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(54) **FIXING DEVICE AND IMAGE FORMING APPARATUS WITH A CONTROLLER TO SWITCH BETWEEN A FIRST HEATING AND A SECOND HEATING**

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(58) **Field of Classification Search**
USPC 399/69
See application file for complete search history.

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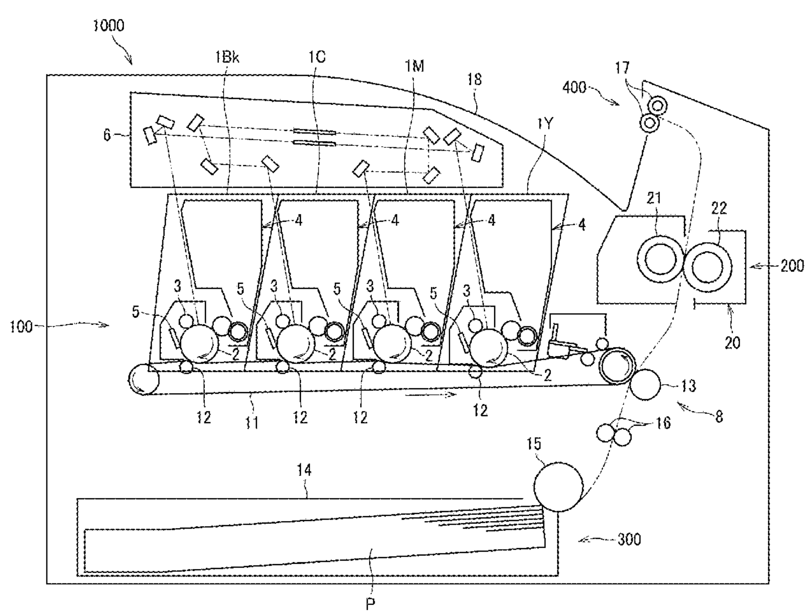
(57) **ABSTRACT**

A fixing device includes a first rotator and a second rotator that form a nip therebetween and fix an image on a recording medium that enters the nip. A heater heats at least one of the first rotator or the second rotator. A controller controls the heater to switch between a first heating and a second heating, to switch from the first heating to the second heating before the recording medium enters the nip, to start the second heating at a time prior to a nip entry time at which the recording medium enters the nip by a delay time period taken for the heater to conduct heat to the nip, and to continue the first heating before the second heating for at least one control cycle at a duty cycle of power supplied to the heater. The duty cycle is not greater than 40%.

8 Claims, 10 Drawing Sheets



(52) **U.S. Cl.**
CPC *G03G 2215/00978* (2013.01); *G03G 2215/2035* (2013.01)

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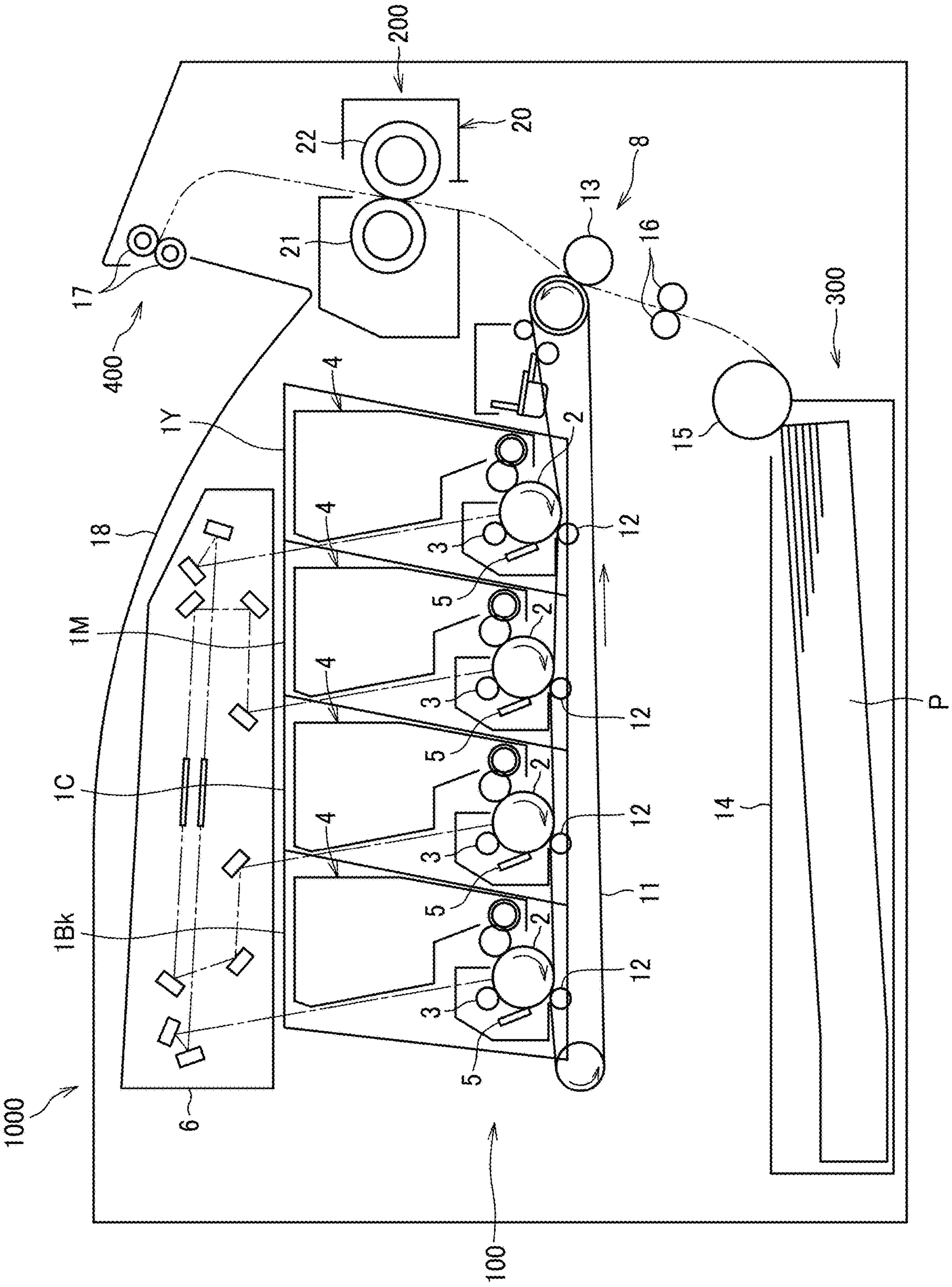
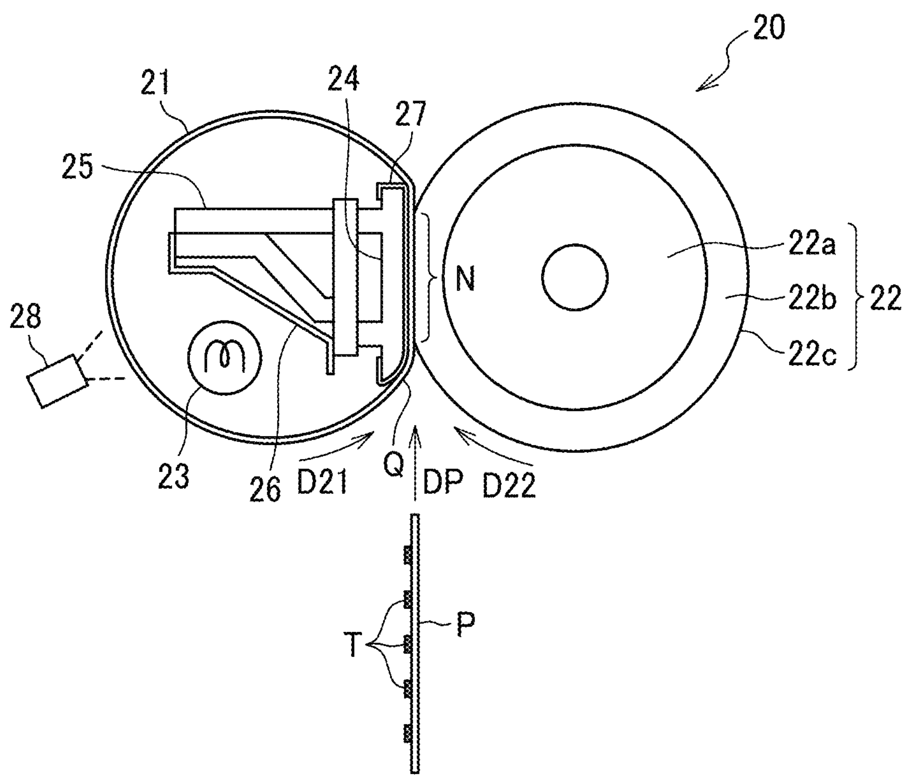

