits adhesion performance through heating) formed on the sheet surface of the electrical steel sheet (base material) is one type of insulating material. However, this

embodiment is not necessarily required to be configured as above. For example, before the electrical steel sheet (base material) enters the press apparatus 100, two or more types of insulating materials may be formed on the sheet surface of the electrical steel sheet (base material) as the insulating material that exhibits adhesion performance through heating. Further, for example, an insulating material that exhibits adhesion performance in a shorter time than the insulating material formed before the electrical steel sheet (base material) enters the press apparatus 100 may be formed on the sheet surface of the electrical steel sheet (base material) after the electrical steel sheet (base material) enters the press apparatus 100.

[0025] This embodiment explains, as an example, the case where the insulating material exhibits adhesion performance through heating due to the thermosetting resin contained in the insulating material. For example, as long as a thermosetting resin is used as the insulating material that exhibits adhesion performance through heating, for example, an acrylic resin may be used. Further, by using another known resin (for example, an epoxy resin, a polyimide resin), an insulating material that exhibits adhesion performance through heating may be formed. Incidentally, a plurality of types of materials (for example, a plurality of types of resins) may be used as a material for exhibiting adhesion performance

through heating.

[0026] In Fig. 1, this embodiment explains, as an example, the case where an electrical steel sheet M having the above-described insulating material formed on two sheet surfaces (a front surface and a rear surface) thereof is the base material. Incidentally, the electrical steel sheet M, which is the base material, is a strip-shaped sheet. The electrical steel sheet M is unwound from a coil set on a not-illustrated uncoiler installed on the upstream side (negative direction side of the x-axis) of the press apparatus 100, for example, and is conveyed toward the downstream side (positive direction side of the x-axis). A conveyance speed of the electrical steel sheet M may be varied, or does not have to be varied. Further, in addition to moving toward the downstream side, the electrical steel sheet M may move toward the upstream side. This embodiment explains, as an example, the case where the electrical steel sheet M is conveyed according to a preset speed pattern. The speed pattern is, for example, information indicating the relationship between a duration from a timing at which unwinding of the coil is started, and a conveyance speed and a conveyance direction of the electrical steel sheet M.

[0027] In Fig. 1, this embodiment explains, as an example, the case where the press apparatus 100 includes the upper die 110 and the lower die 120.

Further, this embodiment explains, as an example,

the case where the upper die 110 includes a first punch 111a, a second punch 111b, a third punch 111c, a fourth punch 111d, a fifth punch 111e, and a sixth punch 111f. Further, this embodiment explains, as an example, the case where the lower die 120 includes a first die 121a, a second die 121b, a third die 121c, a fourth die 121d, a fifth die 121e, and a sixth die 121f.

[0028] In the example illustrated in Fig. 1, the first punch 111a, the second punch 111b, the third punch 111c, the fourth punch 111d, the fifth punch 111e, and the sixth punch 111f each move in a vertical direction (a direction parallel to the z-axis). This embodiment explains, as an example, the case where the first punch 111a, the second punch 111b, the third punch 111c, the fourth punch 111d, the fifth punch 111e, and the sixth punch 111f can be individually moved.

[0029] This embodiment explains, as an example, the case where the first punch 111a and the first die 121a form a pair to punch out a partial region of the electrical steel sheet M. Similarly, this embodiment explains, as an example, the case where the second punch 111b and the second die 121b, the third punch 111c and the third die 121c, the fourth punch 111d and the fourth die 121d, the fifth punch 111e and the fifth die 121e, and the sixth punch 111f and the sixth die 121f form pairs respectively to punch out partial regions of the electrical steel sheet M.

[0030] This embodiment explains, as an example, the case where the first punch 111a, the second punch 111b, the third punch 111c, the first die 121a, the second die 121b, and the third die 121c are punches and dies for manufacturing a rotor core. Further, this embodiment explains, as an example, the case where the fourth punch 111d, the fifth punch 111e, the sixth punch 111f, the fourth die 121d, the fifth die 121e, and the sixth die 121f are punches and dies for manufacturing a stator core. In this case, the first punch 111a, the second punch 111b, the third punch 111c, the first die 121a, the second die 121b, and the third die 121c correspond to the fourth punch 111d, the fifth punch 111e, the sixth punch 111f, the fourth die 121d, the fifth die 121e, and the sixth die 121f respectively. The difference between the punches and the dies for manufacturing the rotor core and the punches and the dies for manufacturing the stator core lies in the difference in the shape and size of the regions punched out from the electrical steel sheet M. Therefore, in the following, explanations of specific examples of a shape and the like of the stator core are omitted.

[0031] Fig. 2A is a view illustrating an example of a region to be punched out from the electrical steel sheet M by the first punch 111a and the first die 121a. In Fig. 2A to Fig. 2D, black regions represent regions to be punched out from the electrical steel sheet M. Incidentally, the region to be punched out

is a region to be separated from the base material. This embodiment explains, as an example, the case where a portion to be a hole in the rotor core is punched out by the first punch 111a and the first die 121a. A part of the portion to be a hole in the stator core may be punched out by the first punch 111a and the first die 121a. Fig. 2B is a view illustrating an example of a region to be punched out from the electrical steel sheet M by the second punch 111b and the second die 121b. This embodiment explains, as an example, the case where portions unnecessary as a separating sheet used for manufacturing the rotor core are punched out by the second punch 111b and the second die 121b. Incidentally, the role of the separating sheet will be explained later.

[0032] Fig. 2C is a view illustrating an example of a region to be punched out by the third punch 111c and the third die 121c after punching by the first punch 111a and the first die 121a is performed, without punching by the second punch 111b and the second die 121b being performed. The shape illustrated in Fig. 2C (shape of the black region) is the same as a planar shape of the rotor core. That is, this embodiment explains, as an example, the case where an electrical steel sheet having the planar shape illustrated in Fig. 2C and having the same thickness as the electrical steel sheet M is the electrical steel sheet constituting the rotor core.

In the following explanation, the electrical steel sheet constituting the laminated core (the rotor core and the stator core) is referred to as a first electrical steel sheet as necessary. In this embodiment, the first electrical steel sheet is an example of a first soft magnetic sheet. As described above, this embodiment explains, as an example, the case where an outer edge of the first electrical steel sheet is punched out by the third punch 111c and the third die 121c.

[0033] Fig. 2D is a view illustrating an example of a region to be punched out by the third punch 111c and the third die 121c after punching by the first punch 111a and the first die 121a and punching by the second punch 111b and the second die 121b are performed. In this embodiment, an electrical steel sheet having the planar shape illustrated in Fig. 2D and having the same thickness as the electrical steel sheet M described an example of the separating sheet used when manufacturing the rotor core. In the following explanation, the electrical steel sheet constituting the separating sheet is referred to as a second electrical steel sheet as necessary. In this embodiment, the second electrical steel sheet is an example of a second soft magnetic sheet. As described above, this embodiment explains, as an example, the case where an outer edge of the second electrical steel sheet is punched out by the third punch 111c and the third die 121c.

[0034] Incidentally, the planar shape of the second soft magnetic sheet (second electrical steel sheet (electrical steel sheet constituting the separating sheet)) is not limited to the shape illustrated in Fig. 2D. For example, it may be a shape illustrated in Fig. 2E. Fig. 2E is a view illustrating a modified example of the region to be punched out by the third punch 111c and the third die 121c after punching by the first punch 111a and the first die 121a and punching by the second punch 111b and the second die 121b are performed. Incidentally, the black region in Fig. 2E is also a region to be punched out from the electrical steel sheet M, similarly to the black regions in Fig. 2A to Fig. 2D.

[0035] In Fig. 1, the first electrical steel sheet and the second electrical steel sheet punched out by the third punch 111c and the third die 121c enter a space existing in a region below the third punch 111c (negative direction side of the z-axis) of the region within the lower die 120. Similarly, the first electrical steel sheet and the second electrical steel sheet punched out by the sixth punch 111f and the sixth die 121f also enter a space existing in a region below the sixth punch 111f (negative direction side of the z-axis) of the region within the lower die 120. In the following explanation, the space into which the first electrical steel sheet and the second electrical steel sheet enter is referred to as a lamination space as necessary.

[0036] In Fig. 1, a horizontally long rectangle illustrated in gray represents the second electrical steel sheet. Further, a horizontally long rectangle illustrated in white represents the first electrical steel sheet.

[0037] The first electrical steel sheet and the second electrical steel sheet for manufacturing the rotor core are sequentially punched out by the third punch 111c and the third die 121c. Similarly, the first electrical steel sheet and the second electrical steel sheet for manufacturing the stator core are sequentially punched out by the sixth punch 111f and the sixth die 121f. This embodiment explains, as an example, the case where a punching step is implemented by punching by the third punch 111c and the third die 121c and punching by the sixth punch 111f and the sixth die 121f.

[0038] As described above, when manufacturing the first electrical steel sheet that constitutes the rotor core, for example, the first punch 111a, the third punch 111c, the first die 121a, and the third die 121c are used. Further, when manufacturing the separating sheet (second electrical steel sheet) for the rotor core, for example, the first punch 111a, the second punch 111b, the third punch 111c, the first die 121a, the second die 121b, and the third die 121c are used. Incidentally, when manufacturing the separating sheet for the rotor core, for example, the first punch 111a and the first die 121a do not

have to be used.

[0039] Further, when manufacturing the first electrical steel sheet that constitutes the stator core, for example, the first punch 111a, the third punch 111c, the fourth punch 111d, the sixth punch 111f, the first die 121a, the third die 121c, the fourth die 121d, and the sixth die 121f are used. Incidentally, when manufacturing the first electrical steel sheet that constitutes the stator core, for example, at least one of the pair of the first punch 111a and the first die 121a and the pair of the third punch 111c and the third die 121c does not have to be used. When manufacturing the separating sheet (second electrical steel sheet) for the stator core, for example, the first punch 111a, the fourth punch 111d, the fifth punch 111e, the sixth punch 111f, the first die 121a, the fourth die 121d, the fifth die 121e, and the sixth die 121f are used. Incidentally, when manufacturing the separating sheet for the stator core, for example, at least one of the pair of the first punch 111a and the first die 121a and the pair of the fourth punch 111d and the fourth die 121d does not have to be used.

[0040] When each punch and die operate as described above, the punch and die may perform punching in synchronization with another punch and die. However, when there is no region to be punched out from the electrical steel sheet M, each punch and die do not have to operate.

Incidentally, the number of pairs of the punch and the die included in the press apparatus 100 varies depending on the planar shapes and the like of the rotor core, the stator core, and the separating sheet. The number of pairs of the punch and the die included in the press apparatus 100 may be greater than the number (= 6) illustrated in Fig. 1.

[0041] This embodiment explains, as an example, the case where the control of the operation of the press apparatus 100 as described above is implemented by a control device 200. For example, based on a conveyance speed of the electrical steel sheet M and a punching pattern, the control device 200 selects a punch to operate from among the first punch 111a, the second punch 111b, the third punch 111c, the fourth punch 111d, the fifth punch 111e, and the sixth punch 111f, and operates the selected punch. The punching pattern is, for example, information for specifying punching performed by a punch and a die. The punching pattern is, for example, information including information on the position, size, and shape of a region to be punched out from the electrical steel sheet M, and identification information of a punch and a die used for punching the region. Incidentally, the position of the region to be punched out from the electrical steel sheet M is, for example, a position based on a predetermined position of the electrical steel sheet M (for example, a position of one corner of a leading end).

[0042] Incidentally, the control device 200 includes, for example, one or more hardware processors such as a CPU (Central Processing Unit), and one or more memories such as a RAM (Random Access Memory) and a ROM (Read Only Memory). In this case, the control device 200 executes various calculations by executing one or more programs stored in the memory using the one or more hardware processors. Further, the control device 200 includes an input device and an output device. Further, the control device 200 may be implemented by a PLC (Programmable Logic Controller) or by dedicated hardware such as an ASIC (Application Specific Integrated Circuit). Incidentally, the functions of the control device 200 may be implemented by a plurality of devices.

[0043] This embodiment explains, as an example, the case where a laminated body 130a, 130b of a number of the first electrical steel sheets corresponding to the height of one rotor core, and a laminated body 130b, 130c subsequent to the laminated body 130a, 130b within the lower die 120 (lamination space), are separated using the second electrical steel sheet (separating sheet). Incidentally, the laminated body refers to a laminated core in the middle of manufacture. The laminated body subsequent to the laminated body 130a is the laminated body 130b. The laminated body subsequent to the laminated body 130b is the laminated body 130c. Similarly, this embodiment explains, as an example, the case where a

laminated body 130d, 130e of a number of the first electrical steel sheets corresponding to the height of one stator core, and a laminated body 130e, 130f subsequent to the laminated body 130d, 130e within the lower die 120 (lamination space), are separated using the second electrical steel sheet. The laminated body subsequent to the laminated body 130d is the laminated body 130e. The laminated body subsequent to the laminated body 130e is the laminated body 130f. As above, "subsequent" refers to being the next in the sequence of the laminated bodies within the lower die 120 (lamination space) when counted from the bottom. Incidentally, in Fig. 1, reference numerals and symbols are not assigned to all the laminated bodies for convenience of notation.

