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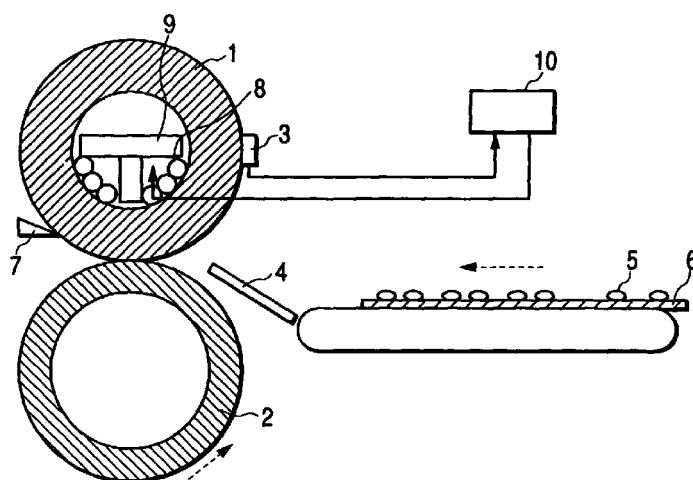
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(54) **Induction heat fixing apparatus and image forming method**

(57) An induction heat fixing apparatus is disclosed which has a rotating member, a pressure member coming in pressure contact with the rotating member to form a nip between the pressure member and the rotating member in such a way that a transfer medium on which a toner image has been formed is passable through the nip, and an electric-current applying means for applying an alternating current to the exciting coil to cause the rotating member to generate heat by induction heating

by means of an eddy current generated in the rotating member. The pressure member is a pressure roller composed of a non-elastic material mandrel, a foamed material layer provided on the non-elastic material mandrel, and a release layer provided on the foamed material layer. Also disclosed is an image-forming method using the induction heat fixing apparatus as a fixing means in the step of fixing a toner image.

FIG. 1



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Description**BACKGROUND OF THE INVENTION**

5 Field of the Invention

[0001] This invention relates to an induction heat fixing apparatus used in image-forming apparatus such as copying machines, printers and facsimile machines of electrophotographic systems, and an image-forming method making use of such a fixing apparatus.

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Related Background Art

[0002] In copying machines, printers and facsimile machines and so forth of electrophotographic systems, various fixing systems are conventionally proposed and put into practice as apparatus for fixing unfixed toner images by heating (hereinafter "heat fixing apparatus") to form permanently fixed images on transfer medium surfaces.

[0003] For example, heat fixing apparatus of a film heating system may include, as disclosed in Japanese Patent Application Laid-open No. 63-313182, apparatus in which a heat-resistant film (fixing film) is inserted between a ceramic heater as a heat-generating source (a heating element) and a pressure roller as a pressure member to form a fixing nip, and as a heating target material a transfer medium having been made to hold thereon an unfixed toner image is guided in between the film and the pressure roller at the fixing nip and is interposedly transported through the fixing nip together with the film so that the heat of the ceramic heater, generated by electrification to a resistance heating element, is imparted to the transfer medium through the film to heat it to fix the toner image by heating.

[0004] However, in conventional apparatus of such a film heating system making use of the ceramic heater as a heat source, there is a problem that energy loss is too great to afford any effective utilization of energy, since the heat must be transmitted to the film.

[0005] There is a further problem that, in view of durability of film, such a system is not suited for its application in high-speed machines (paper output of 50 sheets or more per minute).

[0006] Meanwhile, as disclosed in Japanese Patent Application Laid-open No. 59-33477, an induction heat fixing apparatus is proposed in which high-frequency induction is utilized as a heating source to improve electricity-heat conversion efficiency so as to shorten preheating time. This induction heat fixing apparatus comprises a hollow fixing roller formed of a metallic conductor, and an exciting coil disposed in a concentric circle in the interior of the roller, where a high-frequency electric current is flowed through this exciting coil to generate a high-frequency magnetic field to cause induction eddy current in the fixing roller so that the fixing roller itself can generate Joule heat by the skin effect of the fixing roller itself. However, in the heating system utilizing such high-frequency induction, any optimum fixing-roller construction and toner formulation have not been made clear in the prior art.

[0007] As a heat fixing apparatus, a heat roller system is available. This is a system in which a halogen lamp (halogen heater) is built in as a heat source and a fixing roller (heat roller) as a rotating member for heating and temperature-controlling the roller at given temperatures by heat generation of the halogen lamp and a pressure roller as a pressure member are brought into pressure contact to form a fixing nip, where the rollers in pair are rotated, and as a heating target material a transfer medium having been made to hold thereon an unfixed toner image is guided to the fixing nip and is interposedly transported therethrough so that the transfer medium is heated at the fixing nip by the heat of the fixing roller to fix the toner image by heating.

[0008] However, in conventional apparatus of such a heat roller system making use of the halogen lamp as a heat source, there is a problem that energy loss is too great to afford any effective utilization of energy, since the heat must be transmitted to the apparatus of a heat roller system.

[0009] In particular, in the heat fixing apparatus of a heat roller system constituted of a heating means such as the halogen lamp, after a power source has been put on, it takes a relatively long time until the temperature of fixing roller reaches a given temperature suited for fixing (hereinafter "preheating time"). This is because the roller is heated from its inner side and hence it takes a time until the temperature of roller surface rises. During that time, users can not use the copying machine and must wait for a long time. There is such a problem.

[0010] A method is also possible in which electric power is applied to the fixing roller in a large quantity in order to improve user's handling readiness, but this results in a large power consumption in the fixing apparatus to cause a problem of going against energy saving.

[0011] Accordingly, some studies are made on the construction of a pressure roller and a fixing roller.

[0012] The pressure roller includes two types of;

- (1) what is called "foamed pressure roller", comprising a mandrel made of aluminum or iron and a foamed material layer provided thereon and further covered with a tube of PFA or PTFE; and

(2) what is called "solid pressure roller", comprising the same mandrel as the above and an elastic rubber layer such as a silicone rubber or fluorine-containing rubber layer provided thereon and further covered with a tube of PFA or PTFE.

[0013] The foamed pressure roller has a good releasability and the roller itself has a smaller heat capacity and lower thermal conductivity than the solid pressure roller detailed below. Hence the heat imparted from the surface of the pressure roller may sparingly conduct to the interior, so that the temperature at its surface portion rises quickly and hence the surface layer can quickly be heated up. This can make the preheating time shorter and also allows to gain nip width.

[0014] As for the solid pressure roller, it has a good releasability and its rubber layer has a heat capacity. Correspondingly to that heat capacity, it makes temperature drop of a fixing roller smaller than the above foamed pressure roller when, e.g., the fixing roller is heated to 190°C and thereafter paper feed is started. Also, since rubbers can be made harder than foams, a stable pressure can be applied to the fixing roller at any time.

[0015] However, the solid pressure roller as a pressure roller has a poor durability because the rubber or the like elastic layer is exposed to a high temperature of 180 to 200°C when used. Moreover, since the rubber layer has a heat capacity, there is a problem that the time for which the fixing roller is heated to the service temperature of 180 to 200°C, i.e., what is called wait-up time, is required in excess by the one for heating the pressure roller, resulting in a longer time than the foamed pressure roller. It, however, has not been made clear what pressure roller should preferably be used in the above induction heat type fixing apparatus.

[0016] Thus, in the above induction heat type fixing apparatus, in order to make the most of the advantage that the preheating time can be shortened, it is preferable to use as a pressure roller the foamed pressure roller, which can more quickly be heated up than the solid pressure roller. The foamed pressure roller, however, has a small heat capacity as stated above, and hence has a problem that the fixing roller may undergo a great temperature drop to have a poor fixing performance. It may also be possible to use the combination of the induction heat fixing apparatus with the foamed pressure roller. However, a fixing apparatus having a higher performance can be provided if the improvement in fixing performance can be achieved.

[0017] Meanwhile, the fixing roller includes two types of;

(1) what is called "hard fixing roller", comprising a mandrel made of aluminum or iron, coated thereon with a fluorine-containing resin such as PFA (copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether) or PTFE (polytetrafluoroethylene); and

(2) what is called "soft fixing roller", comprising the same mandrel as the above and an elastic rubber layer such as a silicone rubber or fluorine-containing rubber layer superposed thereon.

[0018] The hard fixing roller has a good releasability and hence has good anti-offset properties and also characterized by having good heat resistance and durability.

[0019] The soft fixing roller has an elasticity, and hence does not excessively crush visible images (toner images being fixed) on transfer mediums and does not disorder the images, promising high-quality fixed images. Moreover, the roller surface undergoes a delicate elastic deformation at the nip, and hence its area of contact with visible images on transfer mediums can be made larger, promising a good fixing performance. This roller has such characteristic features.

[0020] However, the hard fixing roller as a fixing roller has no elasticity, and hence has a problem of a poor fixing performance because of a small area of contact with visible images. The soft fixing roller has a poor durability because the rubber elastic layer is exposed to a high temperature of 180 to 200°C when used. Moreover, since the rubber layer has a heat capacity, there is a problem that the time for which the fixing roller is heated to the service temperature of 180 to 200°C, i.e., what is called wait-up time, is longer than the hard pressure roller. It, however, has not been made clear what fixing roller should preferably be used in the above induction heat type fixing apparatus.

[0021] Thus, in the above induction heat type fixing apparatus, in order to make the most of the advantage that the preheating time can be shortened, it is preferable to use as a fixing roller the hard fixing roller, which has a lower heat capacity than the soft fixing roller. In that case, however, as stated previously there is the problem of a poor fixing performance because of a small area of contact with visible images. It may also be possible to use only the combination of the induction heat type fixing apparatus with the hard fixing roller. However, a fixing apparatus having a higher performance can be provided if the improvement in fixing performance can be achieved.

[0022] In recent years, in an increasing social demand for reducing the quantity of office work paper to be discarded and for resource saving, reclaimed paper produced by reuse of used paper has been put into use as copying and printing paper. Such reclaimed paper, however, is commonly produced with addition of a filler composed chiefly of talc or calcium carbonate in a large quantity in order to improve the whiteness that is inferior to non-reclaimed paper. The filler is added in an amount as much as 10 to 20% as ash of paper in the case of reclaimed paper, while it is in an amount of about 5% in the case of non-reclaimed paper. Where the reclaimed paper is used in a copying machine or a printer

over a long period of time, the filler may partly separate from paper to adhere little by little to the fixing roller or pressure roller, and also the toner may accumulate at the part to which the filler has adhered, tending to cause before long the adhesion of toner from the fixing roller or pressure roller to fixed-image surfaces and adhesion of toner to the back of paper. With regard to such fixed-image contamination, too, it has become necessary to take it into consideration in respect of toner formulation.

SUMMARY OF THE INVENTION

[0023] An object of the present invention is to provide an induction heat fixing apparatus having solved the problems discussed above, and an image-forming method making use of such a fixing apparatus.

[0024] Another object of the present invention is to provide an induction heat fixing apparatus which can shorten preheating time and also has a superior image fixing performance, and an image-forming method making use of such a fixing apparatus.

[0025] Still another object of the present invention is to provide an induction heat fixing apparatus which can be kept from contamination of fixed images even when reclaimed paper is used, and an image-forming method making use of such a fixing apparatus.

[0026] To achieve the above objects, the present invention provides an induction heat fixing apparatus comprising;

a rotating member;

an exciting coil provided in the interior or on the exterior of the rotating member;

a pressure member coming in pressure contact with the rotating member to form a nip between the pressure member and the rotating member in such a way that a transfer medium on which a toner image has been formed is passable through the nip; and

an electric-current applying means for applying an alternating current to the exciting coil to cause the rotating member to generate heat by induction heating by means of an eddy current generated in the rotating member;

wherein the pressure member is a pressure roller comprising a non-elastic material mandrel, a foamed material layer provided on the non-elastic material mandrel, and a release layer provided on the foamed material layer.