200
20
22
21
8
13
16
17
400
300
15
4
1Y
2
12
3
5
18
1M
1C
1Bk
11
14
P
6
1000
100

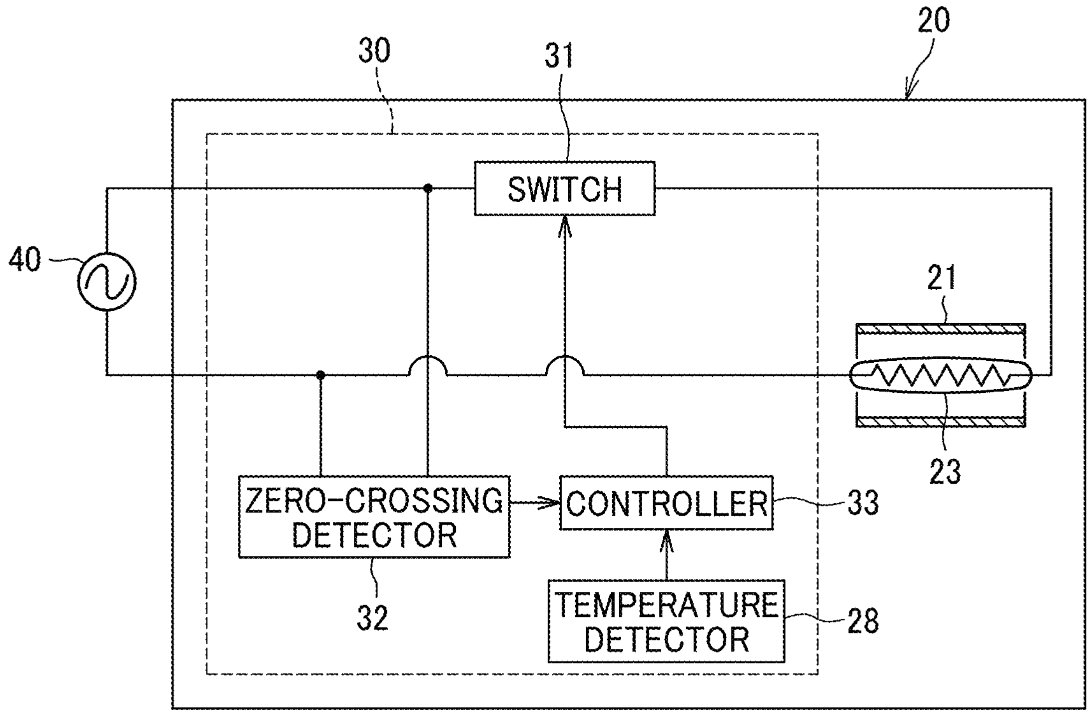
FIG. 1

FIG. 2



20
21
24
27
25
22a
N
22b
22
22c
28
23
26
D21
Q
DP
D22
T
P

FIG. 3



30
31
20
SWITCH
40
21
23
ZERO-CROSSING DETECTOR
CONTROLLER
33
32
TEMPERATURE DETECTOR
28

FIG. 4

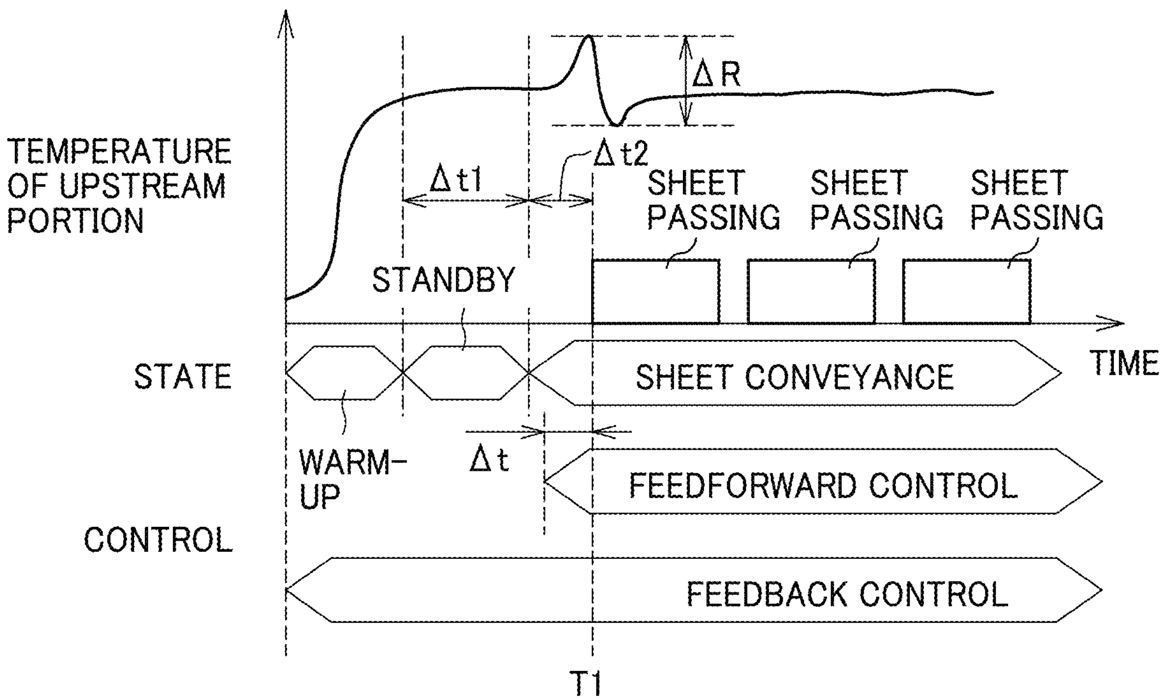

ΔR
Δt2
TEMPERATURE OF UPSTREAM PORTION
Δt1
SHEET PASSING
SHEET PASSING
SHEET PASSING
STANDBY
TIME
STATE
SHEET CONVEYANCE
WARM-UP
Δt
FEEDFORWARD CONTROL
CONTROL
FEEDBACK CONTROL
T1