[0044] Fig. 1 illustrates, as an example, the case where separating sheets 131a, 131b, 131c, and 131d are arranged at positions between the two laminated bodies 130a and 130b, between the two laminated bodies 130b and 130c, and between the two laminated bodies 130d and 130e respectively, which are adjacent to each other in an arrangement order within the lower die 120 (lamination space). This embodiment explains, as an example, the case where a separating material arranging step and a separating material arranging means are implemented by using punching by the second punch 111b and the second die 121b and punching by the third punch 111c and the third die 121c. Incidentally, a plurality of separating sheets

may be stacked at each of the positions between the two laminated bodies 130a and 130b, between the two laminated bodies 130b and 130c, and between the two laminated bodies 130d and 130e, which are adjacent to each other in the arrangement order within the lower die 120 (lamination space).

[0045] The first electrical steel sheets and the second electrical steel sheets that have entered the lamination space below the third punch 111c (on the negative direction side of the z-axis) move downward (to the negative direction side of the z-axis) each time punching by the third punch 111c and the third die 121c is performed. Similarly, the first electrical steel sheets and the second electrical steel sheets that have entered the lamination space below the sixth punch 111f (on the negative direction side of the z-axis) move downward (to the negative direction side of the z-axis) each time punching by the sixth punch 111f and the sixth die 121f is performed.

[0046] This embodiment explains, as an example, the case where the lamination space below the third punch 111c (on the negative direction side of the z-axis) is formed by using the die 121c, a squeeze ring 122a, and a guide ring 123a. Similarly, this embodiment explains, as an example, the case where the lamination space below the sixth punch 111f (on the negative direction side of the z-axis) is formed by using the die 121f, a squeeze ring 122b, and a guide

ring 123b.

[0047] The squeeze ring 122b and the guide ring 123b have the same functions as the squeeze ring 122a and the guide ring 123a, respectively. The difference between the squeeze ring 122a and the guide ring 123a and the squeeze ring 122b and the guide ring 123b lies in the difference in the shape and size of the regions punched out from the electrical steel sheet M. Therefore, in the following, explanations of specific examples of the squeeze ring 122b and the guide ring 123b are omitted.

[0048] The squeeze ring 122a is installed under the die 121c. The squeeze ring 122a supports at least partial regions of outer peripheral surfaces (outer-peripheral-side ends) of the first electrical steel sheets and the second electrical steel sheets. For example, the squeeze ring 122a has a hollow portion having the same size and shape as a punching hole of the die 121c (or a hollow portion slightly smaller than the punching hole of the die 121c). In this case, the shape and size of the hollow portion of the squeeze ring 122a are determined so as to cause a frictional force to be generated between the outer peripheral surfaces (outer-peripheral-side ends) of the first electrical steel sheet and the second electrical steel sheet and the inner peripheral surface of the squeeze ring 122a (that is, so as to cause a lateral pressure to be applied to the first electrical steel sheet and the second electrical

steel sheet). Incidentally, the frictional force (lateral pressure) shall be such that it does not generate residual stress in the first electrical steel sheet and the second electrical steel sheet. Further, the squeeze ring may be integrated with the die.

[0049] The guide ring 123a is installed under the squeeze ring 122a. Similarly to the squeeze ring 122a, the guide ring 123a also supports at least partial regions of the outer peripheral surfaces (outer-peripheral-side ends) of the first electrical steel sheets and the second electrical steel sheets. Incidentally, the frictional force generated between the guide ring 123a (contact portions 310a to 310h in a later-described example) and the first electrical steel sheets and the second electrical steel sheets by the support shall be such that it does not generate residual stress in the first electrical steel sheet and the second electrical steel sheet. This embodiment explains, as an example, the case where the guide ring 123a supports at least partial regions of the outer peripheral surfaces (outer-peripheral-side ends) of the first electrical steel sheets and the second electrical steel sheets with the squeeze ring 122a and another configuration.

[0050] A specific example of the configuration of the guide ring 123a is explained with reference to Fig. 3. Fig. 3 is a cross-sectional view taken along the line I-I in Fig. 1. Specifically, Fig. 3

illustrates a cross section of a region necessary for explanation, of the cross section of the lower die 120 cut perpendicular to a center line 0 of the lamination space below the third punch 111c at the position of the separating sheet 131b. In the following explanation, the center line 0 of the lamination space below the third punch 111c is abbreviated as the center line 0 of the lamination space or the center line 0 as necessary. Incidentally, this embodiment explains, as an example, the case where the center line 0 of the lamination space coincides with a center line of the laminated body 130b (first electrical steel sheets) within the lamination space and a center line of the second electrical steel sheets within the lamination space. Therefore, in the following explanation, the center line 0 also refers to the center line of the laminated body (first electrical steel sheets) within the lamination space and the center line of the second electrical steel sheets within the lamination space.

[0051] In Fig. 3, this embodiment explains, as an example, the case where the guide ring 123a includes contact portions 310a to 310h, elastic portions 320a to 320h, and wall portions 330a to 330b.

Leading end surfaces (surfaces on the center line 0 side) of the contact portions 310a to 310h come into contact with partial regions of the outer peripheral surfaces of the first electrical steel

sheet and the second electrical steel sheet (separating sheet). Fig. 3 illustrates, as an example, the case where the contact portions 310a to 310h are installed at intervals around the center line 0. Specifically, Fig. 3 illustrates, as an example, the case where the contact portions 310a to 310h are installed so as to have 8-fold symmetry with the center line 0 as the rotational symmetry axis. However, the number of contact portions 310a to 310h is not limited to eight. Further, 310a to 310h do not have to have rotational symmetry with the center line 0 as the rotational symmetry axis.

[0052] The elastic portions 320a to 320h are for adjusting the positions of the contact portions 310a to 310h such that a frictional force sufficient to cause the first electrical steel sheets and the second electrical steel sheets to move downward (in the negative direction of the z-axis) in response to punching by the third punch 111c and the third die 121c is generated between the leading end surfaces of the contact portions 310a to 310h and the outer peripheral surfaces of the first electrical steel sheet and the second electrical steel sheet. The elastic portions 320a to 320h are achieved, for example, by using springs. The tips (ends on the center line 0 side) of the elastic portions 320a to 320h are connected to base end surfaces (end surfaces on the side opposite to the center line 0 side) of the contact portions 310a to 310h.

[0053] The wall portions 330a to 330b are for holding the contact portions 310a to 310h and the elastic portions 320a to 320h. Fig. 3 illustrates, as an example, the case where the shape of the wall portions 330a to 330b is an arc-shaped column. Incidentally, the arc-shaped column is one of a plurality of parts obtained by dividing a hollow cylinder into plural parts such that a virtual plane passing through a center line of the hollow cylinder and being in a direction parallel to the center line of the hollow cylinder serves as a cut surface. Base ends (ends on the side opposite to the center line 0 side) of the elastic portions 320a to 320h are connected to the inner peripheral surfaces (surfaces facing the center line 0 side) of the wall portions 330a to 330b.

[0054] As described above, this embodiment explains, as an example, the case where, by using the die 121c, the squeeze ring 122a, and the guide ring 123a, the first electrical steel sheets constituting the rotor core and the second electrical steel sheets (separating sheets 131a to 131b) for manufacturing the rotor core move downward within the lower die 120 while at least partial regions of their outer-peripheral-side ends are supported. In Fig. 1, the downward white arrow line illustrated below the lamination space below the third punch 111c represents this.

[0055] Incidentally, it is not necessarily required

to use the guide ring 123a. For example, by cooling a surface that comes into contact with the outer-peripheral-side ends of the first electrical steel sheets and the second electrical steel sheets within the lamination space, the surface may be moved (slightly) to the center line 0 side. In this case, the first electrical steel sheets and the second electrical steel sheets move downward within the lower die 120 while at least partial regions of their outer-peripheral-side ends are supported by the surface.

[0056] This embodiment explains, as an example, the case where, as described above, the first electrical steel sheets constituting the rotor core and the second electrical steel sheets (separating sheets 131a to 131b) for manufacturing the rotor core are heated within the lower die 120 (lamination space), to thereby temporarily adhere to each other.

[0057] The timing for heating the plurality of first electrical steel sheets within the lamination space may include at least one of a timing at which the first electrical steel sheets and the second electrical steel sheets are moving downward within the lamination space in response to punching by the third punch 111c and the third die 121c, and a timing at which the first electrical steel sheets and the second electrical steel sheets are not moving downward within the lamination space. Regardless of whether or not the first electrical steel sheets and

the second electrical steel sheets are moving downward within the lamination space, the plurality of first electrical steel sheets may be continuously heated when being caused to temporarily adhere to each other. In this case, the time required for causing the plurality of first electrical steel sheets to temporarily adhere to each other can be shortened. On the other hand, when the plurality of first electrical steel sheets are caused to temporarily adhere to each other, heating of the plurality of first electrical steel sheets may be temporarily interrupted. In this case, power consumption can be reduced. For example, the heating of the plurality of first electrical steel sheets may be temporarily interrupted when the first electrical steel sheets and the second electrical steel sheets are moving downward within the lamination space. In this case, the heating of the plurality of first electrical steel sheets may be performed when the first electrical steel sheets and the second electrical steel sheets are not moving downward within the lamination space.

[0058] The adhesion performance exhibited by the insulating material formed on the sheet surfaces of the first electrical steel sheets when the plurality of first electrical steel sheets are caused to temporarily adhere to each other may be any adhesion performance sufficient to prevent the plurality of first electrical steel sheets constituting a

laminated body from being separated during a period from when the laminated body is discharged from the lamination space to when permanent adhesion, which will be described later, is started. However, it is preferable that positional displacement to occur in the plurality of first electrical steel sheets constituting the laminated body should be smaller during a period from when the laminated body is discharged from the lamination space to when the later-described permanent adhesion is performed in the laminated body, and it is most preferable that the positional displacement should be 0 (zero).

[0059] However, when an adhesion force acting between the plurality of first electrical steel sheets that have temporarily adhered to each other is set to be equal to or greater than an adhesion force acting between the plurality of first electrical steel sheets that have permanently adhered to each other, which will be described later, for example, there is a possibility that the time required for the temporary adhesion may increase. In this case, there is a possibility that the productivity of punching may decrease. Therefore, the temporary adhesion is performed such that the adhesion force acting between the plurality of first electrical steel sheets that have temporarily adhered to each other becomes smaller than the adhesion force acting between the plurality of first electrical steel sheets that have permanently adhered to each other, which will be

described later.

[0060] This embodiment explains, as an example, the case where the temporary adhesion of the plurality of first electrical steel sheets is achieved by causing the insulating material to exhibit its adhesion performance such that the adhesion performance of the insulating material is not exhibited to the maximum extent in at least a portion of the insulating material. For example, when the insulating material contains a thermosetting resin, the temporary adhesion of the plurality of first electrical steel sheets may be achieved by causing the thermosetting resin to be in a state in the middle of a curing reaction.

[0061] Further, in this embodiment, the insulating material formed on the sheet surfaces of the first electrical steel sheets exhibits adhesion performance through heating when the plurality of first electrical steel sheets are caused to temporarily adhere to each other. Therefore, it is not necessary to apply pressure to the first electrical steel sheets solely for the purpose of causing the plurality of first electrical steel sheets to temporarily adhere to each other. Accordingly, the press apparatus 100 in this embodiment does not include a dedicated pressure-applying device for causing the plurality of first electrical steel sheets to temporarily adhere to each other. However, pressure may be applied to the first electrical steel

sheets solely for the purpose of causing the plurality of first electrical steel sheets to temporarily adhere to each other. Incidentally, in this embodiment, within the lower die 120, the first electrical steel sheet is pressed by the first electrical steel sheet and the second electrical steel sheet located thereon. Further, within the lower die 120, the first electrical steel sheet is also pressed by punching by the third punch 111c and the third die 121c. However, these pressings are not for causing the plurality of first electrical steel sheets to temporarily adhere to each other.

[0062] When the number of first electrical steel sheets constituting the laminated body discharged from the lamination space is smaller than the number corresponding to the height of the laminated core (for example, when the first electrical steel sheets are discharged from the lamination space (lower die 120) in a disjointed state), the plurality of first electrical steel sheets are not caused to temporarily adhere to each other. From this viewpoint, whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined, for example, based on the height of the laminated body discharged from the lamination space. For example, whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined by whether or not the laminated bodies 130a to 130f have been discharged

from the lamination space at a target height. Specifically, when the height of the laminated body discharged from the lamination space is within a range preset as a range of height required as the height of the laminated core, the plurality of first electrical steel sheets constituting the laminated body may be determined to have temporarily adhered to each other. The height of the laminated body is measured, for example, by using a device for measuring thickness such as a vernier caliper. When the temporary adhesion of the plurality of first electrical steel sheets is insufficient, the adhesion strength of the insulating material is insufficient. In this case, one laminated body is separated into a plurality of laminated bodies. The height of the plurality of laminated bodies becomes a height less than a lower limit value of the range preset as the range of height required as the height of the laminated core. In that case, it is necessary to adjust, for example, at least one of the temperature (heating temperature) of the plurality of first electrical steel sheets when the plurality of first electrical steel sheets are caused to temporarily adhere to each other and the time required for causing the plurality of first electrical steel sheets to temporarily adhere to each other (heating time). Incidentally, a value of the height required as the height of the laminated core may be used instead of the range of height required as the height

of the laminated core.