[0027] The present invention also provides an image-forming method comprising the steps of;

developing an electrostatic latent image formed on an electrostatic latent image bearing member, by the use of a toner to form a toner image;

transferring the toner image to a transfer medium; and

fixing the toner image on the transfer medium, to the transfer medium by a fixing means;

the fixing means is an induction heat fixing apparatus comprising;

a rotating member;

an exciting coil provided in the interior or on the exterior of the rotating member;

a pressure member coming in pressure contact with the rotating member to form a nip between the pressure member and the rotating member in such a way that a transfer medium on which a toner image has been formed is passable through the nip; and

an electric-current applying means for applying an alternating current to the exciting coil to cause the rotating member to generate heat by induction heating by means of an eddy current generated in the rotating member;

wherein the pressure member is a pressure roller comprising a non-elastic material mandrel, a foamed material layer provided on the non-elastic material mandrel, and a release layer provided on the foamed material layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1 cross-sectionally schematically illustrates the construction of an induction heat fixing apparatus according to an embodiment of the present invention.

Fig. 2 cross-sectionally illustrates a foamed pressure roller used in the induction heat fixing apparatus, according to an embodiment of the present invention.

Fig. 3 is a graph showing a comparison in preheating time between a foamed pressure roller according to the present invention and a solid pressure roller as a control, being made in Example 2.

Fig. 4 cross-sectionally illustrates a hard fixing roller used in the induction heat fixing apparatus, according to an embodiment of the present invention.

Fig. 5 is a graph showing a comparison in preheating time between a hard fixing roller and a soft fixing roller as a

control, being made in Example.

Fig. 6 is a graph showing the relationship between main-peak molecular weight of binder resins for toner and image density after leaving in a high-temperature and high-humidity environment.

Fig. 7 is a graph showing the relationship between main-peak molecular weight of binder resins for toner and fixable minimum temperature.

Fig. 8 is a graph showing the relationship between acid value of binder resins for toner and contamination of fixing members.

Fig. 9 is a graph showing the relationship between acid value of binder resins for toner and average image density in a high-temperature and high-humidity environment.

Fig. 10 is a graph showing the relationship between proportion of component with 500,000 or more molecular weight and contamination of fixing members.

Fig. 11 is a graph showing the relationship between proportion of component with 500,000 or more molecular weight and fixable minimum temperature.

Fig. 12 is a graph showing a comparison of differences in fixing performance at leading end portions and rear end portions of A3-size paper, when in Example 4 an induction type heat fixing apparatus of the present invention and a control, halogen lamp fixing apparatus are used.

Fig. 13 illustrates a solid pressure roller used as a control in Example 2.

Fig. 14 illustrates a soft fixing roller used as a control in Example 2.

Fig. 15 schematically illustrates the construction of an image-forming apparatus which can practice the image-forming method of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] The present inventor made extensive studies on the above problems in induction heat fixing apparatus employing an electric-current applying means for applying an alternating current to an exciting coil to cause a rotating member to generate heat by electromagnetic induction heating by means of an eddy current generated in the rotating member. As the result, they have discovered the following: A pressure roller comprising a non-elastic material mandrel, a foamed material layer provided on the non-elastic material mandrel and a release layer provided on the foamed material layer may be used as a pressure member. This effects the following (i) and (ii).

(i) The pressure member (pressure roller) having a foamed material layer has a small thermal conductivity and hence the heat received from the surface side of the pressure roller may conduct to the interior of the pressure roller with difficulty, so that the surface portion of the pressure roller can be heated up with ease and the preheating time can be shortened. This brings about an effect of effective utilization of the feature inherent in induction heat fixing apparatus that the preheating time of a heating member can be shortened. Although on the other hand the pressure roller, having a foamed material layer has a small heat capacity, has a technical problem that the heat tends to be taken away to transfer paper at the time of fixing to tend to cause a drop of surface temperature of the pressure roller, the feature inherent in induction heat fixing apparatus that the surface temperature of the heating member can be kept constant at the time of fixing makes it possible substantially not to cause the technical problem the pressure roller having a foamed material layer has.

(ii) On account of the release layer, the pressure roller surface may hardly be contaminated and hence, even when reclaimed paper to which a filler is added in a large quantity is used as a transfer medium, the filler may hardly adhere to the pressure roller surface, so that the adhesion of toner that is caused by the adhesion of filler can be kept from occurring and hence any contamination of fixed image may hardly occur.

[0030] Accordingly, a pressure roller made up by combination of the above (i) and (ii) may be used in the induction heat fixing apparatus. This brings about an effect that, making the most of the feature inherent in induction heat fixing apparatus that the preheating time of a heating member can be shortened, good fixed images can be formed which are free of any difference in fixing performance between leading end portions and rear end portions of fixed images in the direction of paper feed, and also fixed images can be kept from contamination even when reclaimed paper is used, and many-sheet running performance and high-speed fixing performance can be coped with.

[0031] Based on such discovery, they have accomplished the present invention.

[0032] They have further discovered that, when the rotating member serving as a fixing member comprises a hollow mandrel and a release layer containing fluorine-containing resin, provided on the mandrel, the fixing member can have a small heat capacity, the preheating time can be shortened and also any contamination of the fixing member surface may hardly occur, and that, especially when it is used in combination with the above pressure member, the adhesion of toner from the pressure member to the fixing member may hardly occur, so that fixed images can be kept from contamination even after running on a larger number of sheets.

[0033] In addition, as a toner used to form the toner image to be fixed by the induction heat fixing apparatus having the construction as described above, a toner may be used which has, in its molecular weight distribution as measured by gel permeation chromatography (GPC) of tetrahydrofuran(THF)-soluble matter, a main peak in the region of molecular weight of from 3,000 to 20,000 and contains a component with a molecular weight of 500,000 or more in a proportion of from 3 to 25%. Use of such a toner is preferable because it has a superior low-temperature fixing performance, can provide a broad fixable-temperature range and also may hardly cause any fixed-image contamination due to the contamination of pressure member by toner.

[0034] In particular, the above toner may contain a polyester resin as a binder resin and the polyester resin may have an acid value of from 2 to 50 mg • KOH/g. This is preferable because such a toner may hardly cause any fixed-image contamination and also has a superior developing performance even in a high-humidity environment, so that images with a high image density can be obtained.

[0035] The induction heat fixing apparatus having the above construction is adaptable to an apparatus which performs high-speed fixing at a fixing speed of 200 mm/sec.

[0036] An embodiment of the present invention will be described below in detail with reference to the accompanying drawings.

(1) Induction Heat Fixing Apparatus

[0037] Fig. 1 cross-sectionally schematically illustrates the construction of an induction heat fixing apparatus according to an embodiment of the present invention.

[0038] A rotating member fixing roller 1 and a pressure member pressure roller 2 are so constructed that they are rotatably supported and only the fixing roller 1 is driven. The pressure roller 2 is so disposed as to come in pressure contact with the surface of the fixing roller and be follow-up rotated by the frictional force acting at their pressure contact zone (a nip).

[0039] The pressure member pressure roller 2 in the fixing apparatus of the present invention is pressed against the fixing roller 1 in the direction of its rotational axis by a mechanism making use of a spring (not shown). The pressure roller 2 is set at a load of, e.g., about 40 kg weight, where the pressure contact zone comes to have a width (nip width) of about 7 mm. The nip width may optionally be changed by changing the load.

[0040] An embodiment of the pressure roller 2 in the heat fixing apparatus of the present invention is cross-sectionally illustrated in Fig. 2.

[0041] The pressure roller 2 is a roller comprising a non-elastic material mandrel 21, a foamed material layer 22 provided thereon in peripheral contact, and a release layer 23 further provided on the foamed material layer.

[0042] As materials for the non-elastic material mandrel, usable are, e.g., metallic materials such as iron, aluminum and stainless steel.

[0043] Materials for the foamed material layer may include, e.g., silicone foamed rubbers.

[0044] The release layer may include, e.g., tube layers or coating layers of fluorine-containing resins such as PFA (copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether), PTFE (polytetrafluoroethylene), FEP (copolymer of tetrafluoroethylene with propylene fluoride) and mixtures of any of these. A tube layer of PFA is preferred.

[0045] The pressure roller 2 may specifically include a roller comprising a solid mandrel 21 of 20 mm outer diameter, made of iron, a foamed material layer 22 of 5 mm thick, provided on the periphery of the mandrel, and as a release layer a tube layer 23 formed of PTFE in 10 to 50 μ m thick or PFA in 10 to 50 μ m thick provided in order to improve surface releasability; and made up to have an outer diameter of 30 mm. This roller is hereinafter called "foamed roller 2". The tube layer of PTFE or PFA is preferable because it has a higher durability and also a better releasability than coating layers and hence is suited for the release layer of the pressure roller.

[0046] The foamed material layer 22 may preferably have a layer thickness of from 1 to 7 mm, and more preferably from 3 to 5 mm. If it is in a thickness smaller than 1 mm, the fixing nip between the fixing roller and the pressure roller may be formed with difficulty, resulting in no sufficient fixing performance of the toner. If on the other hand it is in a thickness larger than 7 mm, a great force may be applied between the foamed material layer and the mandrel when the roller is rotated, to tend to cause a problem of separation of the foam layer from the mandrel.

[0047] Through holes may also optionally be provided in the part of the foamed material layer 22 in parallel to the mandrel so that the pressure roller can have a much lower heat capacity.

[0048] A temperature sensor 3 is disposed in touch with the surface of the fixing roller 1. Surface temperature of the fixing roller 1 is automatically so controlled as to be kept at a constant temperature by increasing or decreasing power supply to an exciting coil 8 in accordance with detected signals sent from the temperature sensor 3.

[0049] A transfer guide 4 is disposed at a position where a transfer medium 6 transported while holding unfixed images 5 thereon is guided to the nip formed between the fixing roller 1 and the pressure roller 2.

[0050] A separation claw 7 is disposed in touch with the surface of the fixing roller 1 in order to separate the transfer medium 6 forcibly, when the transfer medium 6 is unwantedly clung to the fixing roller 1 after it has passed the nip, to

prevent jam.

[0051] The exciting coil 8 is connected to a high-frequency converter 10, and a high-frequency power of 10 to 2,000 kW is supplied. Accordingly, several fine strands made into litz wires (Lietzendraft wires) are used. Taking account of a case of heat conduction to winding wires, a heat-resistant material may preferably be used in its cover.

[0052] As a magnetic-material core 9, a core having a high permeability and a low loss may preferably be used. When an alloy such as Permalloy is used as the magnetic-material core 9, eddy current loss in the core may greatly occur because of high-frequency power. Accordingly, it may be formed in a laminated structure. The core is used in order to make the magnetic circuit more efficient and to effect magnetic shielding. This magnetic circuit portion of the coil and core may be an empty core when any means for enabling sufficient magnetic shielding is available.

[0053] In the embodiment shown in Fig. 1, the exciting coil is disposed in the interior of the fixing roller. Alternatively, where there is an ample space, the coil may be disposed outside the roller in such a way that it is set along the roller periphery. In such a case, compared with the case where the coil is provided inside the roller, the coil can be kept from undergoing temperature rise. Where the coil can be kept from undergoing temperature rise, the electric power applied to the coil can effectively be converted into electric current. This is effective also from the viewpoint of lowering the electric power necessary for the fixing apparatus.

[0054] The fixing roller 1 may include, e.g., a hard roller comprising a hollow mandrel and a release layer formed of PFA or the like, provided on the mandrel in order to improve surface releasability. Incidentally, what is meant by the hard roller in the present invention is a roller which comprises a mandrel and, provided thereon directly or via an adhesive layer, a release layer formed of a resin, and in which the total thickness of layers formed on the mandrel is 100 μm or smaller.