FIG. 5

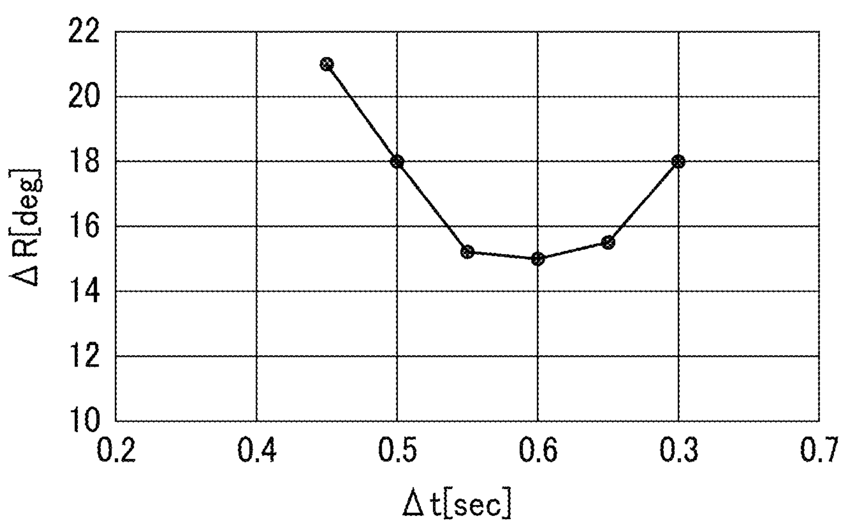

22
20
18
16
14
12
10
ΔR[deg]
0.2
0.4
0.5
0.6
0.3
0.7
Δt[sec]