[0063] Whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined by performing at least one of determining whether or not manufacturing conditions when causing the plurality of first electrical steel sheets to temporarily adhere to each other satisfy predetermined conditions, and determining whether or not characteristics of the laminated body discharged from the lamination space satisfy predetermined conditions, instead of or in addition to determining whether or not the plurality of first electrical steel sheets constituting the laminated body have temporarily adhered to each other based on the height of the laminated body discharged from the lamination space.

[0064] For example, whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined based on the adhesion strength of the insulating material exhibited by the temporary adhesion at a timing at which they are discharged from the lamination space. Further, when the plurality of first electrical steel sheets are locally heated, whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined based on the size of regions of the plurality of first electrical steel sheets to be heated within the regions of the plurality of first electrical steel

sheets. Further, whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined based on the temperature of the plurality of first electrical steel sheets when they are caused to temporarily adhere to each other. Further, when the plurality of first electrical steel sheets are caused to temporarily adhere to each other by applying radiant heat onto the plurality of first electrical steel sheets, whether or not the plurality of first electrical steel sheets have temporarily adhered to each other may be determined based on the size of regions onto which the radiant heat is applied within the regions of the plurality of first electrical steel sheets. The radiant heat may be applied onto a partial region within the regions of the outer peripheral surfaces (outer-peripheral-side ends) of the respective first electrical steel sheets. Incidentally, applying the radiant heat onto the plurality of first electrical steel sheets corresponds to irradiating the plurality of first electrical steel sheets with electromagnetic waves (for example, near-infrared rays). Further, the outer peripheral surface of the first electrical steel sheet is a surface surrounding the center line of the first electrical steel sheet and facing the outer side of the first electrical steel sheet (the side where a heat source of the radiant heat exists). In the example illustrated in Fig. 3, the center line

of the first electrical steel sheet is the center line 0.

[0065] As described above, although the method of determining whether or not the plurality of first electrical steel sheets have temporarily adhered to each other is not limited, a specific example of the method of determining upper and lower limits of the adhesion strength of the insulating material exhibited by the temporary adhesion at a timing at which the plurality of first electrical steel sheets are discharged from the lamination space is explained. First, the lower limit of the adhesion strength of the insulating material exhibited by the temporary adhesion at a timing of discharge from the lamination space may be determined based on the mass of the laminated core. On the other hand, the upper limit of the adhesion strength of the insulating material exhibited by the temporary adhesion at a timing of discharge from the lamination space may be determined based on a method of separating the laminated bodies 130a to 130c. When the laminated bodies 130a to 130c are separated by using the second electrical steel sheets (separating sheets 131a to 131b) as in this embodiment, the upper limit of the adhesion strength of the insulating material may be determined based on a contact area or the like between the second electrical steel sheet (separating sheets 131a to 131b) and the first electrical steel sheet.

[0066] For example, when a laminated core is

configured by laminating 278 first electrical steel sheets each having an outer diameter of 220 mm and a thickness of 0.25 mm, the lower limit of the adhesion strength of the insulating material at a timing of discharge from the lamination space is, for example, 3.6×10^{-2} (kgf/mm²). The method of measuring the adhesion strength of the insulating material is not particularly limited. For example, the adhesion strength of the insulating material may be measured (calculated) as follows. First, both end surfaces in the lamination direction of the laminated body discharged from the lamination space are fixed to a tensile tester using a double-sided adhesive tape or the like. The laminated body fixed in this manner is pulled by the tensile tester in a direction perpendicular to the adhesive surfaces (lamination direction). Then, a value obtained by dividing the maximum load required to break at least a portion of the adhesive surface of the laminated body by the area of the adhesive surface may be simply calculated as the adhesion strength of the insulating material. Further, the adhesion strength may be evaluated by a tensile strength. When it is possible to cut out a test piece having a predetermined size from the laminated body discharged from the lamination space, the adhesion strength of the insulating material may be measured (calculated) by using, for example, "Testing methods for tensile strength of adhesive bonds" described in JIS K 6849 1994.

[0067] When the adhesion strength of the insulating material measured as described above at a timing at which the laminated body is discharged from the lamination space is 3.5×10^{-2} (kgf/mm²) or more or 5.0×10^{-2} (kgf/mm²) or more, the plurality of first electrical steel sheets constituting the laminated body may be determined to be in a temporarily adhered state. Further, the ratio of the adhesion strength of the insulating material between the first electrical steel sheets may be, for example, 0.2 or more, 0.3 or more, or 0.4 or more. Further, the ratio of the adhesion strength of the insulating material between the first electrical steel sheets may be 0.9 or less, 0.7 or less, or 0.5 or less. Here, the ratio of the adhesion strength of the insulating material between the first electrical steel sheets is the ratio of the adhesion strength of the insulating material exhibited by temporary adhesion at a timing of discharge from the lamination space to the adhesion strength of the insulating material exhibited by permanent adhesion at a timing at which heating for the permanent adhesion is completed.

Incidentally, the above numerical ranges also apply to soft magnetic sheets other than the electrical steel sheets.

[0068] Further, the condition for determining whether or not the plurality of first electrical steel sheets have temporarily adhered to each other

may be selected for each attribute of the laminated body. The attributes of the laminated body include, for example, at least one of the type of the first electrical steel sheet, the size of the first electrical steel sheet (for example, at least one of the outer diameter and the thickness), the type of the insulating material, and the thickness of the insulating material.

[0069] However, determining whether or not the plurality of first electrical steel sheets constituting the laminated body have temporarily adhered to each other based on the height of the laminated body discharged from the lamination space is practical because whether or not the plurality of first electrical steel sheets have temporarily adhered to each other can be easily determined. The present inventors have found that as long as the plurality of first electrical steel sheets constituting the laminated body are determined to have temporarily adhered to each other based on the height of the laminated body discharged from the lamination space, as a result, at least one of the examples of the above-described ranges of the adhesion strength is satisfied.

[0070] Further, the temporary adhesion is performed such that the adhesion force acting between the second electrical steel sheet (separating sheets 131a to 131b) and at least one of the two first electrical steel sheets located on and under the second

electrical steel sheet is smaller than the adhesion force acting between the first electrical steel sheets. The former adhesion force is preferably 0 (zero).

[0071] As above, the insulating material formed on the second electrical steel sheet (separating sheets 131a to 131b) may exhibit adhesion performance sufficient to allow the second electrical steel sheet to be separated from the first electrical steel sheet (laminated bodies 130a to 130c) before the later-described permanent adhesion is started. For example, when the laminated bodies 130a to 130c are discharged from the lamination space, the insulating material formed on the sheet surface of the second electrical steel sheet may exhibit adhesion performance sufficient to separate the second electrical steel sheet from at least one of the two first electrical steel sheets (two laminated bodies 130a and 130b, 130b and 130c) located on and under the second electrical steel sheet. Further, for example, after the laminated bodies are discharged from the lamination space, the insulating material formed on the sheet surface of the second electrical steel sheet may exhibit adhesion performance sufficient to allow a worker to manually separate the second electrical steel sheet adhering to the first electrical steel sheet (laminated bodies 130a to 130c) from the first electrical steel sheet. When the second electrical steel sheet is separated from

the first electrical steel sheet, positional displacement occurring in the plurality of first electrical steel sheets constituting the laminated bodies 130a to 130c is preferably as small as possible, and most preferably 0 (zero).

The adhesion strength between the plurality of first electrical steel sheets that have temporarily adhered to each other (laminated bodies 130a to 130c) and the second electrical steel sheet (separating sheets 131a to 131b) is specified by the method described above, for example.

[0072] In Fig. 1 and Fig. 3, this embodiment explains, as an example, the case where first heating devices 140a to 140d are installed within the lower die 120. The first heating devices 140a to 140d are an example of a device for performing the above-described temporary adhesion. The first heating devices 140a to 140b heat the plurality of first electrical steel sheets within the lamination space below the third punch 111c (on the negative direction side of the z-axis). The first heating devices 140c to 140d heat the plurality of first electrical steel sheets within the lamination space below the sixth punch 111f (on the negative direction side of the z-axis). This embodiment explains, as an example, the case where the first heating devices 140a to 140d locally heat the plurality of first electrical steel sheets within the lamination space in order to perform the above-described temporary adhesion.

Locally heating the plurality of first electrical steel sheets means heating only partial regions within the regions of the plurality of first electrical steel sheets. The regions where the plurality of first electrical steel sheets are locally heated include partial regions within the regions of the outer peripheral surfaces of the respective first electrical steel sheets, and do not have to include the remaining partial regions within the regions of the outer peripheral surfaces of the respective first electrical steel sheets.

[0073] The first heating devices 140c to 140d have the same functions as the first heating devices 140a to 140b. The only difference between the first heating devices 140a to 140b and the first heating devices 140c to 140d lies in the difference in the arrangement and specific heating conditions resulting from the different shapes and sizes of the regions to be punched out from the electrical steel sheet M. Therefore, explanations of specific examples of the first heating devices 140c to 140d are omitted below.

[0074] As described above, the insulating material formed on the sheet surface of the electrical steel sheet M, which is the base material, exhibits adhesion performance through heating. The first electrical steel sheet and the second electrical steel sheet are punched out from the electrical steel sheet M. This embodiment explains, as an example, the case where the insulating material formed on the

sheet surfaces of the plurality of first electrical steel sheets constituting the laminated bodies 130a to 130c and the insulating material formed on the sheet surfaces of the second electrical steel sheets (separating sheets 131a to 131b) are of the same type. In this case, when the shape and size of the second electrical steel sheet (separating sheets 131a to 131b) are made the same as those of the first electrical steel sheet, the insulating material formed on the sheet surface of the second electrical steel sheet (separating sheets 131a to 131b) also exhibits adhesion performance comparable to that of the insulating material formed on the sheet surface of the first electrical steel sheet. Therefore, when the plurality of first electrical steel sheets are caused to temporarily adhere to each other, the insulating material formed on the sheet surface of the second electrical steel sheet may exhibit adhesion performance. Incidentally, the insulating material formed on the sheet surfaces of the second electrical steel sheets (separating sheets 131a to 131b) may contain a different type of insulating material from the insulating material formed on the sheet surfaces of the plurality of first electrical steel sheets constituting the laminated bodies 130a to 130c. In this case as well, the insulating material formed on the sheet surfaces of the second electrical steel sheets may exhibit adhesion performance when the plurality of first electrical

steel sheets are caused to temporarily adhere to each other.

[0075] Therefore, as illustrated in Fig. 1 and Fig. 3, this embodiment explains, as an example, the case where distances between the outer-peripheral-side ends of the separating sheet 131b and the first heating devices 140a to 140b are made longer than those between the outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b within the lamination space.

Incidentally, the distance here is the shortest distance. Further, in Fig. 3, a leader line with a reference numeral and symbol (130b) is attached to the first electrical steel sheet constituting the upper surface of the laminated body 130b.

[0076] For example, the distances between the outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b, and the distance between the outer-peripheral-side end of the separating sheet 131b and the first heating device 140a are determined, for example, by the type of the heating device and the type of the insulating material formed on the separating sheet 131b. For example, when the first heating devices 140a to 140b are heating devices using near-infrared rays or the like, the distances between the outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b each are, for example, 20 mm or less, and preferably 5 mm or less. Further, the

outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b may be in complete contact with each other. Further, the distance between the outer-peripheral-side end of the separating sheet 131b and the first heating device 140a is 20 mm or more, and preferably 50 mm or more.

[0077] As described above, the distances between the outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b, and the distance between the outer-peripheral-side end of the separating sheet 131b and the first heating device 140a may be appropriately set according to the type of the heating device, the type of the insulating material formed on the separating sheet 131b, or the like. Incidentally, these distances are the shortest distances. Further, the above-described numerical ranges of these distances also apply to soft magnetic sheets other than the electrical steel sheets.

[0078] Incidentally, the positions of the first heating devices 140a to 140b when determining the above-described shortest distance may be, for example, any positions of the first heating devices 140a to 140b. However, the positions of the first heating devices 140a to 140b for determining the distances from the outer-peripheral-side ends of the separating sheet 131b are set to be the same as the positions of the first heating devices 140a to 140b for determining the distances from the outer-peripheral-side ends of the laminated body 130b.