[0055] The mandrel of the fixing roller may preferably be made of iron, having a high permeability. This is because a high-frequency magnetic field generated by high-frequency electric current flowing through the exciting coil disposed inside or outside the fixing roller is made to enter the mandrel to generate the eddy current in the mandrel. Also, the mandrel may preferably have a wall thickness as small as possible because the fixing roller can have a smaller heat capacity and the preheating time can be shortened. However, it must have a strength to a certain extent so that the fixing roller does not warp when the pressure roller is rotated in pressure contact with it. To keep the strength of the fixing roller, the mandrel may have a wall thickness which is larger when the roller has a larger diameter and is smaller when the roller has a smaller diameter. For example, the mandrel may preferably have a wall thickness of from 0.3 to 1.0 mm, and more preferably from 0.5 to 0.8 mm, when the roller has an outer diameter of from 32 to 35 mm.

[0056] If the mandrel has a wall thickness smaller than 0.3 mm, the part at which the nip has been formed may deform permanently when the fixing roller and the pressure roller are left overnight as they stand in pressure contact. If on the other hand it has a wall thickness larger than 1.0 mm, a less significance may result on the induction heat system that can shorten the preheating time.

[0057] A preferred embodiment of the fixing roller in the heat fixing apparatus of the present invention is cross-sectionally illustrated in Fig. 4.

[0058] In Fig. 4, the fixing roller 1 is a roller comprising a hollow mandrel 11 and a release layer 12 provided thereon in peripheral contact.

[0059] In the present invention, as materials for the release layer 12 of the fixing roller 1, preferably usable are fluorine-containing resins such as PFA (copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether), PTFE (polytetrafluoroethylene) and FEP (copolymer of tetrafluoroethylene with propylene fluoride). It may preferably be a release layer formed of a fluorine-containing resin which is PFA or PTFE, and particularly preferably be a release layer formed of a fluorine-containing resin which is a mixture of PFA and PTFE. The release layer may be formed on the mandrel via an adhesive layer for the purpose of improving its adhesion to the mandrel.

[0060] In general, in a transfer step where a visible image in the course of image formation is electrostatically transferred to a transfer medium, transfer electric charges having a polarity opposite to that of the toner held on the transfer medium may leak to the release layer at the fixing roller surface, whereupon an electrostatic attraction acting between the transfer medium and the toner may lower, so that the toner may adhere to the fixing roller side to tend to contaminate the fixing roller. Such contamination of the fixing roller can be prevented by making the fixing roller have a higher breakdown strength. As an effective method therefor, a method is available in which a mixture of PTFE with PFA is used as the release layer.

[0061] The PTFE has superior non-stickiness and low-frictional properties and have a high continuous-service heat resistance temperature. Accordingly, it is often used as a material for surface release layers. The PTFE, however, has so high a melt viscosity as to cause pinholes in its film at the time of baking. On the other hand, the PFA has a lower melting point than the PTFE, and also has a low melt viscosity. Hence, the mixture of PTFE with PFA can keep the pinholes from occurring in film at the time of baking. As the result, the film can be made to have a higher breakdown strength, and the fixing roller can more effectively be kept from contamination.

[0062] For the reasons stated above, it is preferable to use the release layer formed of the fluorine-containing resin which is a mixture of PFA and PTFE.

[0063] In the present invention, as the mixture of PFA and PTFE, a mixture is preferred in which the mixing proportion of the PFA to the PTFE is from 30 to 95% by weight.

[0064] The fixing roller 1 may specifically include a hard roller comprising, as shown in Fig. 4, a hollow mandrel 11 of 32 mm outer diameter and 0.3 mm wall thickness, made of iron, and a release layer 12 of 20 μm thick, formed of PFA. The release layer may preferably have a layer thickness of from 10 to 100 μm , and more preferably from 20 to 50 μm . If it is in a layer thickness smaller than 10 μm , the fixing roller may come to have a poor durability when paper is continuously fed and the release layer becomes abraded. If on the other hand it is in a layer thickness larger than 100 μm , the heat conduction from the mandrel up to the release layer surface may be too poor to ensure the fixing performance of the toner.

(2) Toner

[0065] The toner used in the present invention contains a binder resin and a colorant, and more preferably in addition thereto a charge control agent and a wax.

[0066] The binder resin used in the toner in the present invention may include vinyl type copolymers such as styrene resins, and polyester resins. In particular, it is preferable to use polyester resins.

[0067] The charge control agent may include, as negative charge control agents, metal complex salts of monoazo dyes, metal complex salts of hydroxycarboxylic acid, dicarboxylic acid, aromatic diols or the like, and resins containing acid components. It may also include, as positive charge control agents, nigrosine dyes, azine dyes, triphenylmethane dyes or pigments, quaternary ammonium salts, and polymers having a quaternary ammonium salt in the side chain.

[0068] The wax used in the present invention is used in order to improve releasability of the toner to a fixing member itself such as the fixing roller and to prevent offset, and may include, e.g., low-molecular weight polyethylene, low-molecular weight polypropylene, polyolefin copolymers, and polyolefin waxes.

[0069] In the present invention, the toner may preferably have, in its molecular weight distribution as measured by gel permeation chromatography (GPC) of tetrahydrofuran (THF)-soluble matter, a main peak in the region of molecular weight of from 3,000 to 20,000 and contains a component with a molecular weight of 500,000 or more in a proportion of from 3 to 25%.

[0070] If the toner has no main peak in the region of molecular weight of from 3,000 to 20,000 in its molecular weight distribution as measured by GPC of THF-soluble matter but has a main peak in the region of molecular weight less than 3,000, it may have a low developing performance in a high-humidity environment, and tends to cause a decrease in image density especially after leaving in the high-humidity environment, and also have a poor low-temperature fixing performance. Here, what is meant by poor low-temperature fixing performance is that fixable temperature is high, and consequently that fixable minimum temperature is high.

[0071] If the toner has no main peak in the region of molecular weight of from 3,000 to 20,000 and has a main peak in a higher molecular-weight region than 20,000, it may have a low-temperature fixing performance.

[0072] If, in the molecular weight distribution as measured by GPC of THF-soluble matter, the toner also contains the component with a molecular weight of 500,000 or more in a proportion smaller than 3%, the filler in transfer paper may adhere to the fixing member surface as a result of many-sheet running and concurrently therewith the toner tends to accumulate there, tending to cause image contamination by toner.

[0073] If the toner contains the component with a molecular weight of 500,000 or more in a proportion larger than 25%, it may have a low-temperature fixing performance.

[0074] In the present invention, the THF-soluble matter of the toner is a toner component soluble in THF. The molecular weight can be measured by GPC under conditions shown below. In the present invention, molecular weights of 1,000 or more are measured.

[0075] Columns are stabilized in a heat chamber of 40°C. To the columns kept at this temperature, THF as a solvent is flowed at a flow rate of one (1) ml per minute, and about 100 μl of THF sample solution is injected therein to make measurement. In measuring the molecular weight of the sample, the molecular weight distribution ascribed to the sample is calculated from the relationship between the logarithmic value and count number of a calibration curve prepared using several kinds of monodisperse polystyrene standard samples. As the standard polystyrene samples used for the preparation of the calibration curve, it is suitable to use, e.g., samples with molecular weights of from 100 to 10,000,000, which are available from Toso Co., Ltd. or Showa Denko K.K., and to use at least about 10 standard polystyrene samples. An RI (refractive index) detector is used as a detector. Columns should be used in combination of a plurality of commercially available polystyrene gel columns. For example, they may preferably comprise a combination of Shodex GPC KF-801, KF-802, KF-803, KF-804, KF-805, KF-806, KF-807 and KF-800P, available from Showa Denko K.K.; or a combination of TSKgel G1000H(H_{XL}), G2000H(H_{XL}), G3000H(H_{XL}), G4000H(H_{XL}), G5000H(H_{XL}), G6000H(H_{XL}), G7000H(H_{XL}) and TSK guard column, available from Toso Co., Ltd.

[0076] In Examples given layer, in the above method of measurement, two connections of GMH-HT 30 cm (available from Toso Co. Ltd.) are used, and measurement is made at a temperature of 135°C and at a flow rate of 1.0

ml/minute, using an apparatus GPC-150C (manufactured by Waters Co.)

[0077] From the GPC molecular weight distribution obtained by the above method, a proportion of integral value of the content of the component with a molecular weight of 500,000 or more to integral value of the content of the component with a molecular weight of 1,000 or more may be calculated to obtain the content of the component with a molecular weight of 500,000 or more.

[0078] The sample is prepared in the following way.

[0079] The sample is put in THF, and is allowed to stand for few hours, followed by thorough shaking (until any agglomerates of the sample disappear), which is further allowed to stand for at least 12 hours. In that course, it is so allowed to stand in the THF for at least 24 hours. Thereafter, the solution having been passed through a sample-treating filter (pore size: 0.2 to 0.5 μm ; for example, MAISHORI DISK H-25-2, available from Toso Co., Ltd. may be used) is used as the sample for GPC. Also, the sample is so adjusted that the binder resin component in the toner is in a concentration of from 0.5 to 5 mg/ml.

[0080] The toner used in the present invention and having the above properties can be obtained by, e.g., a method shown below.

[0081] First, a specific binder resin as described below and optionally a pigment or dye as a colorant, a charge control agent and other additives are thoroughly mixed by means of a mixing machine such as a ball mill. Thereafter, the mixture obtained is melt-kneaded using a heat kneader such as a heat roll, a kneader or an extruder to make the resin and others melt one another and, in the resultant kneaded product, external additives and so forth are dispersed or dissolved, followed by cooling to solidity and thereafter pulverization and classification. Thus the toner according to the present invention can be obtained.

[0082] The binder resin used in the toner of the present invention can be produced in the following way.

[0083] A first polyester resin containing in a large quantity a low-molecular weight component not containing any THF-insoluble matter and a second polyester resin containing in a large quantity a high-molecular weight component containing THF-insoluble matter are mixed and used. This is preferable because molecular weight distribution can be adjusted with ease.

[0084] The first polyester resin may preferably contain the THF-insoluble matter in an amount of 0% by weight based on the weight of the polyester resin and contain a THF-soluble matter having a weight-average molecular weight (Mw) of from 7,000 to 100,000 and a number-average molecular weight (Mn) of from 2,000 to 10,000 and having a main peak in the region of molecular weight of from 3,000 to 13,000.

[0085] The second polyester resin may preferably contain the THF-insoluble matter in an amount of from 10 to 50% by weight based on the weight of the polyester resin and contain a THF-soluble matter having an Mw of from 30,000 to 500,000 and an Mn of from 2,500 to 15,000 and having a main peak in the region of molecular weight of from 5,000 to 15,000.

[0086] The THF-insoluble matter referred to in the present invention indicates the weight proportion of a polyester resin component that has become insoluble in THF of the polyester resin, and is defined by a value measured in the following way.

[0087] Polyester resin is weighed in a certain amount of from 0.5 to 1.0 g (W_1 g), which is then put in a cylindrical filter paper (No. 86R, available from Toyo Roshi K.K.) and set in a Soxhlet extractor. Extraction is carried out for 20 hours using from 100 to 200 ml of THF as a solvent, and the soluble component extracted by the use of the solvent is evaporated, followed by vacuum drying at 100°C for several hours. Then the THF-soluble resin component is weighed (W_2 g). The THF-insoluble matter is determined from the following equation.

$$\text{THF-insoluble matter (\% by weight)} = \{(W_1 - W_2)/W_1\} \times 100$$

[0088] The first polyester resin and the second polyester resin may preferably be mixed in a proportion of from 1:9 to 9:1, and more preferably from 2:8 to 8:2, in weight ratio and used as a material for binder resin before the toner is produced.

[0089] As the binder resin used in the present invention, the polyester resin may preferably be used as stated above, and also the binder resin may preferably have an acid value of from 2 to 50 mg • KOH/g.

[0090] If the binder resin has an acid value smaller than 2 mg • KOH/g, the fixed-image contamination due to contamination of fixing member may tend to occur. If it has an acid value larger than 50 mg • KOH/g, the average image density tends to lower in a high-humidity environment.

[0091] In the present invention, the acid value of the binder resin can be determined in the following way.

- Measurement of Acid Value -

[0092] Measured according to JIS K-0070 as basic operation.