FIG. 6A

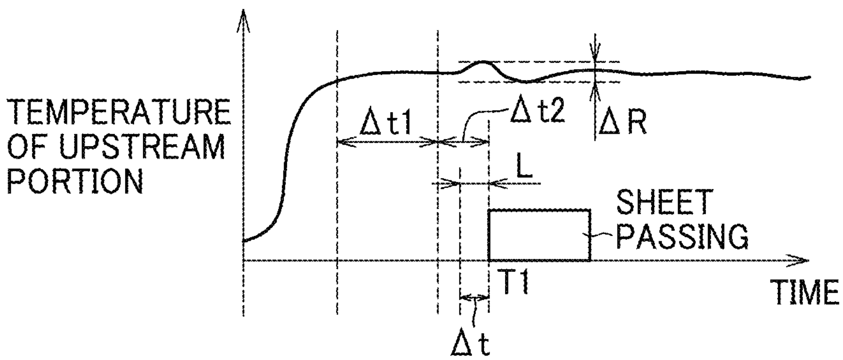


FIG. 6B

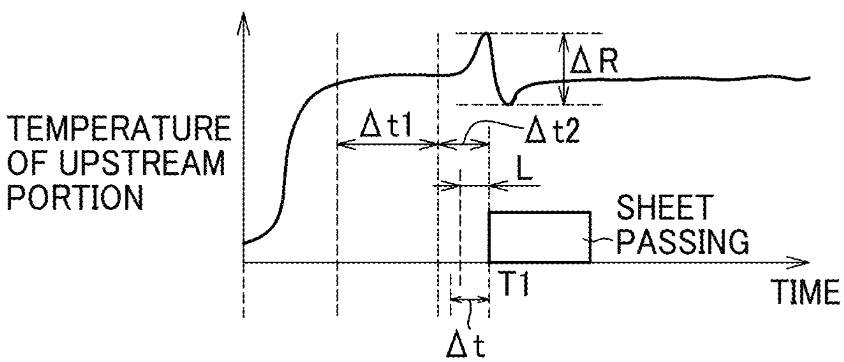


FIG. 6C

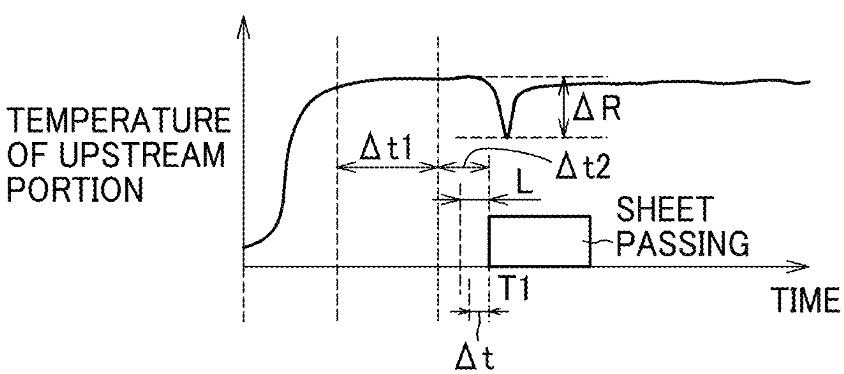


FIG. 7

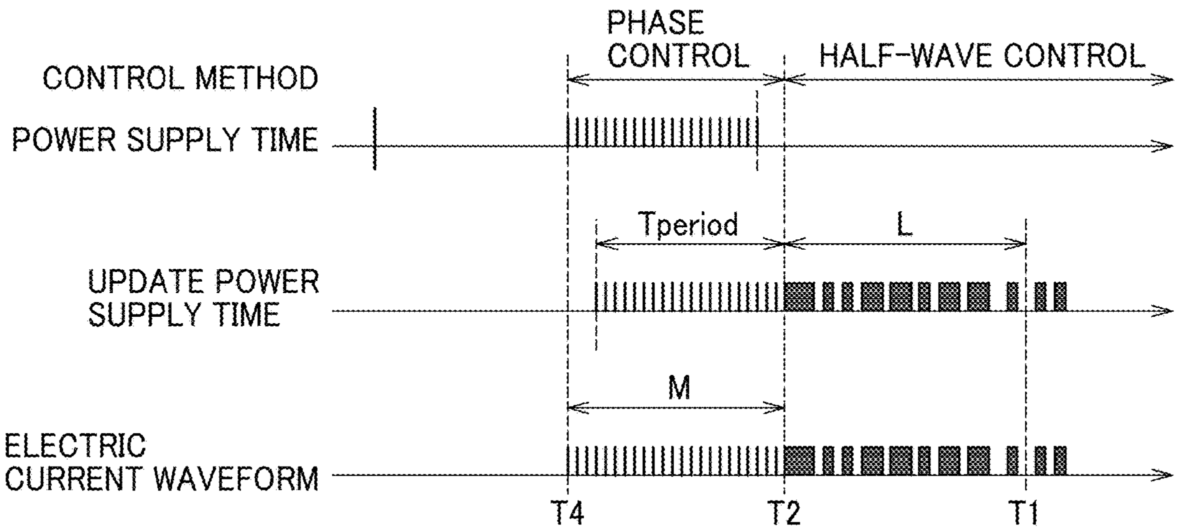


FIG. 8

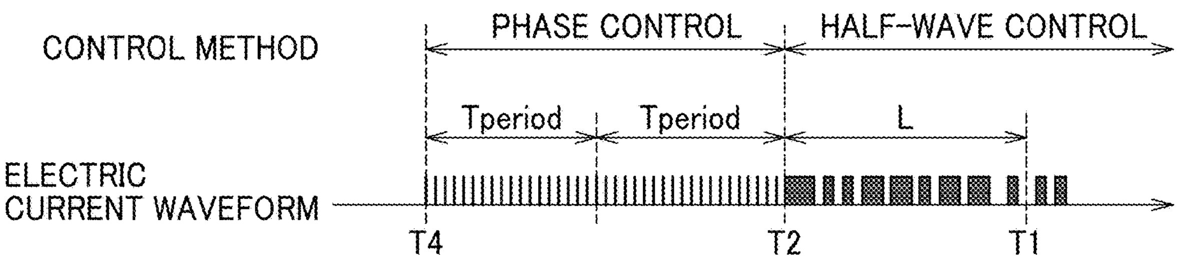


FIG. 9

FIG. 10

FIG. 11

FIG. 12

FIG. 13

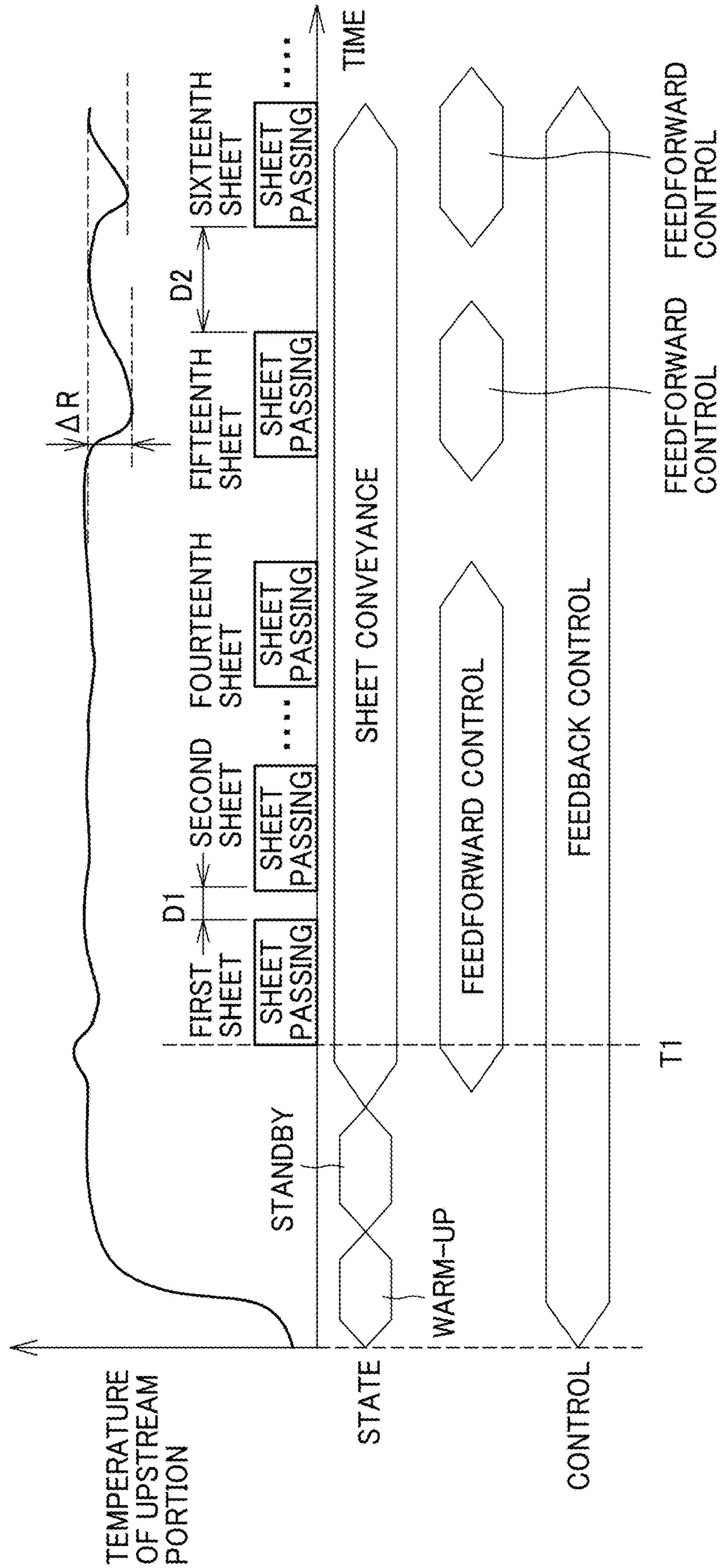

TEMPERATURE OF UPSTREAM PORTION
STATE
CONTROL
TIME
T1
ΔR
D1
D2
FIRST SHEET
SECOND SHEET
FOURTEENTH SHEET
FIFTEENTH SHEET
SIXTEENTH SHEET
SHEET PASSING
SHEET PASSING
SHEET PASSING
SHEET PASSING
SHEET PASSING
WARM-UP
STANDBY
SHEET CONVEYANCE
FEEDFORWARD CONTROL
FEEDFORWARD CONTROL
FEEDFORWARD CONTROL
FEEDBACK CONTROL