[0079] For example, in Fig. 3, the shortest distance between the outer-peripheral-side end of the separating sheet 131b and the first heating device 140a is a straight-line distance between a position 1310a of the outer-peripheral-side end of the separating sheet 131b and a position 1400a of the first heating device 140a. Further, for example, in Fig. 3, the shortest distance between the outer-peripheral-side end of the laminated body 130b and the first heating device 140a is a straight-line distance between a position 1300a of the outer-peripheral-side end of the laminated body 130b and the position 1400a of the first heating device 140b. Similarly, in Fig. 3, the shortest distance between the outer-peripheral-side end of the separating sheet 131b and the first heating device 140b is a straight-line distance between a position 1310b of the outer-peripheral-side end of the separating sheet 131b and a position 1400b of the first heating device 140b. Further, for example, in Fig. 3, the shortest distance between the outer-peripheral-side end of the laminated body 130b and the first heating device 140b is a straight-line distance between a position 1300b of the outer-peripheral-side end of the laminated body 130b and the position 1400b of the first heating device 140a. Incidentally, the positions 1400a and 1400b of the first heating devices 140a and 140b may be, for example, positions (for example, positions of the center of gravity) within a region from which a

heat transfer medium for heating an object to be heated (first electrical steel sheet) is output to the outside, of the regions of the first heating devices 140a and 140b. The heat transfer medium is determined according to the type of the first heating devices 140a and 140b. The heat transfer medium is, for example, an electromagnetic wave, a current, a magnetic flux, or the like. More specifically, when the first heating devices 140a to 140b are near-infrared heaters, the heat transfer medium is near-infrared rays.

[0080] In order to establish the relationship between the distances between the outer-peripheral-side ends of the separating sheet 131b and the first heating devices 140a to 140b and the distances between the outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b as described above, this embodiment explains, as an example, the case where a plurality of cutout portions 210a to 210b are formed in the outer-peripheral-side end of the second soft magnetic sheets (separating sheets 131a to 131b) as illustrated in Fig. 1, Fig. 2D, and Fig. 3. In the lamination space, the second soft magnetic sheets (separating sheets 131a to 131b) are arranged such that at least partial regions of the cutout portions 210a to 210b formed in the sheet surfaces of the second soft magnetic sheets are located closer to the center line 0 (center line of two laminated bodies)

side than the outer-peripheral-side ends of the two laminated bodies 130a to 130b and the two laminated bodies 130b to 130c arranged above and below the cutout portions 210a to 210b. Fig. 2D and Fig. 3 illustrate, as an example, the case where all the regions of the cutout portions 210a to 210b are located closer to the center line 0 side than the outer-peripheral-side ends of the two laminated bodies 130a to 130b and the two laminated bodies 130b to 130c arranged above and below the cutout portions 210a to 210b. As above, the cutout portions 210a to 210b formed in the outer-peripheral-side ends of the second soft magnetic sheets (separating sheets 131a to 131b) include regions located closer to the center line 0 side than the outer-peripheral-side ends of the two laminated bodies 130a to 130b and the two laminated bodies 130b to 130c arranged on and under the second soft magnetic sheets within the lamination space. Fig. 2D and Fig. 3 illustrate, as an example, the case where two such cutout portions 210a to 210b are formed.

[0081] Incidentally, the dimensions of the cutout portion are not limited. For example, the length in the circumferential direction (a direction around the center line 0) of an outer peripheral edge of the one cutout portion 210a or 210b may be $1/10$ or more, $1/8$ or more, or $1/6$ or more of the outer diameter of the first electrical steel sheets constituting the laminated bodies 130a to 130f. Further, for example,

the circumferential length of the outer peripheral edge of the one cutout portion 210a or 210b may be $1/2$ or less, $1/3$ or more, or $1/4$ or more of the outer diameter of the first electrical steel sheets constituting the laminated bodies 130a to 130f. Further, the circumferential length of the outer peripheral edge of the one cutout portion 210a or 210b may be, for example, 30 mm or more, or 50 mm or more. Here, the circumferential length of the outer peripheral edge of the one cutout portion 210a or 210b is the circumferential length of a portion corresponding to the one cutout portion 210a or 210b of the outer peripheral edge of the second electrical steel sheet, assuming that the cutout portion 210a or 210b is not formed. In Fig. 3, the circumferential length of the outer peripheral edge of the one cutout portion 210a or 210b is the length of an arc that is a part of a circle in contact with the contact portions 310a to 310h, and is the length of one of the two arcs illustrated in regions not indicated by oblique lines.

[0082] Further, the length in a radial direction of the one cutout portion 210a or 210b is not limited. For example, it may be $1/10$ or more, $1/8$ or more, or $1/6$ or more of the radius of the first electrical steel sheets constituting the laminated bodies 130a to 130f. Further, for example, the radial length of the one cutout portion 210a or 210b may be $4/5$ or less, $3/5$ or less, or $2/5$ or less. Further, the

radial length of the one cutout portion 210a or 210b may be, for example, 20 mm or more, or 30 mm or more.

[0083] Incidentally, as illustrated in Fig. 2D and Fig. 3, this embodiment explains, as an example, the case where the planar shape of the separating sheets 131a to 131b is a shape surrounding the center line 0. However, this embodiment is not necessarily required to be configured in this manner. For example, a plurality of separating sheets may be arranged on the same plane. For example, in Fig. 2D, two separating sheets may be configured such that a black region on the positive direction side of the y-axis and a black region on the negative direction side of the y-axis are separated from each other. Such two separating sheets separated from each other may be arranged so as to have two-fold symmetry with the center line 0 as the rotational symmetry axis.

[0084] As illustrated in Fig. 3, this embodiment explains, as an example, the case where, when viewed along the center line 0, the two first heating devices 140a to 140b are installed at positions sandwiching the laminated body 130b therebetween. Specifically, as an example, the case is explained where, when viewed along the center line 0, the two first heating devices 140a to 140b are arranged at positions facing each other with a gap therebetween via the center line 0. Further, of the plurality of first heating devices 140a to 140b, one of the first heating devices 140a and 140b is installed at a

position facing one of the cutout portions 210a and 210b of the plurality of cutout portions 210a to 210b with a gap therebetween, and the other of the first heating devices 140a and 140b is installed at a position facing the other of the cutout portions 210a and 210b with a gap therebetween. The state where the first heating devices 140a, 140b and the cutout portions 210a, 210b have a gap therebetween respectively corresponds to a state where the first heating devices 140a, 140b and an imaginary line indicating the outer-peripheral-side end of the first electrical steel sheet, assuming that the cutout portions 210a, 210b are not formed, have a gap therebetween. Incidentally, the two-dot chain line illustrated in Fig. 2D is the imaginary line indicating the outer-peripheral-side end of the first electrical steel sheet, assuming that the cutout portions 210a, 210b are not formed.

[0085] In this embodiment, the first heating devices 140a to 140b locally heat the regions of the first electrical steel sheets located above and below the cutout portions 210a to 210b of the second electrical steel sheet. Therefore, the adhesion performance of the insulating material is partially exhibited in the heated regions. On the other hand, the cutout portions 140a to 140b are formed in the second electrical steel sheet, and further, the first heating devices 140a to 140b locally heat the regions where the cutout portions 140a to 140b of the second

electrical steel sheet are formed. Therefore, the second electrical steel sheet is not sufficiently heated due to the heating, and the adhesion performance of the insulating material formed on the sheet surface of the second electrical steel sheet is not easily exhibited. Thus, even when the insulating material is formed on the whole or most of the sheet surface of the second electrical steel sheet, it is possible to prevent the adhesion performance of the insulating material from being sufficiently exhibited. In this way, it is possible to inhibit exhibition of the adhesion performance of the insulating material formed on the second electrical steel sheets (separating sheets 131a to 131b) (preferably, to prevent the adhesion performance of the insulating material from being exhibited) while allowing the adhesion performance of the insulating material formed on the sheet surface of the first electrical steel sheets to be exhibited. Incidentally, the number of first heating devices to be installed at positions facing one cutout portion with a gap therebetween is not limited to one, and may be two or more.

[0086] Further, this embodiment explains, as an example, the case where the first heating devices 140a to 140b are installed at positions facing all of the cutout portions 210a to 210b each having a gap therebetween. However, the first heating devices only need to be set at a position facing at least one

cutout portion with a gap therebetween. In this case, the first heating devices do not have to be installed at positions facing all of the cutout portions each having a gap therebetween.

[0087] The number of first heating devices is not limited to two, and may be one, or three or more. The number of cutout portions formed in the separating sheet is also not limited to two, and may be one, or three or more. The number, position, and heating method of the first heating devices, and the shape and size of the separating sheet may be determined by trial and error, or may be determined based on results of heat transfer analysis during the temporary adhesion.

[0088] For example, the plurality of first heating devices may be installed at positions facing one cutout portion 210a or 210b with a gap therebetween. However, from the viewpoint of improving the parallelism of the upper surface and the lower surface of the laminated core, it is preferable that the separating sheets 131a to 131b (second electrical steel sheets) should have the two cutout portions 210a to 210b formed at positions sandwiching the center line 0 therebetween when viewed along the center line 0 of the separating sheets. Specifically, when viewed along the center line 0, it is preferable that the two cutout portions 210a to 210b should be arranged at positions facing each other with a gap therebetween via the center line 0. There may be a

plurality of pairs of such two cutout portions 210a and 210b. Further, as illustrated in Fig. 2D and Fig. 3, it is more preferable that the two cutout portions 210a and 210b should be formed in the separating sheets 131a to 131b (second electrical steel sheets) so as to have two-fold symmetry with the center line 0 of the separating sheets 131a to 131b (second electrical steel sheets) as the rotational symmetry axis.

[0089] When the separating sheets 131a to 131b have the cutout portions 210a to 210b as in this embodiment, it is preferable to raise the temperature of at least partial regions of the first electrical steel sheets located above and below the cutout portions 210a to 210b by 25°C or more relative to the minimum temperature of the regions of the first electrical steel sheets not located above and below the cutout portions 210a to 210b. This embodiment is configured as above, and thereby it is possible to reliably suppress the adhesion force acting between the separating sheets 131a to 131b and the first electrical steel sheets. Specifically, on the same circumference of the first electrical steel sheet, it is preferable to raise the temperature of the regions of the first electrical steel sheets located above and below the cutout portions 210a to 210b by 25°C or more relative to the minimum temperature of the regions of the first electrical steel sheets not located above and below the cutout portions 210a to

210b. Incidentally, the temperature of the first electrical steel sheet is calculated, for example, by numerically simulating the heat conductions of the first electrical steel sheet and the second electrical steel sheet within the lamination space. In this case, the temperature is calculated for each discretized region. The minimum temperature is, for example, the minimum temperature among the temperatures of a plurality of discretized regions. [0090] Further, in addition to or instead of the above, it is preferable to lower the temperature of the regions of the first electrical steel sheets not located above and below the cutout portions 210a to 210b by 25°C or more relative to an adhesion start temperature of the insulating material formed on the sheet surface of the first electrical steel sheet. Further, it is preferable that the temperature of the regions of the first electrical steel sheets located above and below the cutout portions 210a to 210b should be equal to or more than the adhesion start temperature of the insulating material formed on the sheet surface of the first electrical steel sheet. Here, the adhesion start temperature is a temperature at which the insulating material starts to exhibit adhesion performance. For example, in the case where the insulating material exhibits adhesion performance through heating due to the thermosetting resin contained in the insulating material, the adhesion start temperature may be a curing temperature of the

thermosetting resin. The curing temperature may be a curing start temperature (a temperature at which a curing reaction starts). The adhesion start temperature may be, for example, a value published by a manufacturer of the adhesive.

[0091] Incidentally, in Fig. 3, the regions of the first electrical steel sheets located above and below the cutout portions 210a to 210b are regions (right and left white regions) other than the region of the separating sheet 131b, within the region of the first electrical steel sheet (laminated body 130b).

The outputs of the first heating devices 140a to 140b capable of achieving the temperatures as described above may be investigated in advance.

[0092] Fig. 4 is a view illustrating an example of the relationship between a temperature of the first electrical steel sheet and time. In Fig. 4, T_s is the temperature of the first electrical steel sheet before starting temporary adhesion (heating by the first heating devices 140a to 140b). In the following explanation, this temperature is referred to as a pre-temporary adhesion start temperature as necessary. In Fig. 1, this embodiment explains, as an example, the case where the pre-temporary adhesion start temperature T_s is measured by thermometers 150a to 150b.

[0093] The thermometers 150a to 150b are thermocouples, for example. Incidentally, in Fig. 1, for convenience of illustration, the thermometers

150a to 150b are illustrated so as to be able to measure the temperature of the uppermost first electrical steel sheet within the lamination space. However, the first electrical steel sheet to be measured by the thermometers 150a, 150b may be the first electrical steel sheet before heating by the first heating devices 140a to 140b and 140c to 140d is started. In this case, the first electrical steel sheet to be measured by the thermometers 150a and 150b may be the first electrical steel sheet immediately before heating by the first heating devices 140a to 140b and 140c to 140d is started. Further, the first electrical steel sheet to be measured by the thermometers 150a and 150b may be the first electrical steel sheet immediately after heating by the first heating devices 140a to 140b and 140c to 140d is started. Further, the thermometers 150a to 150b may be radiation thermometers or the like.