1) As a sample, additives other than the binder resin (polymer component) are removed therefrom before its use, or the acid value and content of components other than binder resin and cross-linked binder resin are previously determined. A pulverized product of a sample is precisely weighed in an amount of from 0.5 to 2.0 g, and the weight of the polymer component is represented by W (g). For example, when the acid value of the binder resin is measured from that of the toner, the acid value and content of the colorant, magnetic material or the like are separately measured in advance, and the acid value of the binder resin is determined by calculation.

2) The sample is put in a 300 ml beaker, to which 150 ml of a toluene/ethanol (4:1) mixed solvent is added to carry out dissolution.

3) Titration is made with an ethanol solution of 0.1 mol/L of KOH by means of a potential difference titration device (for example, automatic titration may be utilized by means of a potential difference titration device AT-40 Win Workstation and a motorized buret ABP-410, both manufactured by Kyoto Denshi K.K.).

4) The amount of the KOH solution used in this titration is represented by S (ml). Measurement is simultaneously made on a blank, and the amount of the KOH solution in this measurement is represented by B (ml).

5) The acid value is calculated according to the following equation.

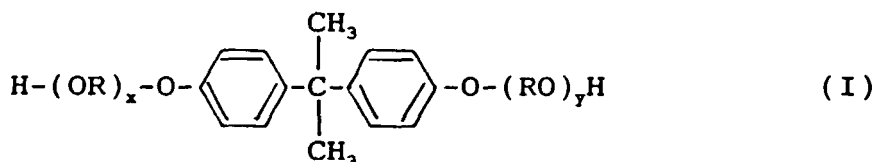
$$\text{Acid value (mg} \cdot \text{KOH/g)} = \{(S-B) \times f \times 5.6\} / W$$

(f: factor of KOH solution)

[0093] The binder resin having an acid value of from 2 to 50 mg · KOH/g can be produced in the following way.

[0094] The polyester resin used as a chief component of the binder resin is obtained by condensation of an alcohol with carboxylic acid, a carboxylate or a carboxylic anhydride.

[0095] As the alcohol component, it is a diol component represented by the following Formula (I);



wherein R represents an ethylene group or a propylene group, x and y are each an integer of 1 or more, and an average value of x + y is 2 to 7.

[0096] The diol component represented by the above formula may include, e.g., polyoxypropylene(2.2)-2,2-bis(4-hydroxyphenyl)propane, polyoxypropylene(3.3)-2,2-bis(4-hydroxyphenyl)propane, polyoxyethylene(2.0)-2,2-bis(4-hydroxyphenyl)propane, polyoxypropylene(2.0)-polyoxyethylene(2.0)-2,2-bis(4-hydroxyphenyl)propane and polyoxypropylene(6)-2,2-bis(4-hydroxyphenyl)propane. Other diol may further optionally be added, as exemplified by ethylene glycol, diethylene glycol, triethylene glycol, 1,2-propylene glycol, 1,3-propylene glycol, 1,4-butanediol, neopentyl glycol, 1,4-butanediol, 1,5-pentanediol and 1,6-hexanediol, bisphenol A, hydrogenated bisphenol A, and other divalent alcohols.

[0097] Carboxylic acids such as the carboxylic acid, carboxylate and carboxylic anhydride may include the following: As a dibasic carboxylic acid, it may include, e.g., maleic acid, fumaric acid, citraconic acid, itaconic acid, glutaconic acid, phthalic acid, isophthalic acid, terephthalic acid, cyclohexanedicarboxylic acid, succinic acid, adipic acid, sebacic acid, azelaic acid, malonic acid, and alkyl- or alkenylsuccinic acids such as n-butylsuccinic acid, n-butenylsuccinic acid, isobutylsuccinic acid, isobutenylsuccinic acid, n-octylsuccinic acid, n-octenylsuccinic acid, n-dodecylsuccinic acid, n-dodecenylsuccinic acid, isododecylsuccinic acid and isododecenylsuccinic acid; and may further include anhydrides or lower alkyl esters of these; and other divalent carboxylic acids.

[0098] In the present invention, trihydric or higher, polyfunctional monomers may be used. Of the trihydric or higher, polyfunctional monomers, a trihydric or higher alcohol component may include sorbitol, 1,2,3,6-hexanetetrol, 1,4-sorbitan, pentaerythritol, dipentaerythritol, tripentaerythritol, 1,2,4-butanetriol, 1,2,5-pentanetriol, glycerol, 2-methylpropanetriol, 2-methyl-1,2,4-butanetriol, trimethylolpropane, trimethylolpropane and 1,3,5-trihydroxybenzene, and other trihydric or higher alcohols; and a tribasic or higher carboxylic acid component may include 1,2,4-benzenetricarboxylic acid, 2,5,7-naphthalenetricarboxylic acid, 1,2,4-naphthalenetricarboxylic acid, 1,2,4-butanetricarboxylic acid, 1,2,5-hexanetricarboxylic acid, 1,3-dicarboxyl-2-methyl-2-methylenecarboxypropane, tetra(methylenecarboxyl) methane, 1,2,7,8-octanetetracarboxylic acid, Empol trimer acid, anhydrides or lower alkyl esters of these, and other tribasic or higher carboxylic acids.

[0099] As the polybasic carboxylic acid, it may include tetracarboxylic acids represented by the following Formula

(II):



wherein W represents an alkylene group or alkenylene group having 1 to 30 carbon atoms having at least one side chain having one (1) or more carbon atoms; and derivatives thereof, such as anhydrides thereof and lower alkyl esters thereof.

[0100] Monobasic carboxylic acids represented by the following Formula (III) or monohydric alcohols represented by the following Formula (IV) may also be used as part of the polyester constituent component.



wherein R^1 represents a straight-chain, branched or cyclic alkyl group or alkenyl group having 12 or more carbon atoms.



wherein R^2 represents a straight-chain, branched or cyclic alkyl group or alkenyl group having 12 or more carbon atoms.

[0101] The alcohol component may be used in an amount of from 40 to 60 mol%, and preferably from 45 to 55 mol%; and the acid component, from 60 to 40 mol%, and preferably from 55 to 45 mol%. Also, the trihydric or higher, polyhydric or polybasic components may preferably be in an amount of from 1 to 60 mol% of the whole components.

[0102] The polyester described above is usually obtainable by commonly known condensation polymerization.

[0103] In the present invention, as the colorant of the toner, dyes and/or pigments may be used in the case of color toners, and magnetic materials such as magnetic iron oxide may be used in the case of magnetic toners.

[0104] In the case of a magnetic toner, it may preferably contain magnetic iron oxide as an internal additive as the colorant and a fluidity improver such as fine silica powder as an external additive.

[0105] Other additives may also be used so long as they substantially do not adversely affect the toner, which may include, e.g., lubricant powders such as Teflon powder, zinc stearate powder and polyvinylidene fluoride powder; abrasives such as cerium oxide powder, silicon carbide powder and strontium titanate powder; fluidity-providing agents such as titanium oxide powder and aluminum oxide powder; anti-caking agents; and conductivity-providing agents such as carbon black powder and zinc oxide powder. Reverse-polarity organic fine particles and inorganic fine particle may also be used in a small quantity as a developability improver.

[0106] An example of a specific image forming apparatus that can be used for carrying out the image forming method of the present invention is described with reference to Fig. 15.

[0107] Reference numeral 101 denotes a rotary drum type photosensitive member serving as an electrostatic latent image bearing member. The photosensitive member 101 is constituted basically of a conductive substrate layer 101b formed of aluminum and a photoconductive layer 101a formed on its periphery, the surface layer portion of the photoconductive layer 101a being constituted of a polycarbonate resin containing a charge-transporting material and 8% by weight of fine fluorine resin powder; and is rotatingly driven in the clockwise direction as viewed on the drawing, at a peripheral speed of 200 mm/sec.

[0108] Reference numeral 102 denotes a charging roller serving as a contact charging member, which is constituted basically of a mandrel 102b at the center and provided on its periphery a conductive elastic layer 102a formed of epichlorohydrin rubber containing carbon black.

[0109] The charging roller 102 is brought into pressure contact with the surface of the photosensitive member 101 under a pressure of 40 g/cm as linear pressure, and is follow-up rotated with the rotation of the photosensitive member 101.

[0110] Reference numeral 103 denotes a charging bias power source for applying a voltage to the charging roller 102, and the surface of the photosensitive member 101 is uniformly charged to polarity and potential of about -700 V upon application of a bias of about DC -1.4 kV to the charging roller 102.

[0111] Subsequently, as a latent image forming means, electrostatic latent images are formed by imagewise exposure 104. The electrostatic latent images formed are developed by a negatively chargeable toner held in a developing means 105 and are rendered visible images one after another as toner images. The developing means 105 has at least, e.g., a toner container for holding therein a magnetic toner, a toner-carrying member internally provided with a magnet

and set rotatably for carrying and transporting by magnetic binding force the magnetic toner held in the toner container, and a toner layer thickness regulation member for regulating the layer thickness of the magnetic toner carried on the surface of the toner-carrying member. The toner-carrying member is disposed keeping a given distance to the photo-sensitive member. At the time of development, a development bias voltage having an AC bias voltage and a DC bias voltage is applied to the toner-carrying member, whereby the magnetic toner on the toner-carrying member is moved to the photosensitive member surface to perform development.

[0112] Reference numeral 106 denotes a transfer roller serving as a contact transfer member, which is constituted basically of a mandrel 106b at the center and provided on its periphery a conductive elastic layer 106a formed of an ethylene-propylene-butadiene copolymer containing carbon black.

[0113] The transfer roller 106 is brought into pressure contact with the surface of the photosensitive member 101 under a pressure of 20 g/cm as linear pressure, and is rotated at a speed equal to the peripheral speed of the photo-sensitive member 101.

[0114] As a transfer medium 108, e.g., an A4-size sheet of paper is used. This paper is fed to be held between the photosensitive member 101 and the transfer roller 106, and a bias of DC -5 kV with a polarity reverse to that of the toner is simultaneously applied from a transfer bias power source 107, so that the toner images on the photosensitive member 101 are transferred to the surface side of the transfer medium 108. Hence, at the time of transfer, the transfer roller 106 is brought into pressure contact with the photosensitive member 101 via the transfer medium 108.

[0115] Next, the transfer medium 108 is transported to an induction heat fixing apparatus 111 according to the present invention, constituted basically of a fixing roller 111a and a foamed pressure roller 111b having a foamed material layer and a release layer, brought into contact with the fixing roller under pressure, and is passed between the fixing roller 111a and the foamed pressure roller 111b, whereupon the toner images are fixed to the transfer medium 108, which medium is then outputted as an image-formed material.

[0116] After the toner images have been transferred, the surface of the photosensitive member 101 is cleaned to remove the adherent contaminants such as transfer residual toner by means of a cleaning assembly 109 having an elastic cleaning blade formed basically of an elastic material such as polyurethane rubber, brought into pressure contact with the photosensitive member 101 in the counter direction at a linear pressure of 25 g/cm, and is further destatized by means of a charge eliminating exposure assembly 110. Then, images are repeatedly formed thereon.

[0117] As describe above, on account of the use of the induction heat fixing apparatus of the present invention, making the most of its feature that wait-up time can be shortened, a satisfactory image-fixing performance can be ensured without causing any difference in fixing performance between leading end portions and rear end portions of transfer mediums. Also when reclaimed paper is used, fixed images can be kept from contamination. In addition, the process speed of copying machines is expected to be made higher and higher, and, even in such a case, the present invention can promise a stable fixing performance.

EXAMPLES

[0118] The present invention will be described below in greater detail by giving Examples, which, however, by no means limit the present invention.

Example 1

[0119] The toner used in the present invention was produced.

- Binder Resin Production 1 -

[0120] The following binder resins were produced as binder resins for toners.

(Binder Resin A)

[0121] Binder resin A was produced using the following materials.