FIG. 14

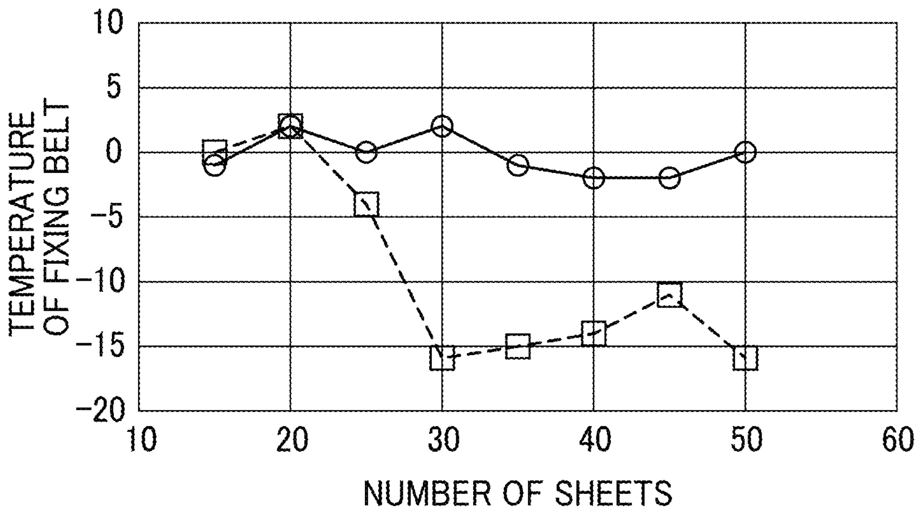

10
5
0
−5
−10
−15
−20
TEMPERATURE
OF FIXING BELT
10
20
30
40
50
60
NUMBER OF SHEETS

FIG. 15

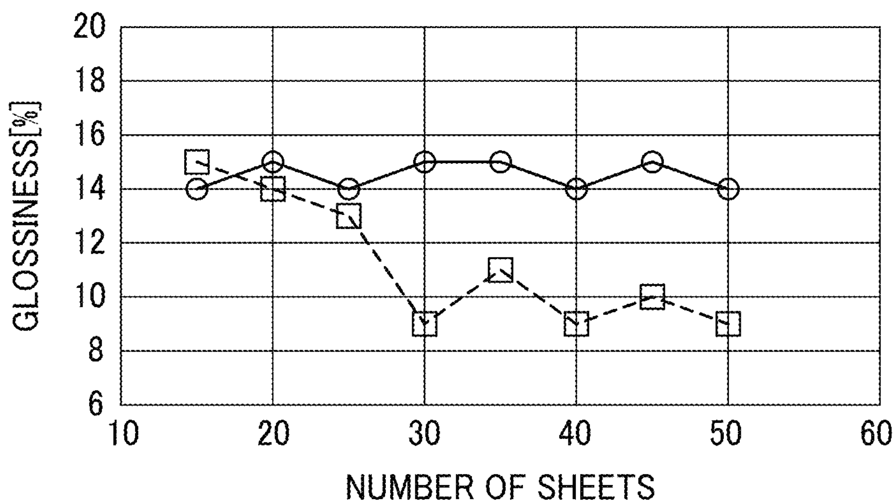

20
18
16
14
12
10
8
6
GLOSSINESS[%]
10
20
30
40
50
60
NUMBER OF SHEETS

FIG. 16

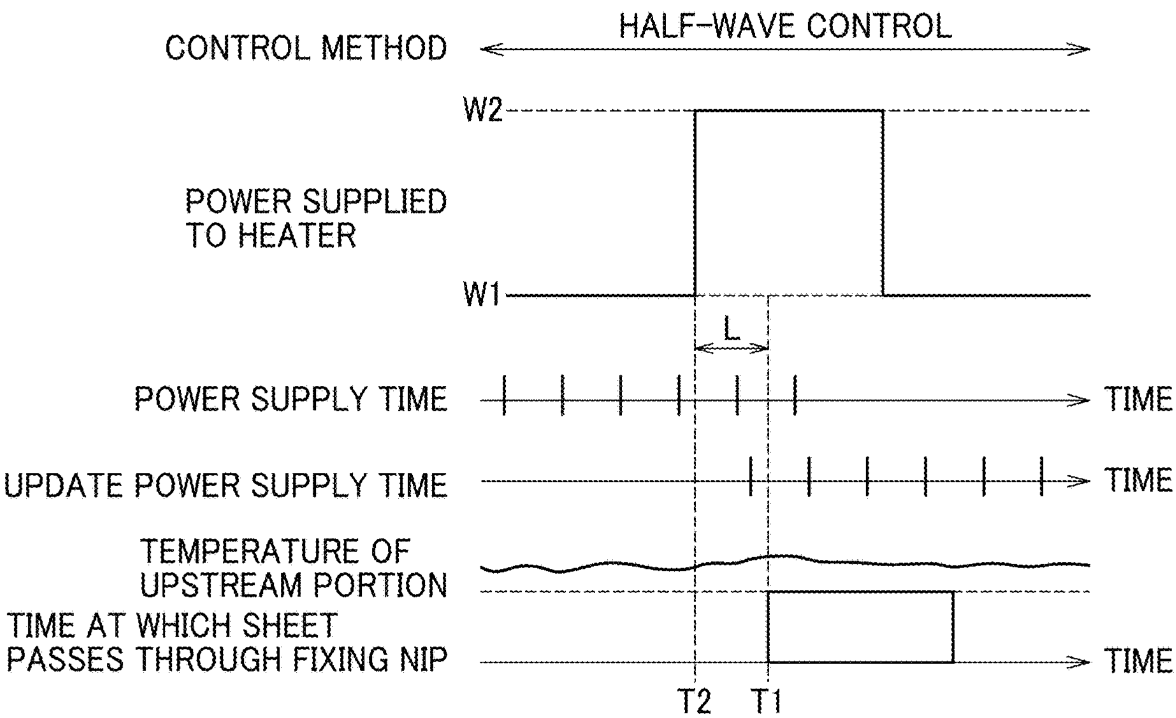

CONTROL METHOD
HALF-WAVE CONTROL
W2
POWER SUPPLIED TO HEATER
W1
L
POWER SUPPLY TIME
TIME
UPDATE POWER SUPPLY TIME
TIME
TEMPERATURE OF UPSTREAM PORTION
TIME AT WHICH SHEET PASSES THROUGH FIXING NIP
TIME
T2
T1

FIG. 17

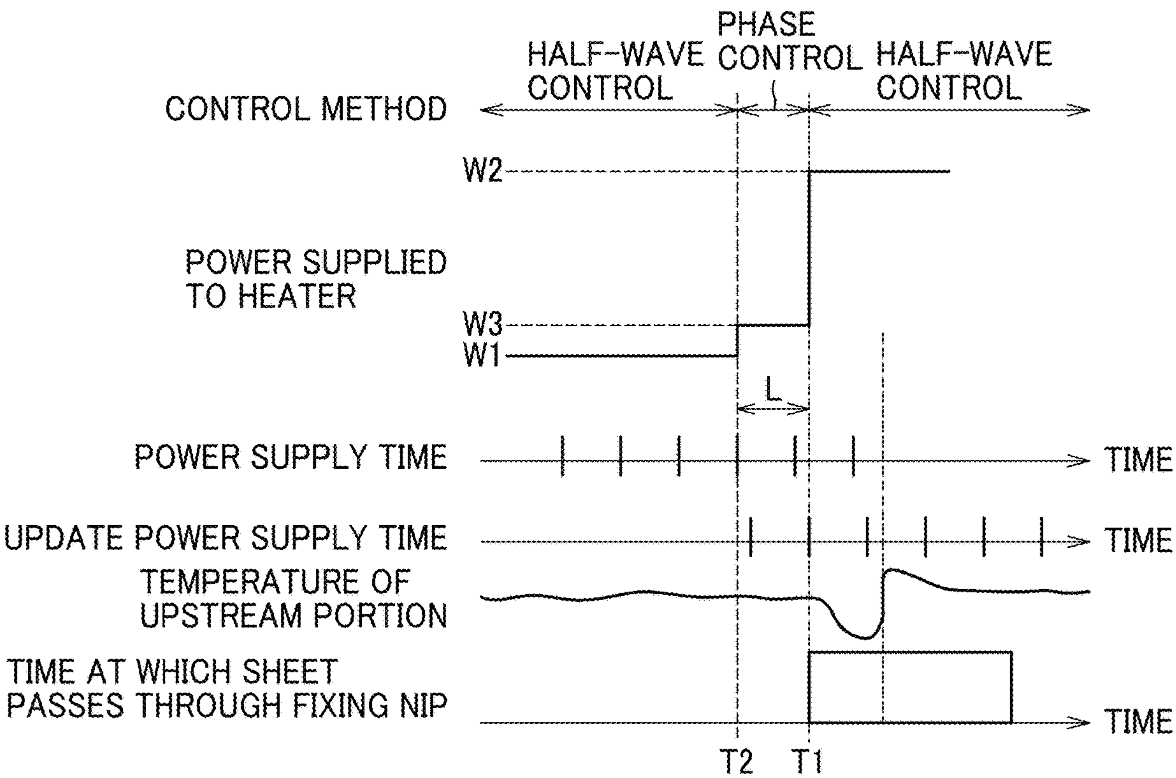

HALF-WAVE CONTROL
PHASE CONTROL
HALF-WAVE CONTROL
CONTROL METHOD
W2
POWER SUPPLIED TO HEATER
W3
W1
L
POWER SUPPLY TIME
TIME
UPDATE POWER SUPPLY TIME
TIME
TEMPERATURE OF UPSTREAM PORTION
TIME AT WHICH SHEET PASSES THROUGH FIXING NIP
TIME
T2
T1