[0094] In Fig. 4, 0 on the horizontal axis is a timing for starting heating by the first heating devices 140a to 140b. Investigating the relationship between the heating time and the temperature of the first electrical steel sheets (laminated bodies 130a to 130c) with the outputs of the first heating devices 140a to 140b kept constant is performed while varying the outputs of the first heating devices 140a to 140b, and thereby graphs 410a to 410b are created. Fig. 4 illustrates, as an example, the graphs 410a

and 410b in the case where the outputs of the first heating devices 140a and 140b are 80% and 70% of their rated outputs, respectively.

[0095] T_a is a target temperature of the first electrical steel sheet after the temporary adhesion. t_h is the duration from the measurement timing of the pre-temporary adhesion start temperature T_s to the timing at which the temporary adhesion is completed (in this case, 0 on the horizontal axis of Fig. 4 represents the measurement timing of the pre-temporary adhesion start temperature T_s).

[0096] An example of the method of setting heating conditions in the first heating devices 140a to 140c by using the graphs 410a to 410b and measured values of the thermometer 150a is explained below.

First, the pre-temporary adhesion start temperature T_s is measured by the thermometer 150a. Next, the measured value of the pre-temporary adhesion start temperature T_s is subtracted from the target temperature T_a of the first electrical steel sheet. In the following explanation, the value obtained by this subtraction ($T_a - T_s$) is referred to as a temperature increase amount. Further, the duration from the measurement timing of the pre-temporary adhesion start temperature T_s to the timing at which the temporary adhesion is completed is calculated as an example of the duration for which heating by the first heating devices 140a to 140b is performed. In the following explanation, this

duration is referred to as a temporary adhesion required time as necessary. The temporary adhesion required time t_h is calculated based on, for example, the number of times of punching per unit time by the third punch 111c and the third die 121c and the thickness of the electrical steel sheet M. In Fig. 4, a graph that represents a value closest to the temperature increase amount $T_a - T_s$ at the temporary adhesion required time t_h is selected from the graphs 410a to 410b. An output corresponding to the selected graph is set as the output of the first heating devices 140a to 140b. Fig. 4 illustrates, as an example, the case where the output of the first heating devices 140a to 140b is set to 70% of the rated output.

[0097] Incidentally, the method of calculating the output of the first heating devices 140a to 140b is not limited to the method described above. Two graphs that sandwich the temperature increase amount $T_a - T_s$ at the temporary adhesion required time t_h may be selected from the graphs 410a to 410b. In this case, the output of the first heating devices 140a to 140b may be calculated by interpolating the outputs corresponding to the two graphs based on the temperature increase amount $T_a - T_s$ at the temporary adhesion required time t_h and the temperatures of the two graphs at the temporary adhesion required time t_h .

[0098] This embodiment explains, as an example, the case where the setting of the heating conditions for

the first heating devices 140a to 140b as described above and the control of the operation of the first heating devices 140a to 140b are implemented by the control device 200. For example, the control device 200 sets the heating conditions by calculating the output of the first heating devices 140a to 140b based on the temperatures measured by the thermometers 150a to 150b, the graphs 410a to 410c illustrated in Fig. 4, and the target temperature T_a of the first electrical steel sheet. The control device 200 operates the first heating devices 140a to 140b such that the output of the first heating devices 140a to 140b becomes the output calculated in this manner. Further, the control device 200 operates the first heating devices 140c to 140d in the same manner as the first heating devices 140a to 140b. Incidentally, the outputs of the first heating devices 140a to 140d may be updated. For example, the outputs of the first heating devices 140a to 140d may be updated when the attribute of the laminated bodies 130a to 130c changes. The attributes of the laminated body include, for example, at least one of the type of the first electrical steel sheet, the size of the first electrical steel sheet (for example, at least one of the outer diameter and the thickness), the type of the insulating material, and the thickness of the insulating material.

As described above, this embodiment explains, as an example, the case where a heating condition

setting step and a heating condition setting means are implemented by using the thermometers 150a to 150b and the control device 200.

[0099] The heating method by the first heating devices 140a to 140b is not limited as long as the temporary adhesion can be performed as described above. The heating by the first heating devices 140a to 140b may be contact heating or non-contact heating. The contact heating is heating performed in a state where the first heating devices 140a to 140b are in contact with an object to be heated. The non-contact heating is heating performed in a state where the first heating devices 140a to 140b are not in contact with an object to be heated. However, the heating by the first heating devices 140a to 140b is preferably non-contact heating. This is because, for example, the first electrical steel sheet can be easily heated in a short time while the first electrical steel sheet is moving within the lower die 120. In the case where the heating by the first heating devices 140a to 140b is non-contact heating, the heating by the first heating devices 140a to 140b may be, for example, radiant heating, induction heating, or dielectric heating. However, the heating by the first heating devices 140a to 140b is preferably heating by irradiation with near-infrared rays, which is an example of radiant heating. In this case, the first heating devices 140a to 140b include near-infrared heaters. The wavelength of the near-

infrared rays output by the near-infrared heater is preferably 700 nm or more and less than 1400 nm. Such near-infrared rays enter not only the first electrical steel sheet but also the insulating material, thus allowing for direct heating of the insulating material. Therefore, the insulating material can be uniformly heated. Accordingly, softening of the insulating material starts from the region of the insulating material near the interface with the first electrical steel sheet, and thus it is possible to inhibit the insulating material from melting out from the vicinity of the interface.

[0100] Further, it is more preferable that the near-infrared heaters included in the first heating devices 140a to 140b should concentrate the near-infrared rays linearly along the lamination direction (z-axis direction) of the laminated bodies 130a to 130c. This is because the positions to be irradiated with near-infrared rays can be determined with high accuracy. Fig. 3 illustrates, as an example, the state where such near-infrared rays L are irradiated onto the outer-peripheral-side end of the laminated body 130b. However, the near-infrared heater may output parallel rays, for example.

[0101] Incidentally, this embodiment has explained, as an example, the case where the cutout portions 210a to 210b are formed in the outer-peripheral-side ends of the second soft magnetic sheets (separating sheets 131a to 131b). However, the cutout portions

do not have to be formed in the second soft magnetic sheet. For example, the planar shape of the second soft magnetic sheet may be the shape illustrated in Fig. 2E. Even when the second soft magnetic sheet illustrated in Fig. 2E is used as a separating sheet, the distances between the outer-peripheral-side ends of the separating sheet and the first heating devices 140a to 140b within the lamination space are longer than the distances between the outer-peripheral-side ends of the laminated body 130b and the first heating devices 140a to 140b.

[0102] Further, the separating sheet does not have to be the electrical steel sheet (second electrical steel sheet) punched out from the electrical steel sheet M being the base material. Further, the insulating material that exhibits adhesion performance through heating does not have to be formed on the sheet surface of the separating sheet. In this case, the insulating material that exhibits adhesion performance through heating does not have to be formed on the sheet surface of the separating sheet. In this case, an insulating material that does not exhibit adhesion performance at the temperature at which the insulating material formed on the electrical steel sheet M, which is the base material, exhibits adhesion performance may be formed on the sheet surface of the separating sheet. Further, the insulating material that exhibits adhesion performance through heating may be formed

only on a partial region within the region of the sheet surface of the separating sheet. For example, the ratio of the region of the sheet surface of the separating sheet where the insulating material that exhibits adhesion performance through heating is formed to the area of the sheet surface of the separating sheet may be 0.8 or less, preferably 0.4 or less, and more preferably 0.2 or less. Further, in the case where the plurality of first electrical steel sheets are caused to temporarily adhere to each other by heating only partial regions of the plurality of first electrical steel sheets, the insulating material that exhibits adhesion performance through heating does not have to be formed on the regions of the sheet surfaces of the separating sheets facing the regions where the plurality of first electrical steel sheets are heated.

[0103] As described above, this embodiment explains, as an example, the case where a temporary adhesion step is implemented by using the guide rings 123a and 123b and the first heating devices 140a to 140b and 140c to 140d.

[0104] In Fig. 1, this embodiment explains, as an example, the case where a discharge space communicating with the lamination space is formed in a region below the lamination space of the region within the lower die 120. In the discharge space, it is set that nothing comes into contact with the outer-peripheral-side ends of the laminated bodies

130a to 130c (first electrical steel sheets) and the separating sheets 131a to 131b (second electrical steel sheets). That is, when viewed along the center line 0, the outer edge of the discharge space is set to be located outside the outer edge of the lamination space.

[0105] This explains, as an example, the case where each of the laminated bodies 130a to 130c and each of the laminated bodies 130d to 130e, on which the temporary adhesion has been completed, are discharged downward below the lower die 120 via such a discharge space and placed on receiving tables 160a and 160b respectively. At this time, the laminated bodies 130a to 130c and 130d to 130e may fall by their own weight, or may be taken out by being gripped by a robot arm or the like. The difference between the configuration after the laminated bodies 130a to 130c are discharged from the lower die 120 and the configuration after the laminated bodies 130d to 130e are discharged from the lower die 120 lies in the difference in the shape and size of the regions punched out from the electrical steel sheet M. Therefore, in the following, explanations of specific examples of the configuration after the laminated bodies 130d to 130e are discharged from the lower die 120 are omitted.

[0106] This embodiment explains, as an example, the case where, when the laminated bodies 130a to 130c are discharged, the separating sheets 131a and 131b

are separated from at least the laminated bodies 130b and 130c on the separating sheets 131a and 131b among the laminated bodies 130a to 130b and the laminated bodies 130b to 130c on and under the separating sheets 131a and 131b. As described above, even when the separating sheets 131a and 131b are not separated from the laminated bodies 130a and 130b located under the separating sheets 131a and 131b within the lower die 120, the insulating material formed on the sheet surfaces of the separating sheets 131a to 131b (second electrical steel sheets) may exhibit adhesion performance, provided that the adhesion performance is of such an extent that the separating sheets 131a and 131b can be separated from the laminated bodies 130a and 130b after being discharged from the lower die 120 or the like so as to prevent the plurality of first electrical steel sheets constituting the laminated bodies 130a and 130b from separating (preferably to prevent positional displacement thereof). Further, the insulating material formed on the sheet surfaces of the separating sheets 131a to 131b (second electrical steel sheets) does not have to exhibit adhesion performance.

[0107] Fig. 1 illustrates, as an example, the case where the separating sheet 131a is present on the laminated body 130a discharged from the lower die 120. In this case, a worker may collect the separating sheet 131a. As described above, since the adhesion force acting between the separating sheet 131a and

the first electrical steel sheets located on and under the separating sheet 131a is 0 (zero) or low, the worker can collect the separating sheet 131a so as to prevent the plurality of first electrical steel sheets constituting the laminated body 130a from separating (preferably to prevent positional displacement thereof). Further, when the laminated body 130a is discharged from the lower die 120, the separating sheet 131a on the laminated body 130a may separate therefrom spontaneously. In this case, the worker collects the separating sheet 131a that has separated from the laminated body 130a. Incidentally, the collection of the separating sheet 131a may be performed by an apparatus.

[0108] As described above, this embodiment explains, as an example, the case where a separating step and a separating means are implemented by causing the laminated bodies 130a to 130c and 130d to 130e to be discharged downward below the lower die 120 via the discharge space.

[0109] Fig. 5 is a view explaining an example of a step performed on the laminated body 130a discharged from the lower die 120.

In Fig. 5, this embodiment explains, as an example, the case where the laminated body 130a placed on the receiving table 160a is sent to a conveying device 520 by an extrusion device 510. In Fig. 5, the white arrow line attached beside the extrusion device 510 represents this. The conveying

device 520 conveys the laminated body 130a. In Fig. 5, the white arrow line attached beside the conveying device 520 represents this. The conveying device 520 includes, for example, a conveying belt.

Incidentally, as described above, when the separating sheet 131a is present on the laminated body 130a placed on the receiving table 160a, the separating sheet 131a may be collected before the laminated body 130a is sent to the conveying device 520, or may be collected while the laminated body 130a is being conveyed by the conveying device 520.

[0110] The laminated body 130a conveyed by the conveying device 520 is set in second heating devices 530a to 530b by a worker or an apparatus such as a crane. At this time, a key ring 550 is inserted into a hollow portion of the laminated body 130a. The shape of the key ring 550 is preferably closer to the shape of the hollow portion of the laminated body 130a, and most preferably the same. The key ring 550 is a metallic object. The key ring 550 only needs to have such a size that the outer peripheral surface of the key ring 550 after thermal expansion comes into contact with the inner peripheral surface of the laminated body 130a to such an extent that it does not generate residual stress in the laminated body 130a. A wider contact region between the outer peripheral surface of the key ring 550 after thermal expansion and the inner peripheral surface of the laminated body 130a is better. Most preferably, the

outer peripheral surface of the key ring 550 after thermal expansion comes into contact with the entire region of the inner peripheral surface of the laminated body 130a.