Terephthalic acid	15 mol%
Fumaric acid	25 mol%
Trimellitic anhydride	5 mol%

(continued)

PO-BPA	30 mol%
EO-BPA	25 mol%

[0122] PO-BPA stands for polyoxypropylene(2.2)-2,2-bis(4-hydroxyphenyl)propane, and EO-BPA stands for polyoxyethylene(2.2)-2,2-bis(4-hydroxyphenyl)propane (the same applies hereinafter).

[0123] The above materials were charged into a 5-liter four-necked flask, which was then fitted with a reflux condenser, a water separator, an N₂ gas feed pipe, a thermometer and a stirrer. Condensation polymerization reaction was carried out at 230°C while N₂ was fed into the flask, to obtain a polyester resin, binder resin A. Its physical properties are shown in Table 1.

(Binder Resin B)

[0124] Binder resin B was produced using the following materials.

Fumaric acid	35 mol%
Trimellitic anhydride	10 mol%
PO-BPA	30 mol%
EO-BPA	25 mol%

[0125] These were subjected to condensation polymerization reaction in the same manner as the production of the binder resin A except that 3 mol% of trimellitic anhydride was further added in the course of condensation polymerization. Thus, a polyester resin, binder resin B was obtained. Physical properties of the binder resin B thus obtained are shown in Table 1.

(Binder Resin C)

[0126] Binder resin C was produced using the following materials.

PO-BPA	50 mol%
Ethylene glycol	10 mol%
Terephthalic acid	25 mol%
Fumaric acid	10 mol%
Trimellitic anhydride	5 mol%

[0127] The above materials were charged into a 5-liter four-necked flask, which was then fitted with a reflux condenser, a water separator, an N₂ gas feed pipe, a thermometer and a stirrer. Condensation polymerization reaction was carried out at 200°C while N₂ was fed into the flask, followed by further condensation polymerization at 220°C under reduced pressure to obtain a polyester resin, binder resin C. Physical properties of the binder resin C thus obtained are shown in Table 1.

(Binder Resin D)

[0128] Binder resin D was produced using the following materials.

5

10

Terephthalic acid	3 mol%
Isophthalic acid	30 mol%
Trimellitic anhydride	15 mol%
n-Dodecenylsuccinic acid	10 mol%
PO-BPA	30 mol%
EO-BPA	12 mol%

15

[0129] The above materials were subjected to condensation polymerization reaction in the same manner as the production of the binder resin A to obtain binder resin D. Physical properties of the binder resin D thus obtained are shown in Table 1.

(Binder Resin E)

20

[0130] Binder resin E was produced using the following materials.

25

30

Terephthalic acid	5 mol%
Isophthalic acid	30 mol%
Trimellitic anhydride	13 mol%
n-Dodecenylsuccinic acid	10 mol%
PO-BPA	30 mol%
EO-BPA	12 mol%

35

[0131] The above materials were subjected to condensation polymerization reaction in the same manner as the production of the binder resin A to obtain binder resin E. Physical properties of the binder resin E thus obtained are shown in Table 1.

(Binder Resin F)

40

[0132] Binder resin F was produced using the following materials.

45

50

Terephthalic acid	30 mol%
Trimellitic anhydride	5 mol%
n-Dodecenylsuccinic acid	15 mol%
PO-BPA	50 mol%

[0133] The above materials were subjected to condensation polymerization reaction in the same manner as the production of the binder resin A to obtain binder resin F. Physical properties of the binder resin F thus obtained are shown in Table 1.

55

(Binder Resin G)

[0134] Binder resin G was produced using the following materials.

PO-BPA	50 mol%
Ethylene glycol	15 mol%
Terephthalic acid	23 mol%
Fumaric acid	10 mol%
Trimellitic anhydride	2 mol%

[0135] The above materials were subjected to condensation polymerization reaction in the same manner as the production of the binder resin C to obtain binder resin G. Physical properties of the binder resin G thus obtained are shown in Table 1.

- Binder Resin Production 2 -

[0136] The binder resins A to G obtained were appropriately selected and were mixed by means of a Henschel mixer to obtain binder resins 1 to 5 according to the present invention. As controls binder resins 6 and 7 were obtained. The mixed binder resins and their mixing proportions and physical properties are shown in Table 2.

- Production of Toners -

[0137] Using the binder resins 1 to 7 thus obtained, toners shown below were produced.

(Toner 1)

[0138] Materials shown below were premixed by means of a Henschel mixer, and thereafter the mixture obtained was melt-kneaded by means of a twin-screw extruder (PCM-30, manufactured by Ikegai Corp.) set at 140°C. The kneaded product thus obtained was cooled and then made into coarse powder by means of a cutter mill, followed by pulverization using a fine grinding mill making use of a jet stream. The finely pulverized powder obtained was classified by means of a multi-division classifier utilizing the Coanda effect, to obtain a toner with a weight-average particle diameter of 7.6 μm .

	(by weight)
Binder resin 1	100 parts
Magnetic iron oxide (average particle diameter: 0.2 μm ; Hc: 9.5 kA/m; σ_s : 65 Am ² /kg; σ_r : 7 Am ² /kg)	90 parts
Charge control agent (dicarboxylic acid)	2 parts
Wax (low-molecular weight polyethylene wax)	5 parts

[0139] To 100 parts by weight of the above toner, 1.0 part by weight of hydrophobic fine silica powder having a methanol wettability of 65% and a BET specific surface area of 260 m²/g, having been hydrophobic-treated with 20 parts by weight of hexamethyldisilazane per 100 parts by weight of fine silica powder, and 4.0 parts by weight of fine strontium titanate powder were externally added and mixed to produce magnetic toner 1.

(Toners 2 to 7)

[0140] Under the same formulation as the magnetic toner 1, magnetic toners 2 to 5 were produced using the binder resins 2 to 5, respectively. Mixing proportions of materials are shown in Table 3. Physical properties of the magnetic toners obtained are shown in Table 4. Magnetic toners 6 and 7 were also produced using the binder resins 6 and 7, respectively.

(Toner 8)

[0141] Magnetic toner 8 was produced as a control in the same manner as the production of the magnetic toner 1 except that the kneading temperature of the twin-screw extruder was set at 130°C and the binder resin 5 was used.

5 **[0142]** In Table 3, the amounts of the binder resin, magnetic iron oxide, charge control agent and wax are parts by weight (pbw), and the hydrophobic fine silica powder and strontium titanate are in parts by weight based on 100 parts by weight of internal additives consisting of the binder resin, magnetic iron oxide, charge control agent and wax.

Example 2

10

- Preheating Time Test -

[0143] In an apparatus having the same structure as the induction heat fixing apparatus shown in Fig. 1 in the description of preferred embodiments, a foamed pressure roller 2 as the pressure member having the same structure as that shown in Fig. 2 in the description of preferred embodiments was incorporated to set up an induction heat fixing apparatus, and, as a control, a solid roller 30 as the pressure member shown in Fig. 13 was incorporated to set up an induction heat fixing apparatus. Using these apparatus, preheating time was tested.

[0144] More specific construction of the foamed pressure roller 2 in the present Example is as described below.

15 **[0145]** As shown in Fig. 2, a 5 mm thick foamed material layer 22 and as a release layer a 50 µm thick tube layer 23 formed of PFA were provided on the periphery of a solid mandrel 21 of 20 mm outer diameter, made of iron, and made up to have an outer diameter of 30.1 mm.

[0146] As the control, solid pressure roller 30, used was a roller comprising as shown in Fig. 13 a solid mandrel 31 of 20 mm outer diameter, made of iron, a silicone rubber elastic layer 32 of 5.0 mm thick, provided on the periphery of the mandrel, and as a release layer on its surface a PFA tube layer 33 of 20 µm thick.

20 **[0147]** In Fig. 3, a graph is shown which was made by plotting the preheating time of the foamed pressure roller 2 and that of the solid pressure roller 30 with respect to electric power applied to the fixing apparatus.

[0148] As can be seen from the graph, the foamed pressure roller 2 was able to achieve a shorter preheating time on account of a smaller thermal conductivity than the solid pressure roller 30.

30 Example 3

- Preheating Time Test -

[0149] In an apparatus having the same structure as the induction heat fixing apparatus shown in Fig. 1 in the description of preferred embodiments, a hard fixing roller 1 as the rotating member having the same structure as that shown in Fig. 4 in the description of preferred embodiments was incorporated to set up an induction heat fixing apparatus, and, as a control, a soft fixing roller 40 as the rotating member shown in Fig. 14 was incorporated to set up an induction heat fixing apparatus. (Here, as a pressure member, the same foamed pressure roller as that used in Example 2 was used.) Using these apparatus, preheating time was tested.

40 **[0150]** More specific construction of the hard fixing roller 1 in the present Example is as described below.

[0151] As shown in Fig. 4, a 20 µm thick release layer 12 formed of PFA was provided on the periphery of a hollow mandrel 11 of 32 mm outer diameter and 0.3 mm wall thickness, made of iron, to make up the hard fixing roller 1.

[0152] As the control, soft fixing roller 40, used was a roller comprising as shown in Fig. 14 a hollow mandrel 41 of 32 mm outer diameter and 0.3 mm wall thickness, made of iron, a 20 µm thick release layer 42 formed of PFA provided on the periphery of the mandrel in order to improve surface releasability, and a 500 µm thick silicone rubber layer 43 held between the above two layers.

[0153] In Fig. 5, a graph is shown which was made by plotting the preheating time of the hard fixing roller 1 and that of the soft fixing roller 40 with respect to electric power applied to the fixing apparatus.

50 **[0154]** As can be seen from the graph, the hard fixing roller 1 was able to achieve a shorter preheating time on account of a smaller heat capacity than the soft fixing roller 40 correspondingly to that of the rubber layer.

Example 4

55 **[0155]** The induction heat fixing apparatus of the present invention was set in an electrophotographic copying machine (NP6750, manufactured by CANON INC.) as the image-forming apparatus shown in Fig. 15. Using this remodeled machine and the magnetic toners 1 to 5, a 500,000-sheet running test was made in each of a high-temperature and high-humidity environment (temperature: 30°C; humidity: 80%) and a normal-temperature and normal-humidity environment (temperature: 23°C; humidity: 60%). As controls, similar running tests were also made on the magnetic

toners 6 to 8. Here, fixing speed was set variable so as to be adaptable to the process speed of the apparatus main body.

[0156] More specific construction of the induction heat fixing apparatus used in the present Example is as described below.

[0157] In an apparatus having the same structure as the induction heat fixing apparatus shown in Fig. 1 in the description of preferred embodiments, a hard fixing roller 1 as the rotating member having the same structure as that shown in Fig. 4 in Example 3 and a foamed pressure roller 2 as the pressure member having the same structure as that shown in Fig. 2 in Example 2 were incorporated.

[0158] As shown in Fig. 4, a 20 μm thick release layer 12 formed of PFA was provided on the periphery of a hollow mandrel 11 of 32 mm outer diameter and 0.3 mm wall thickness, made of iron, to make up the hard fixing roller 1. As shown in Fig. 2, a 5 mm thick foamed material layer 22 and a 50 μm thick tube layer 23 formed of PFA were provided on the periphery of a solid mandrel 21 of 20 mm outer diameter, made of iron, to make up the foamed pressure roller 2 having an outer diameter of 30.1 mm.

[0159] In the running test of copying, paper reusing 50% of used paper (filler: 15% as ash; basis weight: 66 g/m²; size: A4) was used as transfer paper.

[0160] Fixing temperature regions were measured in the following way.

[0161] A fixing assembly of a commercially available copying machine NP6085 (manufactured by CANON INC.) was detached to the outside and was so remodeled as to be operable outside the copying machine, capable of being set at any desired fixing temperatures and driven at a process speed of 150 mm/sec. Using this external fixing apparatus of the present Example, sheets of 80 g/m² paper with unfixed images were passed to evaluate fixing performance.

[0162] Temperature control was made at intervals of 5°C in the temperature range of from 120 to 190°C, and unfixed images were fixed at each temperature. Images thus fixed were rubbed with Silbon paper five times under a load of 4.9 kPa, and the point at which image density before rubbing decreased by 10% or less after rubbing was regarded as fixing starting temperature. The lower this temperature is, the better the fixing performance is.