FIG. 18

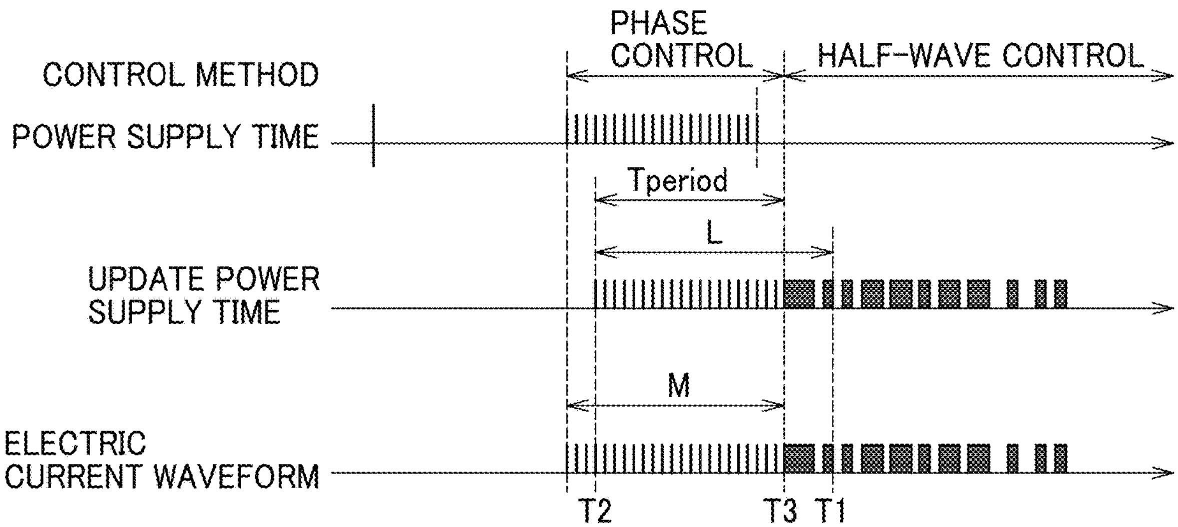


FIG. 19A

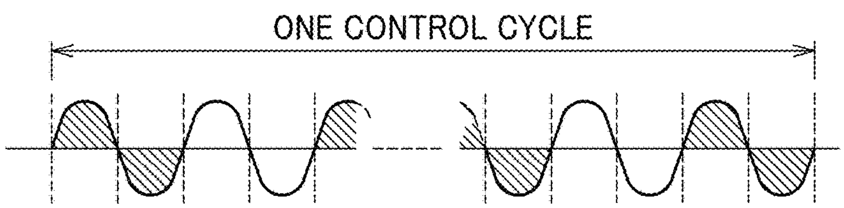
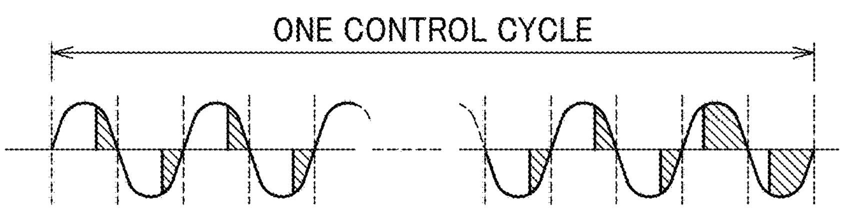


FIG. 19B



FIXING DEVICE AND IMAGE FORMING APPARATUS WITH A CONTROLLER TO SWITCH BETWEEN A FIRST HEATING AND A SECOND HEATING

CROSS-REFERENCE TO RELATED APPLICATION

This patent application is based on and claims priority pursuant to 35 U.S.C. § 119 (a) to Japanese Patent Application No. 2023-069423, filed on Apr. 20, 2023, in the Japan Patent Office, the entire disclosure of which is hereby incorporated by reference herein.

BACKGROUND

Technical Field

Embodiments of this disclosure relate to a fixing device and an image forming apparatus.

Related Art

Related-art image forming apparatuses, such as copiers, facsimile machines, printers, and multifunction peripherals (MFP) having two or more of copying, printing, scanning, facsimile, plotter, and other functions, typically form an image on a recording medium according to image data.

Such image forming apparatuses employ an electrophotographic method that forms a toner image on a recording medium such as a sheet.

For example, an image forming apparatus employing the electrophotographic method includes a fixing device that fixes a toner image on a recording medium under heat.

The fixing device includes a pair of rotators and a heater. The rotators contact each other to form a nip therebetween. The heater heats at least one of the rotators. As the heater is supplied with power from an alternating current power supply, the heater generates heat, heating the rotator to a target temperature at which the rotator fixes the toner image on the recording medium. As the recording medium enters the nip formed between the rotators, the rotator heats the unfixed toner image on the recording medium, fixing the unfixed toner image on the recording medium.

As the alternating current power supply supplies power to the heater, an alternating current voltage may fluctuate sharply. Accordingly, a fluorescent lamp that shares a power system with the fixing device may flicker.

SUMMARY

This specification describes below an improved fixing device. In one embodiment, the fixing device includes a first rotator and a second rotator that contacts the first rotator to form a nip between the first rotator and the second rotator. The first rotator and the second rotator fix an image on a recording medium that enters the nip under heat. A heater heats at least one of the first rotator or the second rotator. A controller controls the heater to switch between a first heating and a second heating, controls the heater to switch from the first heating to the second heating before the recording medium enters the nip, controls the heater to start the second heating at a time prior to a nip entry time at which the recording medium enters the nip by a delay time period taken for the heater to conduct heat to the nip, and controls the heater to continue the first heating before the second

heating for at least one control cycle at a duty cycle of power supplied to the heater. The duty cycle is not greater than 40%.