[0111] Further, on the upper surface (end surface on the positive direction side of the z-axis) and the lower surface of the laminated body 130a, pressure blocks 540a to 540b for applying pressure onto the laminated body 130a in the lamination direction (z-axis direction) of the first electrical steel sheets constituting the laminated body 130a are arranged respectively. The pressure blocks 540a to 540b are configured so as to pressurize the laminated body 130a in the lamination direction (z-axis direction) of the first electrical steel sheets constituting the laminated body 130a, to an extent that no residual stress is generated in the laminated body 130a. The shape of the pressure blocks 540a to 540b is, for example, a cylinder. Further, the lower surface (end surface on the negative direction side of the z-axis) of the pressure block 540a preferably comes into contact with the entire upper surface of the laminated body 130a. The upper surface (end surface on the positive direction side of the z-axis) of the pressure block 540b preferably comes into contact with the entire lower surface of the laminated body 130a.

[0112] After the pressure blocks 540a to 540b and the key ring 550 are set as described above, the

second heating devices 530a to 530b are operated. At this time, the pressure block 540a may be pressed from above to such an extent that it does not generate residual stress in the laminated body 130a. The operation of the second heating devices 530a to 530b may be controlled by the control device 200.

[0113] The second heating devices 530a to 530b heat the plurality of first electrical steel sheets constituting the laminated body 130a for permanent adhesion. The permanent adhesion of the first electrical steel sheets by the second heating devices 530a to 530b is achieved, for example, by causing the adhesion performance of the insulating material formed on the sheet surfaces of the first electrical steel sheets to be exhibited to the maximum extent. The amount of heat applied to the laminated body 130a by the second heating devices 530a to 530b is greater than the amount of heat applied to the laminated body 130a by the first heating devices 140a to 140b. For example, at least one of the temperature of the laminated body 130a during heating and the heating time of the laminated body 130a may be set to be greater when the second heating devices 530a to 530b are used than when the first heating devices 140a to 140b are used. When the insulating material contains a thermosetting resin, the permanent adhesion of the first electrical steel sheets by the second heating devices 530a to 530b may be achieved, for example, by completing the curing reaction of the thermosetting

resin. Further, when portions of the sheet surfaces of the first electrical steel sheets adhere to each other by temporary adhesion, the permanent adhesion of the first electrical steel sheets by the second heating devices 530a to 530b may be achieved by causing the remaining portions of the sheet surfaces of the first electrical steel sheets to adhere to each other. The configurations and conditions for causing the plurality of first electrical steel sheets constituting the laminated body 130a to permanently adhere to each other may be known configurations and conditions used when laminating a plurality of soft magnetic sheets each having an insulating material, which exhibits adhesion performance through heating, formed on the sheet surfaces thereof, and performing adhesion thereon outside the die assembly.

[0114] The second heating devices 530a to 530b may include near-infrared heaters. In this case, it is preferable that the near-infrared heaters included in the second heating devices 530a to 530b should concentrate near-infrared rays linearly along the lamination direction (z-axis direction) of the laminated body 130a. However, the near-infrared heater may output parallel rays, for example. Further, the second heating devices 530a to 530b may include a device that performs heating by thermal radiation other than thermal radiation by near-infrared rays, or may include a device that performs

induction heating.

[0115] As described above, this embodiment explains, as an example, the case where a permanent adhesion step is implemented by using the second heating devices 530a to 530b.

When the heating by the second heating devices 530a to 530b is completed, the laminated core 500 is completed. In Fig. 5, the white arrow line attached beside the laminated core 500 represents this.

[0116] As described above, in this embodiment, the first soft magnetic sheets are sequentially punched out from the electrical steel sheet M using the press apparatus 100 having the die assembly. Thereafter, the plurality of first electrical steel sheets are heated within the lower die 120, to thereby temporarily adhere to each other. Subsequently, the laminated body 130a, 130b of a number of the first electrical steel sheets corresponding to the height of one laminated core 500 is separated from the laminated body 130b, 130c subsequent thereto within the lower die 120. Then, the plurality of first electrical steel sheets constituting each of the laminated bodies 130a to 130c are heated outside the lower die 120, to thereby permanently adhere to each other. Therefore, the laminated core for a rotary electric machine can be efficiently manufactured. The adhesion force can be increased in stages by the adhesion of the plurality of first electrical steel sheets performed within the press apparatus 100

(lower die 120) and the adhesion of the plurality of first electrical steel sheets performed outside the press apparatus 100 (lower die 120), for example. Further, the temporary adhesion of the plurality of first electrical steel sheets only needs to be performed within the press apparatus 100 (lower die 120), thus making it possible to inhibit a decrease in productivity of the punching. For example, it is possible to inhibit the punching from being delayed for the adhesion of the first electrical steel sheets. Further, it is possible to inhibit positional displacement of the plurality of first electrical steel sheets constituting each of the laminated bodies 130a to 130c outside the press apparatus 100 (lower die 120). Therefore, the work outside the press apparatus 100 (lower die 120) can be easily performed.

[0117] Further, in this embodiment, before the temporary adhesion of the first electrical steel sheets, the separating sheets 131a and 131b are arranged at positions between the laminated bodies 130a and 130b and between the laminated bodies 130b and 130c subsequent thereto within the lower die 120 respectively. Here, the separating sheets 131a to 131b do not have to exhibit adhesion performance during the above-described temporary adhesion. Further, the adhesion performance exhibited by the separating sheets 131a to 131b during the temporary adhesion may be lower than the adhesion performance

exhibited by the insulating material formed on the sheet surfaces of the first electrical steel sheets during the temporary adhesion. This embodiment is configured as above, and thereby, separation of the laminated bodies 130a to 130c can be easily and reliably achieved. Incidentally, the fact that the separating material is not limited to the separating sheet will be described later in a third embodiment.

[0118] Further, in this embodiment, the distances between the first heating devices 140a to 140b and the outer-peripheral-side ends of the separating sheets 131a to 131b, which exhibit adhesion performance through heating, are longer than the distances between the first heating devices 140a to 140b and the outer-peripheral-side ends of the laminated bodies 130a to 130c. Therefore, it is possible to inhibit the separating sheets 131a to 131b from exhibiting adhesion performance through heating. Accordingly, the laminated bodies 130a to 130c can be reliably separated by the separating sheets 131a to 131b.

[0119] Further, in this embodiment, the separating sheets 131a to 131b are the second electrical steel sheets punched out from the electrical steel sheet M by the press apparatus 100. Further, in this embodiment, the second soft magnetic sheets (separating sheets 131a and 131b) are arranged at positions between the two laminated bodies 130a and 130b and between the two laminated bodies 130a and

130c within the lower die 120 respectively. Therefore, arranging the second soft magnetic sheets (separating sheets 131a and 131b) at the positions between the two laminated bodies 130a and 130b and between the two laminated bodies 130a and 130c respectively can be achieved with a simple configuration. Thus, it is preferable that the separating sheets 131a to 131b and the first electrical steel sheets should be punched out from the same base material (electrical steel sheet M in this embodiment). However, this embodiment is not necessarily required to be configured in this manner. For example, the separating sheet may be one that exhibits adhesion performance through heating, or may be one that does not exhibit adhesion performance regardless of the presence or absence of heating. In this case, a mechanism for arranging a separating sheet at positions between the two laminated bodies 130a and 130b and between the two laminated bodies 130a and 130c may be configured.

[0120] Further, in this embodiment, the plurality of cutout portions 210a to 210b are formed in the outer-peripheral-side ends of the second soft magnetic sheets (separating sheets 131a and 131b). Further, in this embodiment, the second soft magnetic sheet is arranged such that at least partial regions of the cutout portions 210a to 210b are located closer to the center line O side than the outer-peripheral-side ends of the two laminated bodies 130a and 130b or

130b and 130c arranged above and below the second soft magnetic sheet (separating sheet 131a, 131b) in which the cutout portions 210a to 210b are formed. Therefore, a space can be formed between the two laminated bodies 130a and 130b and between the two laminated bodies 130a and 130c. Accordingly, for example, by heating the regions above and below this space, it is possible to inhibit the insulating material formed on the sheet surfaces of the second soft magnetic sheets (separating sheets 131a and 131b) from exhibiting adhesion performance. Therefore, the separation of the laminated bodies 130a to 130c can be performed more reliably.

[0121] Further, in this embodiment, one of the plurality of first heating devices 140a to 140b is installed at a position facing one of the plurality of cutout portions 210a to 210b with a gap therebetween. Therefore, it is possible to more reliably inhibit the separating sheets 131a to 131b from exhibiting adhesion performance.

[0122] Further, in this embodiment, during the temporary adhesion, the temperature of at least a partial region of the regions located above and below the cutout portions 210a to 210b of the regions of the first electrical steel sheets is raised by 25°C or more relative to the minimum temperature of the regions of the first electrical steel sheets not located above and below the cutout portions 210a to 210b. Therefore, the adhesion strength in the former

region can be increased, while the adhesion strength in the latter region can be weakened. Further, the adhesion strength at the separating sheets 131a to 131b can be weakened. Thus, the separation of the laminated bodies 130a to 130c can be performed more reliably.

[0123] Further, in this embodiment, the plurality of cutout portions 210a to 210b include two cutout portions formed at positions sandwiching the center line 0 when viewed along the center line 0.

Therefore, the parallelism of the upper surface and the lower surface of the laminated core 500 can be improved.

[0124] Further, in this embodiment, the first heating devices 140a to 140b used during the temporary adhesion include at least two first heating devices installed at positions sandwiching the laminated bodies 130a to 130c when viewed along the center line 0. Therefore, the parallelism of the upper surface and the lower surface of the laminated core 500 can be improved.

[0125] Further, in this embodiment, the first heating devices 140a to 140b include near-infrared heaters. Therefore, the insulating material can be uniformly heated. Further, in this embodiment, the near-infrared heaters concentrate near-infrared rays linearly along the lamination direction of the laminated bodies 130a to 130c. Therefore, the heating positions of the laminated bodies 130a to

130c can be determined with high accuracy.

[0126] Further, in this embodiment, heating conditions of the first heating devices 140a to 140b are set based on the duration for which heating by the first heating devices 140a to 140b is performed, a target temperature of the laminated bodies 130a to 130c after the temporary adhesion is completed, and the temperature of the first electrical steel sheets before the heating by the first heating devices 140a to 140b is completed. Therefore, the temporary adhesion by the first heating devices 140a to 140b can be more reliably achieved. Further, automatic operation of the first heating devices 140a to 140b becomes possible.

[0127] (Second embodiment)

Next, a second embodiment is explained. This embodiment is one in which a configuration for more reliably implementing the separation of the laminated bodies 130a to 130c and the separation of the laminated bodies 130d to 130f using the separating sheets 131a to 131b and 131c to 131d is added to the first embodiment. Therefore, in the explanation of this embodiment, parts that are the same as those in the first embodiment are denoted by the same reference numerals and symbols as those in Fig. 1 to Fig. 5, and detailed explanations thereof are omitted.

[0128] Fig. 6 is a view illustrating an example of the configuration of a press apparatus 100 and a nozzle 610. The press apparatus 100 illustrated in

Fig. 6 may be the same as the press apparatus 100 illustrated in Fig. 1.

In Fig. 6, this embodiment explains, as an example, the case where the nozzle 610 is installed upstream of the press apparatus 100. The nozzle 610 supplies a volatile material, which volatilizes by heating and does not react with an insulating material by heating, onto a sheet surface of an electrical steel sheet M that has not been punched out by the press apparatus 100. In the following explanation, the volatile material that volatilizes by heating and does not react with an insulating material by heating is abbreviated as a volatile material as necessary. The volatile material may be, for example, an oil that volatilizes by heating such as processing oil, or may be another liquid. The nozzle 610 is preferably one capable of switching the supply of the volatile material on and off by an external operation. Further, the nozzle 610 may be one capable of adjusting a supply amount by an external operation. For example, switching the supply of the volatile material on and off or the like may be performed by operating a solenoid valve provided in the nozzle 610. Incidentally, the solenoid valve may be installed outside the nozzle 610.