[0163] The above fixing apparatus was set at a process speed of 100 mm/sec. Using this external fixing apparatus, sheets of 60 g/m² paper with unfixed images were passed to evaluate anti-offset properties.

[0164] In the evaluation, temperature control was made at intervals of 5°C in the temperature range of from 190 to 240°C, and how offset occurred was observed to make evaluation by maximum temperature at which no offset occurred. The higher this temperature is, the better the anti-offset properties are. (Evaluation environment: normal temperature/normal humidity, 23°C/60%RH).

[0165] The difference between these non-offset maximum temperature and fixing starting temperature is regarded as a fixing temperature region. It follows that, the broader this temperature region is, the higher fixing performance the toner has. In the evaluation test, conditions under which the fixing temperature region minimum temperature is set and conditions under which the fixing temperature region maximum temperature is measured are different and set severer.

Hence, it follows that the toner has a still broader fixing temperature region in actual products.

[0166] In the running test in the high-temperature and high-humidity environment, the test machine was left for 3 days in this environment after the 500,000-sheet running test was finished, and thereafter images were reproduced to measure image density.

[0167] From the results of these tests, fixing temperature region, contamination of fixing member, average image density in high-humidity environment and image density after leaving in that environment were examined to obtain the results as shown in Table 5.

[0168] Here, the contamination of fixing member was evaluated according to the following criteria.

A: No contamination is seen on the fixing member.

B: Contamination is a little seen on the fixing member.

C: Contamination occurs on the fixing member, but does not affect images.

D: Contamination occurs on the fixing member, and contamination by toner occurs also on images.

[0169] Here, A to C are regarded as an allowable range.

[0170] With regard to the image density, 1.30 or higher is regarded as an allowable range in respect of the average image density, and 1.20 or higher in respect of the image density after leaving.

[0171] The relationships between the above image density after leaving and so forth and various values of toner's physical properties are summarized in Figs. 6 to 11.

[0172] As can be seen from these results, the toners 1 to 5 in the present invention have a fixing temperature region in a width as large as at least 90°C, which is necessary for enhancing the freedom of fixing apparatus designing, have a fixable minimum temperature of as good as 140°C or below, and also showed good results on both the image density after leaving in high-humidity environment and the average image density in high-humidity environment.

[0173] The toner 6, however, caused fixing member contamination because the acid value of its binder resin was

less than 2 mg • KOH/g. Fig. 8 also shows a tendency to increase in fixing member contamination with a decrease in acid value.

[0174] The toner 7, having an acid value higher than 50 mg • KOH/g, showed an average image density in high-humidity environment of as low as 1.26. Fig. 9 also shows a tendency to decrease in average image density in high-humidity environment with an increase in acid value.

[0175] The toner 7, having in its molecular weight distribution as measured by GPC of THF-soluble matter no main peak in the region of molecular weight of from 3,000 to 20,000 and having a main peak present in the region of molecular weight less than 3,000, shows an image density after leaving of as low as 1.19. It is also confirmable from Fig. 7 that the low-temperature fixing performance is poor when the main peak is present in the region of small molecular weight.

[0176] The toner 6, having no main peak in the region of molecular weight of from 3,000 to 20,000 and having a main peak present in the region of molecular weight more than 20,000, has a fixing temperature region starting to range from a relatively high temperature of 145°C. This is also presented by Fig. 7.

[0177] The toners 6 and 8, containing in their molecular weight distribution as measured by GPC of THF-soluble matter the component with a molecular weight of 500,000 or more in a proportion less than 3%, show the fixing member contamination at a serious level. Fig. 10 shows a tendency that the fixing member contamination is more serious as that component approaches to 3%.

[0178] The toner 7, containing the component with a molecular weight of 500,000 or more in a proportion more than 25%, has a low-temperature fixing performance and has a fixing temperature region starting to range from a relatively high temperature of 150°C. This is also conformable from Fig. 11.

[0179] As can be seen from the foregoing, in the induction heat fixing apparatus, a good low-temperature fixing performance can be achieved and the fixing member contamination may hardly occur when the foamed pressure roller is used and also the hard fixing roller is used, and as a toner having a good developing performance it is preferable for the toner to have, in its molecular weight distribution as measured by GPC of THF-soluble matter, a main peak in the region of molecular weight of from 3,000 to 20,000 and contain a component with a molecular weight of 500,000 or more in a proportion of from 3 to 25%.

[0180] It can also be seen that the toner is more preferable especially when its binder resin comprises a polyester resin and has an acid value of from 2 mg • KOH/g to 50 mg • KOH/g, because the fixing member can be kept from contamination and the image density does not lower in a high-temperature and high-humidity environment.

Example 5

- Heat Source Test -

[0181] In the induction heat fixing apparatus of the present invention in which the foamed pressure roller 2 used in Example 4 and the hard fixing roller 1 used in Example 4 in the present invention have been incorporated, the toner 1, having the physical properties as described above, was used. Also, a hard film fixing roller in which as a heat source a halogen lamp conventionally used was used in the fixing apparatus in place of the high-frequency induction heat source was used as a control. Using these, the following comparative experiment was made.

[0182] Using external fixing apparatus employing respectively the induction heat source and the halogen lamp, the process speed of each being set variable at 250 mm/s, 300 mm/s, 350 mm/s and 400 mm/s, fixing performance was evaluated on images formed at 10-cm leading end and 10-cm rear end of A3-size paper. The fixing roller was temperature-controlled at 190°C. Results obtained are shown in Fig. 12.

[0183] As can be seen from Fig. 12, there is little difference in fixing performance between the leading end and rear end of the A3-size paper when the induction heat type is used as the heat source, whereas a difference is produced between the leading end and rear end of the A3-size paper when the halogen lamp is used and this difference becomes much greater in proportion to the process speed. Also, even in the case of the fixing roller in combination with the induction heat source, when the toner is outside the scope of what is claimed in the present patent application, a difference is produced between the leading end and rear end of the A3-size paper because of, e.g., a poor low-temperature fixing performance.

[0184] The cause of such a difference is presumed as follows: The halogen lamp is commonly set in the interior of a fixing roller and heats the whole roller. On the other hand, in the induction heat fixing apparatus, as can be seen also from Fig. 1 the coil is disposed only on the side of the nip of the fixing roller and heats the fixing roller only at the part necessary for the fixing of images. Hence, when A3-size paper is passed, in the case of induction heat, the amount of heat taken away by the paper at the nip can effectively be supplied and hence the temperature of the fixing roller does not change between the leading end and rear end of the paper, so that no difference is produced between the leading end and the rear end. On the other hand, in the case of a halogen lamp, the amount of heat taken away by the paper at the nip can not completely be supplied and hence the temperature of the fixing roller necessarily lowers more at the

rear end than the leading end of the paper.

[0185] It is considered that such a phenomenon becomes remarkable with an increase in process speed.

[0186] In the present invention, the pressure roller is the foamed pressure roller, having a smaller heat capacity than the solid pressure roller, and hence the amount of heat accumulated in the pressure roller is small. Accordingly, heat must be supplied from the fixing roller to the pressure roller because heat is necessarily taken away from the foamed pressure roller every time the paper is passed, thus there is a greater tendency of producing the difference in fixing performance between the leading end and the rear end.

Example 6

[0187] Evaluation was made in the same manner as in Example 5 but using an induction heat fixing apparatus in which, in place of the hard fixing roller 1 used in Example 5, the soft fixing roller 40 as shown in Fig. 14, used in Example 3 as a control, was incorporated. As a result, it was found that in the case of the halogen lamp the difference in fixing performance between the leading end and the rear end was 10%, 8%, 7% and 5% in the order of 400 mm/s, 350 mm/s, 300 mm/s and 250 mm/s, respectively, but in the case of induction heat the difference was controllable to 5%, 4%, 3% and 2%, respectively.

Example 7

[0188] Using a induction heat fixing apparatus in which the hard fixing roller used in Example 4 was replaced with a hard fixing roller having the following construction and this hard fixing roller was incorporated, contamination of the fixing roller was tested. To make operation and evaluation therefor, the same 50,000-sheet running test as that for the evaluation on fixing member contamination in Example 4 was made.

[0189] As more specific construction of the hard fixing roller 1 in the present Example, having the same structure as that shown in Fig. 4, a 20 μ m thick release layer 12 formed of a mixture of PFA and PTFE (mixing weight ratio: PFA:PTFE=5:5) was provided on the periphery of a hollow mandrel 11 of 32 mm outer diameter and 0.3 mm wall thickness, made of iron.

[0190] As the result, the fixing member was little contaminated, and better results of evaluation were obtainable than the results of evaluation in Example 4.

Table 1

	Main-peak molecular weight	Acid value
		(mg • KOH/g)
Binder resin A	6,800	28
Binder resin B	9,000	25
Binder resin C	18,500	5
Binder resin D	2,600	57
Binder resin E	3,300	48
Binder resin F	7,400	12
Binder resin G	21,000	1.8

Table 2

	Resin mixing weight ratio	Main-peak molecular weight	Acid value
			(mg • KOH/g)
Binder resin 1	C:B=1:1	13,600	8

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Table 2 (continued)

	Resin mixing weight ratio	Main-peak molecular weight	Acid value
			(mg • KOH/g)
Binder resin 2	A:D=1:1	5,500	42
Binder resin 3	C only	18,500	5
Binder resin 4	E only	3,300	48
Binder resin 5	F only	7,400	12
Binder resin 6	G only	21,000	1.8
Binder resin 7	D only	2,600	57

Table 3

Magnetic toner No.	Binder resin		Magnetic iron oxide	Charge control agent	Wax	Hydrophobic fine silica powder	Strontium titanate
	No.	Amount					
		(pbw)	(pbw)	(pbw)	(pbw)	(pbw)	(pbw)
1	1	100	90	2	2	0.8	1.0
2	2	100	90	2	2	0.8	1.0
3	3	100	90	2	2	0.8	1.0
4	4	100	90	2	2	0.8	1.0
5	5	100	90	2	2	0.8	1.0
6	6	100	90	2	2	0.8	1.0
7	7	100	90	2	2	0.8	1.0
8	5	100	90	2	2	0.8	1.0

Table 4

Magnetic toner No.	Toner weight average particle diameter	Resin component acid value	Results of measurement by GPC of toner's THF-soluble matter	
			Main-peak molecular weight	Proportion of component with molecular weight of 500,000 or more
	(μm)	(mg • KOH/g)		(%)
1	7.6	7	14,000	5.2
2	7.7	37	5,500	14.0
3	7.4	3	19,000	4.0
4	7.6	45	3,300	23.0

Table 4 (continued)

Magnetic toner No.	Toner weight average particle diameter	Resin component acid value	Results of measurement by GPC of toner's THF-soluble matter	
			Main-peak molecular weight	Proportion of component with molecular weight of 500,000 or more
	(μm)	($\text{mg} \cdot \text{KOH/g}$)		(%)
5	7.8	11	7,500	3.0
6	7.3	1.5	21,000	1.0
7	7.5	55	2,700	27.0
8	7.6	12	7,400	2.5

Table 5

Magnetic toner No.	Fixing member contamination	Fixing temperature		Image density after leaving in high= humidity environment	Average image density in high= humidity environment
		Region	Width		
		($^{\circ}\text{C}$)	($^{\circ}\text{C}$)		
1	B	130-230	95	1.35	1.42
2	A	140-235	95	1.27	1.35
3	C	135-225	90	1.36	1.42
4	A	140-235	90	1.23	1.31
5	C	135-225	90	1.25	1.34
6	D	145-220	80	1.26	1.36
7	A	150-230	80	1.19	1.26
8	D	140-225	85	1.26	1.34

[0191] An induction heat fixing apparatus is disclosed which has a rotating member, a pressure member coming in pressure contact with the rotating member to form a nip between the pressure member and the rotating member in such a way that a transfer medium on which a toner image has been formed is passable through the nip, and an electric-current applying means for applying an alternating current to the exciting coil to cause the rotating member to generate heat by induction heating by means of an eddy current generated in the rotating member. The pressure member is a pressure roller composed of a non-elastic material mandrel, a foamed material layer provided on the non-elastic material mandrel, and a release layer provided on the foamed material layer. Also disclosed is an image-forming method using the induction heat fixing apparatus as a fixing means in the step of fixing a toner image.