This specification further describes an improved image forming apparatus. In one embodiment, the image forming apparatus includes an image forming device that forms an image on a recording medium and the fixing device described above that fixes the image on the recording medium.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of embodiments of the present disclosure and many of the attendant advantages and features thereof can be readily obtained and understood from the following detailed description with reference to the accompanying drawings, wherein:

FIG. **1** is a schematic cross-sectional view of an image forming apparatus according to a first embodiment of the present disclosure;

FIG. **2** is a schematic cross-sectional view of a fixing device incorporated in the image forming apparatus depicted in FIG. **1**;

FIG. **3** is a block diagram of a heating control device incorporated in the fixing device depicted in FIG. **2**;

FIG. **4** is a timing chart illustrating conveyance of sheets through the fixing device depicted in FIG. **2** and a temperature control of the fixing device according to the first embodiment of the present disclosure;

FIG. **5** is a graph illustrating a relation between a start time at which the fixing device depicted in FIG. **2** starts a feedforward control and a temperature ripple at an upstream portion of a fixing belt of the fixing device, that is disposed upstream from a fixing nip formed between the fixing belt and a pressure roller;

FIG. **6**A is a graph illustrating one example of change of the temperature ripple that varies depending on the start time of the feedforward control;

FIG. **6**B is a graph illustrating another example of change of the temperature ripple that varies depending on the start time of the feedforward control;

FIG. **6**C is a graph illustrating yet another example of change of the temperature ripple that varies depending on the start time of the feedforward control;

FIG. **7** is a timing chart illustrating the temperature control according to the first embodiment of the present disclosure while the fixing device is heated;

FIG. **8** is a timing chart illustrating the temperature control according to a second embodiment of the present disclosure;

FIG. **9** is a graph illustrating a relation between a number of jobs and a temperature of the fixing belt according to an embodiment 1 and a comparative example 1;

FIG. **10** is a graph illustrating a relation between the number of jobs and a glossiness of an image formed on a sheet according to the embodiment 1 and the comparative example 1;

FIG. **11** is a graph illustrating the relation between the number of jobs and the temperature of the fixing belt according to an embodiment 2 and a comparative example 2;

FIG. **12** is a graph illustrating the relation between the number of jobs and the glossiness of the image formed on the sheet according to the embodiment 2 and the comparative example 2;

FIG. **13** is a timing chart illustrating conveyance of plain paper having a B4 size through the fixing device depicted in FIG. **2** and the temperature control of the fixing device;

FIG. **14** is a graph illustrating a relation between a number of sheets conveyed through the fixing device and the temperature of the fixing belt according to an embodiment 3 and a comparative example 3;

FIG. **15** is a graph illustrating the relation between the number of sheets conveyed through the fixing device and the glossiness of the image formed on the sheet according to the embodiment 3 and the comparative example 3;

FIG. **16** is a timing chart as one example of a feedforward control that supplies a predetermined amount of power before a sheet enters the fixing nip;

FIG. **17** is a timing chart illustrating a temperature control while a sheet is conveyed through a comparative fixing device that is heated;

FIG. **18** is a timing chart illustrating a comparative phase control and a comparative half-wave control;

FIG. **19**A is a diagram illustrating a half-wave control method; and

FIG. **19**B is a diagram illustrating a phase control method.

The accompanying drawings are intended to depict embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted. Also, identical or similar reference numerals designate identical or similar components throughout the several views.

DETAILED DESCRIPTION

In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that have a similar function, operate in a similar manner, and achieve a similar result.

Referring now to the drawings, embodiments of the present disclosure are described below. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

Referring to the attached drawings, the following describes the embodiments of the present disclosure. In the drawings for explaining the embodiments of the present disclosure, identical reference numerals are assigned to elements such as members and parts that have an identical function or an identical shape as long as differentiation is possible and a description of the elements is omitted once the description is provided.

A description is provided of a first embodiment of the present disclosure.

FIG. **1** is a schematic cross-sectional view of an image forming apparatus **1000** according to the first embodiment of the present disclosure. The image forming apparatus **1000** is a printer. Alternatively, the image forming apparatus **1000** may be a copier, a facsimile machine, a printing machine, a multifunction peripheral (MFP) having at least two of printing, copying, facsimile, scanning, and plotter functions, or the like. Image formation described below denotes forming an image having meaning such as characters and figures and an image not having meaning such as patterns. Referring to FIG. **1**, a description is provided of an overall construction and operation of the image forming apparatus **1000** according to the first embodiment of the present disclosure.

A description is provided of the overall construction of the image forming apparatuses **1000**.

As illustrated in FIG. **1**, the image forming apparatus **1000** according to the first embodiment includes an image forming portion **100**, a fixing portion **200**, a recording medium supply portion **300**, and a recording medium ejecting portion **400**. The image forming portion **100**, serving as an image forming device, forms a toner image on a sheet P serving as a recording medium. The fixing portion **200** fixes the toner image on the sheet P. The recording medium supply portion **300** supplies the sheet P to the image forming portion **100**. The recording medium ejecting portion **400** ejects the sheet Ponto an outside of the image forming apparatus **1000**.

A description is provided of a construction of the image forming portion **100**.

The image forming portion **100** includes four image forming units **1**Y, **1**M, **1**C, and **1**Bk, an exposure device **6**, and a transfer device **8**. The exposure device **6** forms an electrostatic latent image on a photoconductor **2** of each of the image forming units **1**Y, **1**M, **1**C, and **1**Bk. The transfer device **8** transfers the toner image onto the sheet P.

The image forming units **1**Y, **1**M, **1**C, and **1**Bk basically have similar constructions, respectively. However, the image forming units **1**Y, **1**M, **1**C, and **1**Bk contain toners, serving as developers, in different colors, that is, yellow, magenta, cyan, and black, respectively, which correspond to color separation components for a color image. For example, each of the image forming units **1**Y, **1**M, **1**C, and **1**Bk includes the photoconductor **2**, a charger **3**, a developing device **4**, and a cleaner **5**. The photoconductor **2** serves as an image bearer that bears an image (e.g., an electrostatic latent image and a toner image) on a surface of the photoconductor **2**. The charger **3** charges the surface of the photoconductor **2**. The developing device **4** supplies the toner as the developer to the surface of the photoconductor **2** to form a toner image. The cleaner **5** cleans the surface of the photoconductor **2**.

The transfer device **8** includes an intermediate transfer belt **11**, four primary transfer rollers **12**, and a secondary transfer roller **13**. The intermediate transfer belt **11** is an endless belt that is stretched taut across a plurality of support rollers. The four primary transfer rollers **12** are disposed within a loop formed by the intermediate transfer belt **11**. The primary transfer rollers **12** are pressed against the photoconductors **2**, respectively, via the intermediate transfer belt **11**, thus forming primary transfer nips between the intermediate transfer belt **11** and the photoconductors **2**. The secondary transfer roller **13** contacts an outer circumferential surface of the intermediate transfer belt **11** to form a secondary transfer nip therebetween.

A description is provided of a construction of the fixing portion **200**.

The fixing portion **200** includes a fixing device **20** that heats the sheet P, fixing the toner image on the sheet P. The fixing device **20** includes a pair of rotators, that is, a fixing rotator **21** and a pressure rotator **22**, that contact each other to form a fixing nip therebetween.

A description is provided of a construction of the recording medium supply portion **300**.

The recording medium supply portion **300** includes a sheet tray **14** (e.g., a paper tray) and a feed roller **15**. The sheet tray **14** loads a plurality of sheets P serving as recording media. The feed roller **15** picks up and feeds a sheet P from the sheet tray **14**. According to the embodiments below, a sheet (e.g., a sheet P) is used as a recording medium. However, the recording medium is not limited to paper as the sheet. In addition to paper as the sheet, the recording media include an overhead projector (OHP) transparency, cloth, a metal sheet, plastic film, and a prepreg sheet pre-impregnated with resin in carbon fibers. In addition to plain paper, the sheets include thick paper, a postcard, an envelope, thin paper, coated paper, art paper, and tracing paper.

A description is provided of a construction of the recording medium ejecting portion **400**.

The recording medium ejecting portion **400** includes an output roller pair **17** and an output tray **18**. The output roller pair **17** ejects the sheet P onto the outside of the image forming apparatus **1000**. The output tray **18** is placed with the sheet P ejected by the output roller pair **17**. The image forming apparatus **1000** further includes a timing roller pair **16**.