[0129] This embodiment explains, as an example, the case where the nozzle 610 supplies the volatile material onto a region of the front surface of the

electrical steel sheet M (sheet surface on the positive direction side of the z-axis), the region including regions to be punched out as the second electrical steel sheets (separating sheets 131a to 131d). In the following explanation, of the region of the sheet surface of the electrical steel sheet M, the region onto which the volatile material is supplied is referred to as a volatile material supply target region as necessary. Further, this embodiment explains, as an example, the case where the nozzle 610 does not supply the volatile material onto regions other than the region preset as the volatile material supply target region. To achieve this as above, for example, the supply of the volatile material from the nozzle 610 may be started when the volatile material supply target region (in this embodiment, the region to be punched out as the second electrical steel sheet (separating sheets 131a to 131d)) reaches a region assumed as a supply region (injection region) of the volatile material by the nozzle 610. Further, the supply of the volatile material from the nozzle 610 may be started immediately before the volatile material supply target region reaches the region assumed as the supply region (injection region) of the volatile material by the nozzle 610. After that, the supply of the volatile material from the nozzle 610 may be stopped, for example, when the volatile material supply target region moves further downstream (to the

positive direction side of the x-axis) than the region assumed as the supply region (injection region) of the volatile material by the nozzle 610. Further, the supply of the volatile material from the nozzle 610 may be stopped immediately after the volatile material supply target region moves further downstream than the region assumed as the supply region (injection region) of the volatile material by the nozzle 610.

[0130] This embodiment explains, as an example, the case where control of the operation of the nozzle 610 as described above is implemented by the control device 200. The control device 200 may control the operation of the nozzle 610, for example, based on a conveyance speed of the electrical steel sheet M and a punching pattern.

[0131] As described above, this embodiment explains, as an example, the case where the separating material is achieved by using the separating sheets 131a to 131d and volatile materials 620a to 620h. Further, this embodiment explains, as an example, the case where a separating sheet arranging step and the separating material arranging means are implemented by using punching by the second punch 111b and the second die 121b, punching by the third punch 111c and the third die 121c, and supply of the volatile material by the nozzle 610.

[0132] Incidentally, the volatile material may be supplied onto a region of the rear surface of the

electrical steel sheet M in addition to or instead of the region of the front surface of the electrical steel sheet M. In the region of the rear surface of the electrical steel sheet M as well, the region including regions to be punched out as the second electrical steel sheets (separating sheets 131a to 131d) is set as the volatile material supply target region.

Further, instead of or in addition to the region of the sheet surface of the electrical steel sheet M including the regions to be punched out as the second electrical steel sheets (separating sheets 131a to 131d), the region of the sheet surface of the electrical steel sheet M that includes, out of the regions to be punched out as the first electrical steel sheet, the region facing the second electrical steel sheet may be set as the volatile material supply target region.

[0133] After the volatile material is supplied as described above, the temporary adhesion explained in the first embodiment is performed in a state where the volatile materials 620a to 620d adhere to at least one of two sheet surfaces of each of the second electrical steel sheets (separating sheets 131a to 131d) punched out by the third punch 111c and the third die 121c (the sixth punch 111f and the sixth die 121f) respectively. Therefore, it is possible to delay the timing at which the insulating material, which is formed on the sheet surfaces of the first

electrical steel sheets facing the sheet surfaces to which the volatile materials 620a to 620d adhere, starts to exhibit adhesion performance. Therefore, it is possible to inhibit the adhesion performance of the insulating material formed on the sheet surface of the first electrical steel sheet from being sufficiently exhibited. For example, when the insulating material contains a thermosetting resin, the timing at which a curing reaction of the thermosetting resin starts can be delayed. Accordingly, the separation of the laminated bodies 130a to 130c and the separation of the laminated bodies 130d to 130f can be achieved more easily and more reliably. Therefore, for example, when the priority is placed on reliably performing the separation of the laminated bodies 130a to 130c and the separation of the laminated bodies 130d to 130f, the configuration of this embodiment may be adopted. However, in this embodiment, additional equipment for supplying the volatile material is required. Therefore, when the priority is placed on reducing equipment costs, for example, the configuration of the first embodiment may be adopted.

[0134] (Third embodiment)

Next, a third embodiment is explained. This embodiment explains, as an example, the case where the separating material includes the volatile material without including the separating sheet. As described above, this embodiment mainly differs from

the first embodiment and the second embodiment in the configuration and process due to the difference in the separating material. Therefore, in the explanation of this embodiment, parts that are the same as those in the first embodiment and the second embodiment are denoted by the same reference numerals and symbols as those in Fig. 1 to Fig. 6, and detailed explanations thereof are omitted.

[0135] Fig. 7 is a view illustrating an example of the configuration of a press apparatus 700 and a nozzle 610.

In Fig. 7, this embodiment explains, as an example, the case where the press apparatus 700 includes an upper die 710 and a lower die 720.

[0136] This embodiment explains, as an example, the case where the upper die 710 is obtained by removing the second punch 111b and the fifth punch 111e and a configuration necessary for installing the second punch 111b and the fifth punch 111e, from the upper die 110 illustrated in Fig. 1 and Fig. 6. Further, this embodiment explains, as an example, the case where the lower die 720 is obtained by removing the second die 121b and the fifth die 121e and a configuration necessary for installing the second die 121b and the fifth die 121e, from the lower die 120 illustrated in Fig. 1 and Fig. 6.

[0137] As explained in the first embodiment, the second punch 111b and the second die 121b are used to manufacture the separating sheets 131a to 131b used

for manufacturing the rotor core. Further, the fifth punch 111e and the fifth die 121e are used to manufacture the separating sheets 131c to 131d used for manufacturing the stator core. Therefore, this embodiment explains, as an example, the case where the separating sheets are not manufactured by the press apparatus 700.

[0138] This embodiment explains, as an example, the case where control of the operation of the press apparatus 700 as described above is implemented by the control device 200. The control device 200 selects, for example, a punch to operate from among the first punch 111a, the third punch 111c, the fourth punch 111d, and the sixth punch 111f based on a conveyance speed of the electrical steel sheet M and a punching pattern, and operates the selected punch.

[0139] Further, in Fig. 7, this embodiment explains, as an example, the case where the nozzle 610 is installed upstream of the press apparatus 700, similarly to the second embodiment. The nozzle 610 supplies a volatile material, which volatilizes by heating and does not react with an insulating material by heating, onto the sheet surface of the electrical steel sheet M that has not been punched out by the press apparatus 100. The volatile material may be the one explained in the second embodiment.

[0140] This embodiment explains, as an example, the

case where the volatile material supply target region is a region of the sheet surface of the electrical steel sheet M that includes, out of the regions to be punched out as the first electrical steel sheet, regions that constitute upper surfaces of the laminated bodies 130a to 130f. In this case, the volatile material supply target region is a region of the front surface (sheet surface on the positive direction side of the z-axis) of the electrical steel sheet M. Further, similarly to the second embodiment, this embodiment explains, as an example, the case where the nozzle 610 does not supply the volatile material onto regions other than the region preset as the volatile material supply target region. The timing of starting and stopping the supply of the volatile material by the nozzle 610 may be, for example, the timing explained in the second embodiment. Further, similarly to the second embodiment, this embodiment explains, as an example, the case where control of the operation of the nozzle 610 is implemented by the control device 200. The control device 200 may control the operation of the nozzle 610, for example, based on a conveyance speed of the electrical steel sheet M and a punching pattern.

[0141] As described above, this embodiment explains, as an example, the case where the separating material is achieved by using volatile materials 730a to 730h. Further, this embodiment explains, as an example, the

case where the separating sheet arranging step and the separating material arranging means are implemented by the supply of the volatile material by the nozzle 610.

[0142] Incidentally, the volatile material supply target region may be a region of the sheet surface of the electrical steel sheet M, including regions that constitute lower surfaces of the laminated bodies 130a to 130f. In this case, a nozzle that supplies the volatile material onto a region of the rear surface of the electrical steel sheet M is installed. Further, the volatile material supply target region may be both the regions constituting the upper surfaces of the laminated bodies 130a to 130f and the regions constituting the lower surfaces of the laminated bodies 130a to 130f.

[0143] Although it is necessary to install the nozzle 610 in this embodiment, the second die 121b and the fifth die 121e, and the second die 121b and the fifth die 121e are not required. Therefore, man-hours (process time) in the press apparatus 700 can be shortened. Further, the equipment cost can be reduced. Therefore, for example, when the priority is placed on these matters, the configuration of this embodiment may be adopted.

[0144] (Examples)

Next, examples are explained. Incidentally, the present disclosure is not limited to the following examples. That is, various conditions described in

these examples are condition examples adopted for confirming the feasibility, effects, and the like of the present disclosure. Therefore, the present disclosure is not limited to the condition examples described in these examples. In addition, the present disclosure can adopt various conditions as long as the object of the present disclosure is achieved without departing from the gist of the present disclosure.

((Common items))

First, items common to the respective examples are explained.

A rotor core and a stator core of an inner-rotor type IPM motor were produced as explained in the first to third embodiments.

The specifications of the IPM motor are as follows. Incidentally, descriptions of specifications irrelevant to the present disclosure, such as operating conditions of the IPM motor, are omitted here.

Outer diameter (diameter): 220 mm

Height: 69.5 mm

Number of poles: 8 poles

Size of permanent magnet: 2 mm (W) × 5 mm (D) × 68 mm (H)

Number of permanent magnets per pole: 2

Flux barrier: None

Number of slots: 48

[0145] Soft magnetic sheets constituting the rotor

core and the stator core are as follows.

Thickness: 0.25 mm

Number of laminated sheets: 278

Steel type: Non-oriented electrical steel sheet
(manufactured by NIPPON STEEL CORPORATION, Grade:
25HX1300)

[0146] An epoxy-based or acrylic-based insulating material was applied to sheet surfaces of such a non-oriented electrical steel sheet, and thereby an insulating material, which exhibits adhesion performance through heating, was formed on the sheet surfaces of the non-oriented electrical steel sheet.

[0147] The following heating device was used as the first heating device (heating device that performs temporary adhesion).

Near-infrared heater (manufactured by HYBEC CORPORATION, Model number: HYP8NS)

Two such near-infrared heaters were prepared and arranged as schematically illustrated in Fig. 3. Temporary adhesion was performed by performing heating under heating conditions in which a temperature of a laminated body (non-oriented electrical steel sheets) rises to 120°C to 160°C in 60 seconds. At that time, a temperature difference between a non-heated portion and a heated portion was set to be 25°C or more.

[0148] The following heating device was used as the second heating device (heating device that performs permanent adhesion).

Near-infrared heater (manufactured by HYBEC CORPORATION, Model number: HYP28Ns)

Two such near-infrared heaters were prepared and arranged as schematically illustrated in Fig. 5. Permanent adhesion was performed by raising the temperature of the laminated body to 160°C to 200°C and then maintaining that temperature for 60 seconds to 1 hour. At that time, a temperature difference between a non-heated portion and a heated portion was set to be 20°C or more.

[0149] Further, whether or not temporary adhesion was performed was confirmed based on whether or not the height of the laminated body taken out from the press apparatus was a height satisfying the specifications of the IPM motor (height: 69.5 mm) described above. Further, whether or not permanent adhesion was achieved in the manufactured laminated core was confirmed by performing a test required for the IPM motor.

[0150]

((First example))

In this example, rotor cores and stator cores were manufactured by the method explained in the first embodiment. Incidentally, the method of the first embodiment is a method in which the separating sheet is used as the separating material and the volatile material is not used.

In this example, a press apparatus having functions similar to those of the press apparatus 100

illustrated in Fig. 1 was used. Based on results obtained by performing a heat transfer analysis during temporary adhesion, a separating sheet for manufacturing the rotor core and a separating sheet for manufacturing the stator core were each designed as separating sheets having functions similar to those of the separating sheet illustrated in Fig. 2D and Fig. 3. Punches and dies (a second punch, a fifth punch, a second die, and a fifth die) for manufacturing these separating sheets were manufactured. Further, punches and dies (a first punch, a third punch, a fourth punch, a sixth punch, a first die, a third die, a fourth die, and a sixth die) for manufacturing the rotor core and the stator core satisfying the specifications of the IPM motor described above were manufactured. Then, with a punching speed of 300 spm, 20 laminated bodies were each manufactured as the laminated body for the rotor core and the laminated body for the stator core by the press apparatus as explained in the first embodiment. Whether or not temporary adhesion was performed was confirmed for 20 of those laminated bodies. As a result, it was confirmed that the temporary adhesion was performed in all of the laminated bodies.

[0151] Further, using the 20 laminated bodies for the rotor core, laminated cores for the rotor core were manufactured as explained in the first embodiment. Similarly, using the 20 laminated bodies

for the stator core, laminated cores for the stator core were manufactured as explained in the first embodiment. Whether or not permanent adhesion was performed was confirmed for the laminated cores manufactured as described above. As a result, it was confirmed that the permanent adhesion was performed in all of the laminated cores.

[0152]

((Second example))

In this example, rotor cores and stator cores were manufactured by the method explained in the second embodiment. Incidentally, the method of the second embodiment is a method in which the separating sheet and the volatile material are used as the separating material.

In this example, a press apparatus and a nozzle having functions similar to those of the press apparatus 100 and the nozzle 610 illustrated in Fig. 6 were used.

The following volatile material was supplied (injected) onto a region of the surface of the non-oriented electrical steel sheet, including regions to be punched out as the separating sheet.