Claims

1. An induction heat fixing apparatus comprising;

- a rotating member;
- an exciting coil provided in the interior or on the exterior of the rotating member;
- a pressure member coming in pressure contact with the rotating member to form a nip between the pressure

member and the rotating member in such a way that a transfer medium on which a toner image has been formed is passable through the nip; and

an electric-current applying means for applying an alternating current to the exciting coil to cause the rotating member to generate heat by induction heating by means of an eddy current generated in the rotating member; wherein said pressure member is a pressure roller comprising a non-elastic material mandrel, a foamed material layer provided on said non-elastic material mandrel, and a release layer provided on said foamed material layer.

2. The apparatus according to claim 1, wherein said release layer is formed of a copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether (PFA), polytetrafluoroethylene (PTFE) or a copolymer of tetrafluoroethylene with propylene fluoride (FEP).
3. The apparatus according to claim 1, wherein said release layer is a tube layer of a copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether (PFA) or a tube layer of polytetrafluoroethylene (PTFE).
4. The apparatus according to claim 1, wherein said release layer has a layer thickness of from 10 μm to 50 μm .
5. The apparatus according to claim 1, wherein said foamed material layer is formed of a silicone foam.
6. The apparatus according to claim 1, wherein said foamed material layer has a layer thickness of from 1 mm to 7 mm.
7. The apparatus according to claim 1, wherein said rotating member comprises a hollow mandrel and a release layer formed of a fluorine-containing resin on the mandrel.
8. The apparatus according to claim 1, wherein said rotating member is a hard roller having a total layer thickness of 100 μm or smaller as all the layers formed on the mandrel.
9. The apparatus according to claim 7, wherein said fluorine-containing resin is a copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether (PFA), polytetrafluoroethylene (PTFE) or a copolymer of tetrafluoroethylene with propylene fluoride (FEP).
10. The apparatus according to claim 7, wherein said fluorine-containing resin comprises a mixture of the PFA and the PTFE.
11. The apparatus according to claim 10, wherein in said mixture the PFA is in a mixing proportion of from 30% by weight to 95% by weight to the PTFE.
12. The apparatus according to claim 7, wherein said release layer has a layer thickness of from 10 μm to 100 μm .
13. The apparatus according to claim 1, wherein said toner has, in its molecular weight distribution as measured by gel permeation chromatography (GPC) of tetrahydrofuran(THF)-soluble matter, a main peak in the region of molecular weight of from 3,000 to 20,000 and contains a component with a molecular weight of 500,000 or more in a proportion of from 3 to 25%.
14. The apparatus according to claim 13, wherein said toner contains as a binder resin a polyester resin having an acid value of from 2 mg $\cdot$ KOH/g to 50 mg $\cdot$ KOH/g.
15. The apparatus according to claim 1, which performs fixing at a fixing speed of 200 mm/second or higher.
16. An image-forming method comprising the steps of;
 - developing an electrostatic latent image formed on an electrostatic latent image bearing member, by the use of a toner to form a toner image;
 - transferring the toner image to a transfer medium; and
 - fixing the toner image on the transfer medium, to the transfer medium by a fixing means;
 - said fixing means is an induction heat fixing apparatus comprising;
 - a rotating member;

an exciting coil provided in the interior or on the exterior of the rotating member;
 a pressure member coming in pressure contact with the rotating member to form a nip between the pressure member and the rotating member in such a way that a transfer medium on which a toner image has been formed is passable through the nip; and
 5 an electric-current applying means for applying an alternating current to the exciting coil to cause the rotating member to generate heat by induction heating by means of an eddy current generated in the rotating member; wherein said pressure member is a pressure roller comprising a non-elastic material mandrel, a foamed material layer provided on said non-elastic material mandrel, and a release layer provided on said foamed material layer.

10 17. The image-forming method according to claim 16, wherein said release layer is formed of a copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether (PFA), polytetrafluoroethylene (PTFE) or a copolymer of tetrafluoroethylene with propylene fluoride (FEP).

15 18. The image-forming method according to claim 16, wherein said release layer is a tube layer of a copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether (PFA) or a tube layer of polytetrafluoroethylene (PTFE).

19. The image-forming method according to claim 16, wherein said release layer has a layer thickness of from 10 μm to 50 μm .

20 20. The image-forming method according to claim 16, wherein said foamed material layer is formed of a silicone foam.

21. The image-forming method according to claim 16, wherein said foamed material layer has a layer thickness of from 1 mm to 7 mm.

25 22. The image-forming method according to claim 16, wherein said rotating member comprises a hollow mandrel and a release layer formed of a fluorine-containing resin on the mandrel.

30 23. The image-forming method according to claim 16, wherein said rotating member is a hard roller having a total layer thickness of 100 μm or smaller as all the layers formed on the mandrel.

24. The image-forming method according to claim 22, wherein said fluorine-containing resin is a copolymer of tetrafluoroethylene with perfluoroalkyl vinyl ether (PFA), polytetrafluoroethylene (PTFE) or a copolymer of tetrafluoroethylene with propylene fluoride (FEP).

35 25. The image-forming method according to claim 22, wherein said fluorine-containing resin comprises a mixture of the PFA and the PTFE.

40 26. The image-forming method according to claim 25, wherein in said mixture the PFA is in a mixing proportion of from 30% by weight to 95% by weight to the PTFE.

27. The image-forming method according to claim 22, wherein said release layer has a layer thickness of from 10 μm to 100 μm .

45 28. The image-forming method according to claim 16, wherein said toner has, in its molecular weight distribution as measured by gel permeation chromatography (GPC) of tetrahydrofuran(THF)-soluble matter, a main peak in the region of molecular weight of from 3,000 to 20,000 and contains a component with a molecular weight of 500,000 or more in a proportion of from 3 to 25%.

50 29. The image-forming method according to claim 28, wherein said toner contains as a binder resin a polyester resin having an acid value of from 2 mg $\cdot$ KOH/g to 50 mg $\cdot$ KOH/g.

30. The image-forming method according to claim 16, wherein said induction heat fixing apparatus performs fixing at a fixing speed of 200 mm/second or higher.

55 31. The image-forming method according to claim 16, wherein in the developing step said electrostatic latent image is developed by moving a toner carried on a toner-carrying member, to the surface of the electrostatic latent image bearing member.

- 32.** The image-forming method according to claim 32, wherein in the developing step said electrostatic latent image is developed while a development bias having an alternating bias is applied to said toner-carrying member.

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FIG. 1

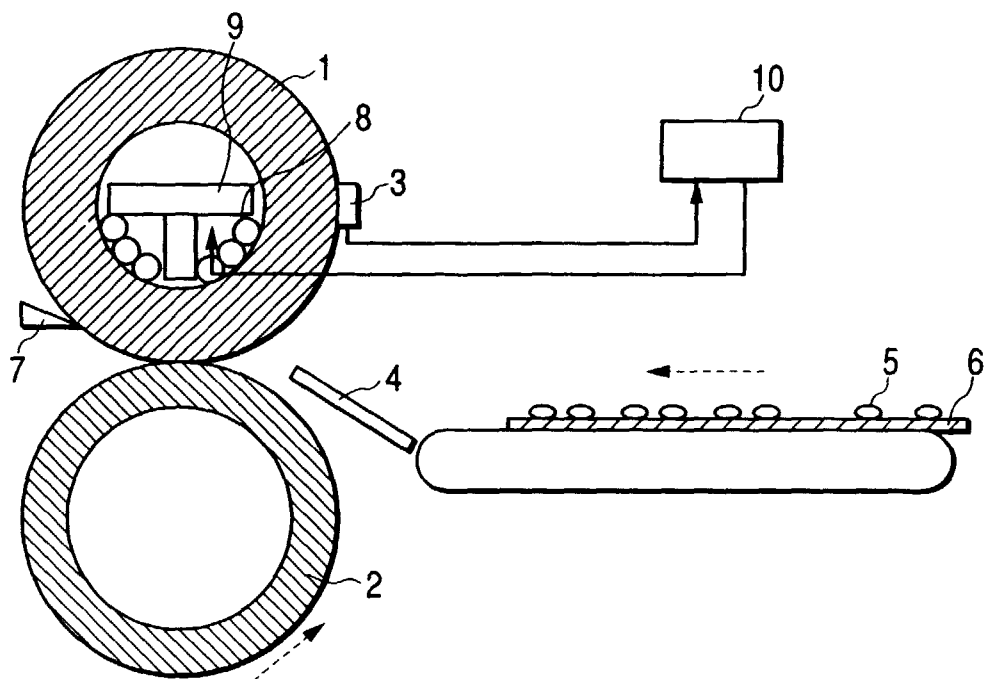


FIG. 2

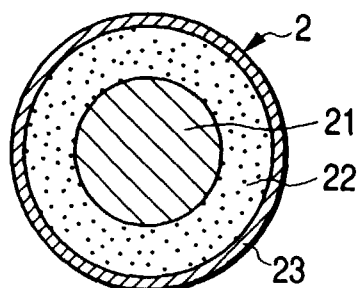


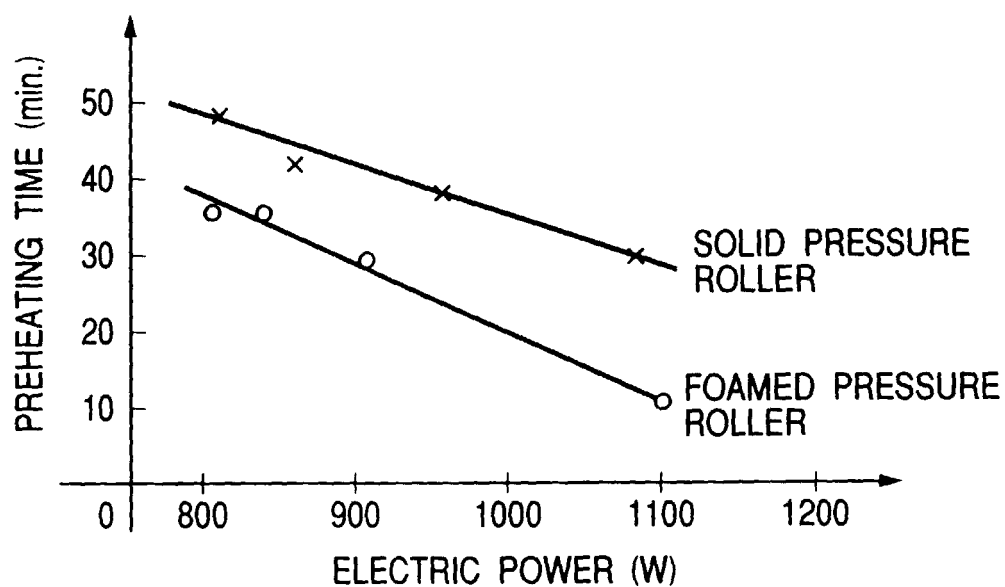
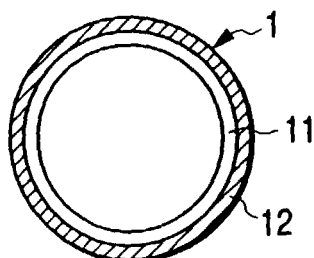
FIG. 3*FIG. 4*