Press oil (manufactured by Nihon Kohsakyu Co., Ltd., Model number: G-6376FX)

With the other manufacturing conditions set the same as those in the first example, laminated cores for the rotor core and laminated cores for the stator core were each manufactured.

[0153] Whether or not temporary adhesion was performed was confirmed for the same number of laminated bodies as in the first example. As a result, it was confirmed that the temporary adhesion was performed in all of the laminated bodies. Further, whether or not temporary adhesion was performed was confirmed for the same number of laminated cores as in the first example. As a result, it was confirmed that the permanent adhesion was performed in all of the laminated cores.

[0154]

((Third example))

In this example, rotor cores and stator cores were manufactured by the method explained in the third embodiment. Incidentally, the method of the third embodiment is a method in which the volatile material is used as the separating material without using the separating sheet.

In this example, a press apparatus and a nozzle having functions similar to those of the press apparatus 700 and the nozzle 610 illustrated in Fig. 7 were used.

The same volatile material (press oil) as in the second example was supplied (injected) onto a region of the surface of the non-oriented electrical steel sheet, including the region that constitutes the upper surface of the laminated body.

[0155] Laminated cores for the rotor core and laminated cores for the stator core were each

manufactured under the same manufacturing conditions as in the first example, except that the punches and dies (the second punch, the fifth punch, the second die, and the fifth die) for manufacturing the separating sheet were not used.

[0156] Whether or not temporary adhesion was performed was confirmed for the same number of laminated bodies as in the first example. As a result, it was confirmed that the temporary adhesion was performed in all of the laminated bodies. Further, whether or not temporary adhesion was performed was confirmed for the same number of laminated cores as in the first example. As a result, it was confirmed that the permanent adhesion was performed in all of the laminated cores.

[0157] (Other embodiments)

Incidentally, the embodiments and the examples of the present disclosure explained above merely illustrate concrete examples of implementing the present disclosure, and the technical scope of the present disclosure is not to be construed in a restrictive manner by these embodiments. That is, the present disclosure may be implemented in various forms without departing from the technical spirit or main features thereof.

INDUSTRIAL APPLICABILITY

[0158] The present disclosure can be utilized for manufacturing a laminated core, for example.

CLAIMS

[Claim 1] A laminated core manufacturing method being a laminated core manufacturing method for manufacturing a laminated core for a rotary electric machine using a soft magnetic sheet as a base material, the method comprising:

a punching step of sequentially punching out first soft magnetic sheets from the base material using a die assembly;

a temporary adhesion step of heating a plurality of the first soft magnetic sheets punched out in the punching step within a lower die of the die assembly, thereby causing the plurality of first soft magnetic sheets to temporarily adhere to each other;

a separating step of separating a laminated body from a laminated body subsequent to the laminated body after the temporary adhesion step; and

a permanent adhesion step of heating the plurality of first soft magnetic sheets constituting the laminated body outside the die assembly, thereby causing the plurality of first soft magnetic sheets to permanently adhere to each other, wherein

an insulating material that exhibits adhesion performance through heating is formed on at least one of two sheet surfaces of the soft magnetic sheet,

within the lower die, the plurality of first soft magnetic sheets move downward in response to punching in the punching step while at least partial regions of outer-peripheral-side ends thereof are supported,

and

the laminated body is configured by laminating a number of the first soft magnetic sheets corresponding to a height of the one laminated core.

[Claim 2] The laminated core manufacturing method according to claim 1, further comprising:

a separating material arranging step of arranging a separating material at a position between the laminated body and the laminated body subsequent to the laminated body within the lower die before the temporary adhesion step, wherein

the separating material does not exhibit adhesion performance in the temporary adhesion step, or exhibits adhesion performance in the temporary adhesion step that is lower than adhesion performance exhibited by the insulating material in the temporary adhesion step.

[Claim 3] The laminated core manufacturing method according to claim 2, wherein

the separating material includes a separating sheet.

[Claim 4] The laminated core manufacturing method according to claim 3, wherein

the separating sheet exhibits adhesion performance through heating, and

a distance between an outer-peripheral-side end of the separating sheet and a first heating device used for heating in the temporary adhesion step is longer than a distance between an outer-peripheral-

side end of the laminated body and the first heating device.

[Claim 5] The laminated core manufacturing method according to claim 3 or 4, wherein

the separating sheet is a second soft magnetic sheet punched out from the base material by the die assembly, and

the separating material arranging step includes arranging the second soft magnetic sheet at a position between the two laminated bodies within the lower die.

[Claim 6] The laminated core manufacturing method according to claim 5, wherein

one or more cutout portions are formed in an outer-peripheral-side end of the second soft magnetic sheet, and

the separating material arranging step includes arranging the second soft magnetic sheet such that at least a partial region of the cutout portion is located closer to a center line side of the two laminated bodies than outer-peripheral-side ends of the two laminated bodies arranged above and below the second soft magnetic sheet in which the cutout portion is formed.

[Claim 7] The laminated core manufacturing method according to claim 6, wherein

there are a plurality of the cutout portions,

there are a plurality of first heating devices used for heating in the temporary adhesion step, and

one first heating device of the plurality of first heating devices is installed at a position facing one cutout portion of the plurality of cutout portions with a gap therebetween.

[Claim 8] The laminated core manufacturing method according to claim 6 or 7, wherein

in the temporary adhesion step, a temperature of at least a partial region of regions of the first soft magnetic sheets located above and below the cutout portion is raised by 25°C or more relative to a minimum temperature of the regions of the first soft magnetic sheets not located above and below the cutout portion.

[Claim 9] The laminated core manufacturing method according to any one of claims 6 to 8, wherein

there are a plurality of the cutout portions, and when viewed along a center line of the second soft magnetic sheet, the plurality of cutout portions include two cutout portions formed at positions sandwiching the center line.

[Claim 10] The laminated core manufacturing method according to any one of claims 6 to 9, wherein

the separating material further includes a volatile material that volatilizes by heating and does not react with the insulating material by heating,

the separating material arranging step includes arranging the volatile material in a region of at least one of two sheet surfaces of the soft magnetic

sheet, and

the region where the volatile material is arranged is at least one of a region including a region to be punched out as the second soft magnetic sheet and a region including, out of a region to be punched out as the first soft magnetic sheet, a region facing the second soft magnetic sheet.

[Claim 11] The laminated core manufacturing method according to claim 10, wherein

the volatile material is oil.

[Claim 12] The laminated core manufacturing method according to claim 2, wherein

the separating material includes a volatile material that volatilizes by heating and does not react with the insulating material by heating,

the separating material arranging step includes arranging the volatile material in a region of at least one of two sheet surfaces of the soft magnetic sheet, and

the region where the volatile material is arranged is a region including a region that constitutes at least one of an upper surface and a lower surface of the laminated body, out of a region to be punched out as the first soft magnetic sheet.

[Claim 13] The laminated core manufacturing method according to claim 12, wherein

the volatile material is oil.

[Claim 14] The laminated core manufacturing method according to any one of claims 1 to 13, wherein

as a first heating device used for heating in the temporary adhesion step, at least two first heating devices installed at positions sandwiching the laminated body when viewed along a center line of the laminated body are included.

[Claim 15] The laminated core manufacturing method according to any one of claims 1 to 14, wherein

a first heating device used for heating in the temporary adhesion step includes a near-infrared heater.

[Claim 16] The laminated core manufacturing method according to claim 15, wherein

the near-infrared heater concentrates near-infrared rays linearly along a lamination direction of the laminated body.

[Claim 17] The laminated core manufacturing method according to any one of claims 1 to 16, further comprising:

a heating condition setting step of setting heating conditions in the temporary adhesion step based on a duration for which heating in the temporary adhesion step is performed, a target temperature of the laminated body after the temporary adhesion is completed, and a temperature of the first soft magnetic before heating in the temporary adhesion step is completed.

[Claim 18] A laminated core manufacturing apparatus being a laminated core manufacturing apparatus that manufactures a laminated core for a rotary electric

machine using a soft magnetic sheet as a base material, the apparatus comprising:

a die assembly for sequentially punching out first soft magnetic sheets from the base material;

a first heating device for performing local heating to cause a plurality of the first soft magnetic sheets punched out by the die assembly to temporarily adhere to each other within a lower die of the die assembly;

a separating means for separating a laminated body from a laminated body subsequent to the laminated body after heating by the first heating device is performed; and

a second heating device for performing heating to cause the plurality of first soft magnetic sheets constituting the laminated body to permanently adhere to each other outside the die assembly, wherein

an insulating material that exhibits adhesion performance through heating is formed on at least one of two sheet surfaces of the soft magnetic sheet,

within the lower die, the plurality of first soft magnetic sheets move downward in response to punching by the die assembly while at least partial regions of outer-peripheral-side ends thereof are supported, and

the laminated body is configured by laminating a number of the first soft magnetic sheets corresponding to a height of the one laminated core.

[Claim 19] The laminated core manufacturing apparatus according to claim 18, further comprising:

a separating material arranging means for arranging a separating material at a position between the laminated body and the laminated body subsequent to the laminated body within the lower die before heating by the first heating device is performed, wherein

the separating material does not exhibit adhesion performance through local heating by the first heating device, or exhibits adhesion performance through local heating by the first heating device that is lower than adhesion performance exhibited by the insulating material through heating by the first heating device.

[Claim 20] The laminated core manufacturing apparatus according to claim 19, wherein

the separating material includes a separating sheet.

[Claim 21] The laminated core manufacturing apparatus according to claim 20, wherein

the separating sheet exhibits adhesion performance through heating, and

a distance between an outer-peripheral-side end of the separating sheet and the first heating device is longer than a distance between an outer-peripheral-side end of the laminated body and the first heating device.

[Claim 22] The laminated core manufacturing apparatus according to claim 20 or 21, wherein

the separating sheet is a second soft magnetic

sheet punched out from the base material by the die assembly, and

the separating material arranging means arranges the second soft magnetic sheet at a position between the two laminated bodies within the lower die.

[Claim 23] The laminated core manufacturing apparatus according to claim 22, wherein

one or more cutout portions are formed in an outer-peripheral-side end of the second soft magnetic sheet, and

the separating material arranging means arranges the second soft magnetic sheet such that at least a partial region of the cutout portion is located closer to a center line side of the two laminated bodies than outer-peripheral-side ends of the two laminated bodies arranged above and below the second soft magnetic sheet in which the cutout portion is formed.

[Claim 24] The laminated core manufacturing apparatus according to claim 23, wherein

there are a plurality of first heating devices as the first heating device,

there are a plurality of the cutout portions, and one first heating device of the plurality of first heating devices is installed at a position facing one cutout portion of the plurality of cutout portions with a gap therebetween.

[Claim 25] The laminated core manufacturing apparatus according to claim 23 or 24, wherein

there are a plurality of the cutout portions, and when viewed along a center line of the second soft magnetic sheet, the plurality of cutout portions include two cutout portions formed at positions sandwiching the center line.

[Claim 26] The laminated core manufacturing apparatus according to any one of claims 22 to 25, wherein

the separating material further includes a volatile material that volatilizes by heating and does not react with the insulating material by heating,

the separating material arranging means arranges the volatile material in a region of at least one of two sheet surfaces of the soft magnetic sheet, and

the region where the volatile material is arranged is at least one of a region including a region to be punched out as the second soft magnetic sheet and a region including, out of a region to be punched out as the first soft magnetic sheet, a region facing the second soft magnetic sheet.

[Claim 27] The laminated core manufacturing apparatus according to claim 26, wherein

the volatile material is oil.

[Claim 28] The laminated core manufacturing apparatus according to claim 19, wherein

the separating material includes a volatile material that volatilizes by heating and does not react with the insulating material by heating,

the separating material arranging means arranges the volatile material in a region of at least one of two sheet surfaces of the soft magnetic sheet, and

the region where the volatile material is arranged is a region including a region that constitutes at least one of an upper surface and a lower surface of the laminated body, out of a region to be punched out as the first soft magnetic sheet.

[Claim 29] The laminated core manufacturing apparatus according to claim 28, wherein

the volatile material is oil.

[Claim 30] The laminated core manufacturing apparatus according to any one of claims 18 to 29, further comprising:

as the first heating device, at least two first heating devices installed at positions sandwiching the laminated body when viewed along a center line of the laminated body.

[Claim 31] The laminated core manufacturing apparatus according to any one of claims 18 to 30, wherein

the first heating device includes a near-infrared heater.

[Claim 32] The laminated core manufacturing apparatus according to claim 31, wherein

the near-infrared heater concentrates near-infrared rays linearly along a lamination direction of the laminated body.

[Claim 33] The laminated core manufacturing

apparatus according to any one of claims 18 to 32, further comprising:

a heating condition setting means for setting heating conditions in the first heating device based on a speed at which the first soft magnetic sheet is moved downward within the lower die, a target temperature of the laminated body after the temporary adhesion is completed, and a temperature of the first soft magnetic in a state where heating by the first heating device is not performed.