FIG. 5

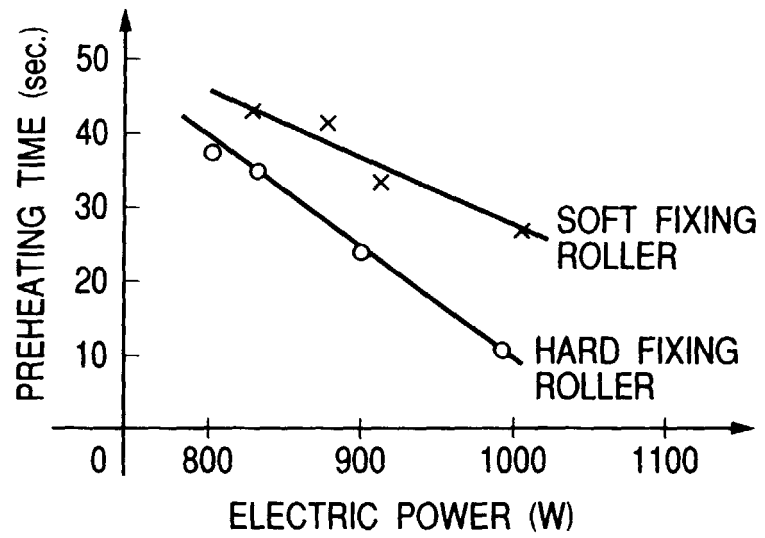


FIG. 6

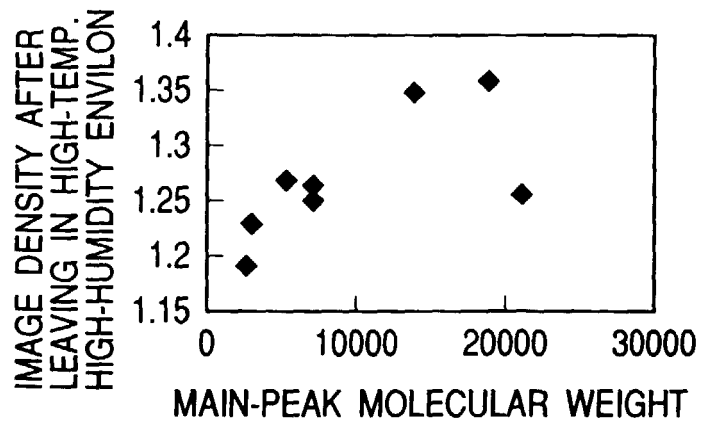


FIG. 7

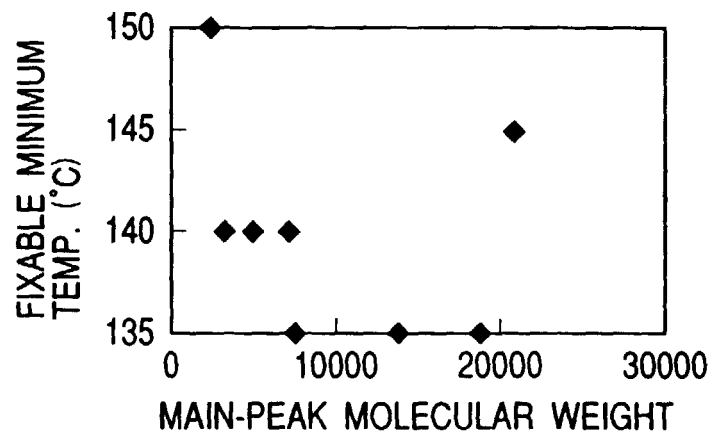


FIG. 8

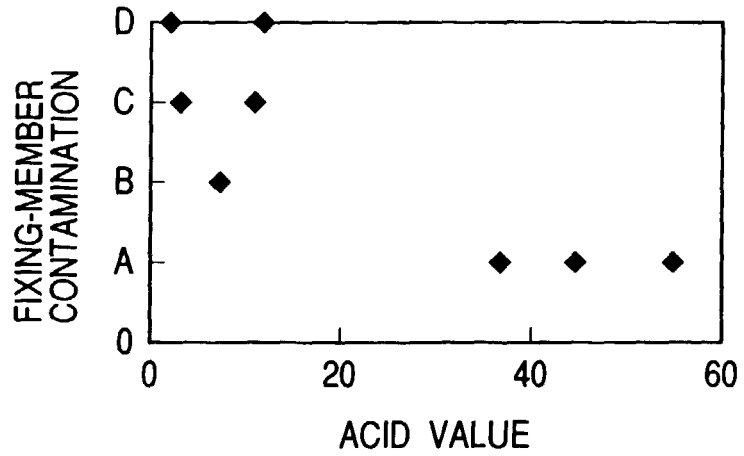


FIG. 9

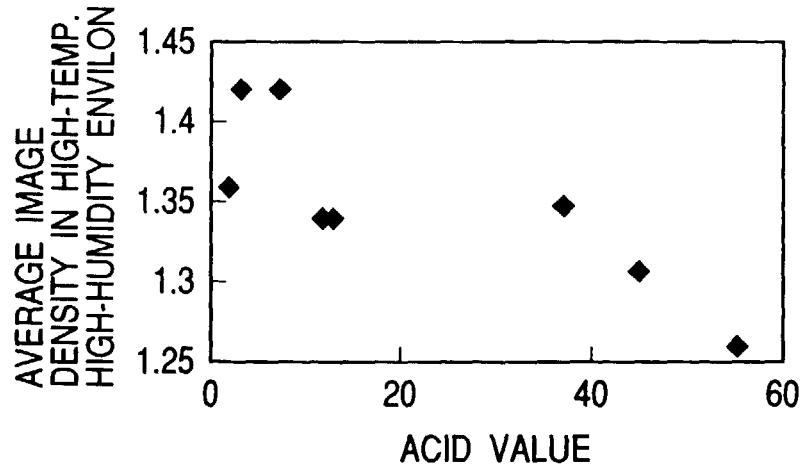


FIG. 10

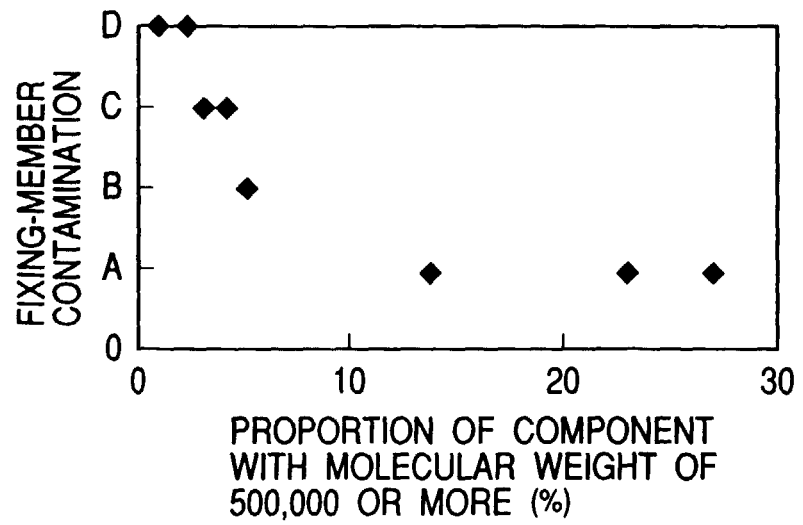


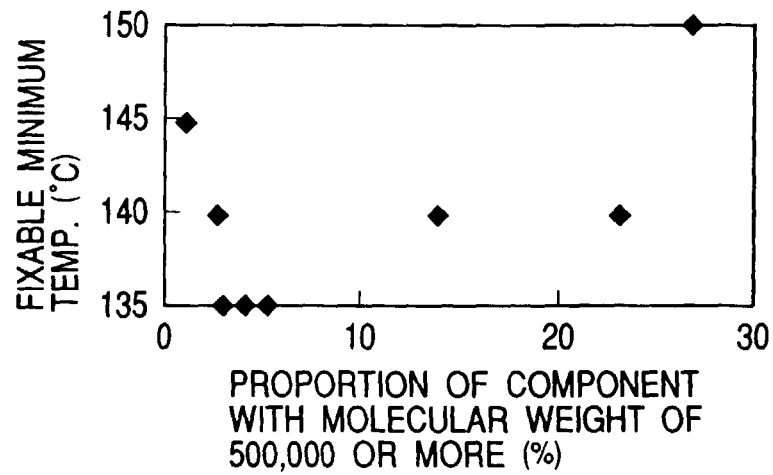
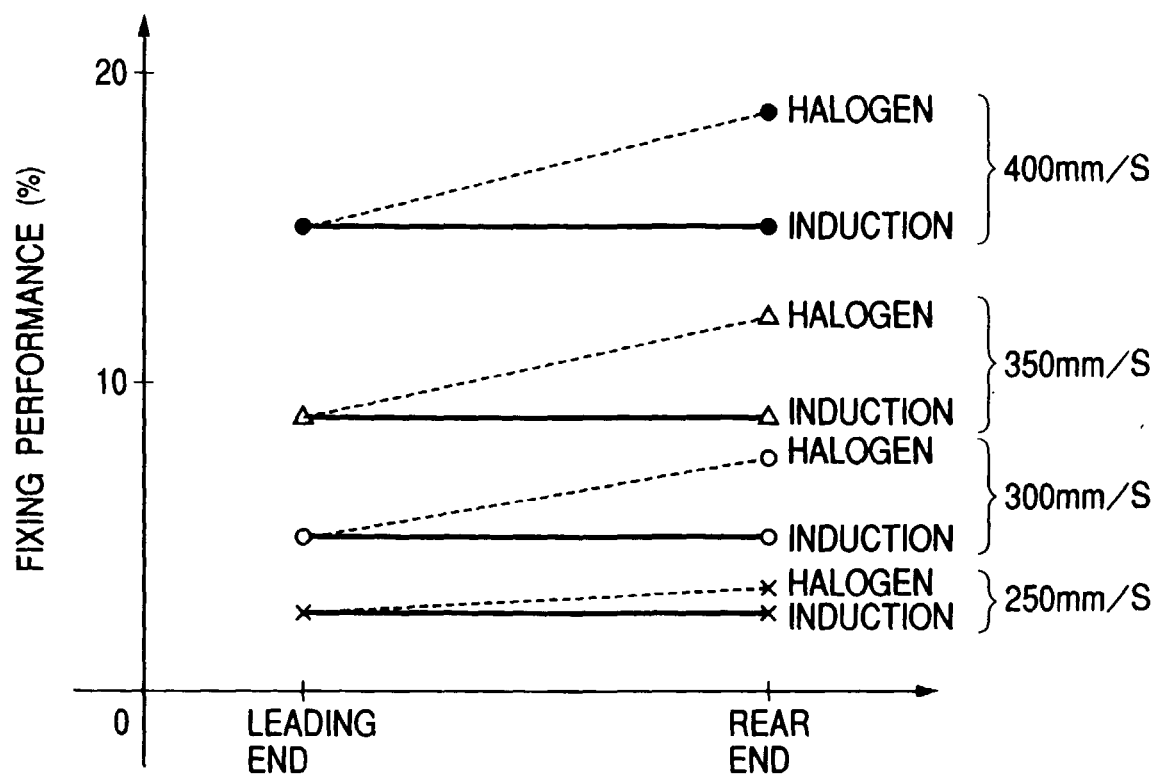
FIG. 11*FIG. 12*

FIG. 13

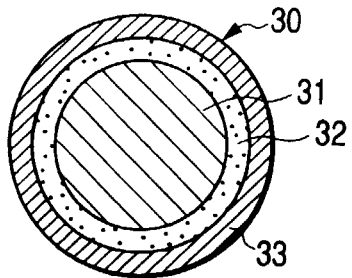


FIG. 14

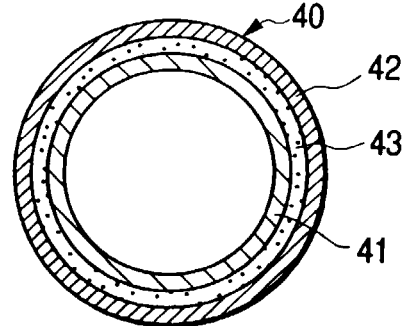


FIG. 15