Referring to FIG. **1**, a description is provided of image forming processes performed by the image forming apparatus **1000** according to the first embodiment of the present disclosure.

As the image forming apparatus **1000** receives an instruction to start printing, a driver starts driving and rotating the photoconductor **2** of each of the image forming units **1**Y, **1**M, **1**C, and **1**Bk and the intermediate transfer belt **11** of the transfer device **8**. The feed roller **15** starts rotation, feeding a sheet P from the sheet tray **14**. As the sheet P fed by the feed roller **15** comes into contact with the timing roller pair **16**, the timing roller pair **16** temporarily halts the sheet P. Thus, the timing roller pair **16** temporarily interrupts conveyance of the sheet P until the toner image, that is to be transferred onto the sheet P, is formed on the intermediate transfer belt **11**.

The charger **3** of each of the image forming units **1**Y, **1**M, **1**C, and **1**Bk charges the surface of the photoconductor **2** evenly at a high electric potential. The exposure device **6** exposes the charged surfaces of the photoconductors **2**, respectively, according to image data (e.g., print data) sent from a terminal. Alternatively, if the image forming apparatus **1000** is a copier, the exposure device **6** exposes the charged surfaces of the photoconductors **2**, respectively, according to image data created by a scanner that reads an image on an original. Accordingly, the electric potential of an exposed portion on the surface of each of the photoconductors **2** decreases, forming an electrostatic latent image on the surface of each of the photoconductors **2**. The developing device **4** of each of the image forming units **1**Y, **1**M, **1**C, and **1**Bk supplies toner to the electrostatic latent image formed on the photoconductor **2**, forming a toner image thereon. When the toner images formed on the photoconductors **2** reach the primary transfer nips defined by the primary transfer rollers **12** in accordance with rotation of the photoconductors **2**, respectively, the primary transfer rollers **12** transfer the toner images formed on the photoconductors **2** onto the intermediate transfer belt **11** driven and rotated counterclockwise in FIG. **1** successively such that the toner images are superimposed on the intermediate transfer belt **11**. Thus, the superimposed toner images form a full color toner image on the intermediate transfer belt **11**. Alternatively, one of the four image forming units **1**Y, **1**M, **1**C, and **1**Bk may be used to form a monochrome toner image or two or three of the four image forming units **1**Y, **1**M, **1**C, and **1**Bk may be used to form a bicolor toner image or a tricolor toner image. After the toner image formed on the photoconductor **2** is transferred onto the intermediate transfer belt **11**, the cleaner **5** removes residual toner and the like remaining on the photoconductor **2** therefrom.

The full color toner image formed on the intermediate transfer belt **11** is conveyed to the secondary transfer nip defined by the secondary transfer roller **13** in accordance with rotation of the intermediate transfer belt **11** and is transferred onto the sheet P conveyed by the timing roller pair **16**. The sheet P transferred with the full color toner image is conveyed to the fixing device **20**. As the sheet P passes through the fixing nip formed between the fixing rotator **21** and the pressure rotator **22** that contact each other, the fixing rotator **21** and the pressure rotator **22** fix the full color toner image on the sheet P under heat and pressure. The sheet P is conveyed to the recording medium ejecting portion **400** where the output roller pair **17** ejects the sheet P onto the output tray **18**. Thus, a series of image forming processes is finished.

Referring to FIG. **2**, a description is provided of a construction of the fixing device **20** according to the first embodiment of the present disclosure.

As illustrated in FIG. **2**, in addition to the pair of rotators, that is, the fixing rotator **21** and the pressure rotator **22**, the fixing device **20** according to the embodiment includes a heater **23**, a nip formation pad **24**, a support **25**, a reflector **26**, a slide aid **27**, and a temperature detector **28**.

The fixing rotator **21** is one of the rotators and serves as a first rotator. The fixing rotator **21** contacts an unfixed toner image bearing side of the sheet P, that bears an unfixed toner image T (e.g., unfixed toner), and fixes the unfixed toner image T on the sheet P. The pressure rotator **22** is another one of the rotators and serves as a second rotator. The pressure rotator **22** contacts the fixing rotator **21** to form a fixing nip N between the fixing rotator **21** and the pressure rotator **22**.

According to the embodiment, the fixing rotator **21** is an endless belt (e.g., a fixing belt) that has flexibility. The pressure rotator **22** is a roller (e.g., a pressure roller) that includes an elastic layer. The fixing rotator **21** may be a roller instead of the belt. The pressure rotator **22** may be a belt instead of the roller.

For example, the fixing rotator **21** is the belt having an outer diameter of 30 mm and a length of 360 mm in a longitudinal direction of the fixing rotator **21**. The fixing rotator **21** includes an inner coating layer as an innermost layer, a base layer, a thermal conduction layer, an elastic layer, and a release layer as an outermost layer. The inner coating layer has a thickness of 10 μm, for example. The base layer is made of nickel and has a thickness of 30 μm, for example. The thermal conduction layer is made of copper and has a thickness of 10 μm, for example. The elastic layer is made of silicone rubber and has a thickness of 120 μm, for example. The release layer is made of perfluoroalkoxy alkane (PFA) and has a thickness of 7 μm, for example.

For example, the pressure rotator **22** is the roller having an outer diameter of 32 mm and a length of 340 mm in a longitudinal direction of the pressure rotator **22**. The pressure rotator **22** includes a core **22***a* (e.g., a core metal) as an innermost layer, an elastic layer **22***b*, and a release layer **22***c* as an outermost layer. For example, the core **22***a* is made of iron and has an outer diameter of 24 mm. The core **22***a* is solid or hollow. The elastic layer **22***b* is made of foam rubber and has a thickness of 4 mm, for example. The release layer **22***c* is made of PFA and has a thickness of 50 μm, for example.

The heater **23** radiates thermal energy including an electromagnetic wave such as infrared light onto a target object, thus heating the target object without contacting the target object. According to the embodiment, the heater **23** is a halogen heater that emits infrared light onto the target object, heating the target object. The halogen heater is disposed within a loop formed by the fixing rotator **21**. The halogen heater emits infrared light that irradiates an inner circumferential face of the fixing rotator **21**, thus heating the fixing rotator **21** on the inner circumferential face thereof. Alternatively, the heater **23** may heat the pressure rotator **22** instead of the fixing rotator **21**.

The nip formation pad **24** is disposed within the loop formed by the fixing rotator **21**. The nip formation pad **24** and the pressure rotator **22** sandwich the fixing rotator **21** and define the fixing nip N between the fixing rotator **21** and the pressure rotator **22**. The nip formation pad **24** is made of heat-resistant resin, for example. The nip formation pad **24** presses against an outer circumferential face of the pressure rotator **22** via the fixing rotator **21**, forming the fixing nip N between the fixing rotator **21** and the pressure rotator **22**.

The support **25** supports the nip formation pad **24**. The support **25** supports an opposite face of the nip formation pad **24**, that is opposite to a fixing nip opposed face of the nip formation pad **24**, that is disposed opposite the fixing rotator **21** and the fixing nip N. Hence, the support **25** receives pressure from the pressure rotator **22**, suppressing a bend of the nip formation pad **24**. Thus, the support **25** causes the nip formation pad **24** to form the fixing nip N that has an even width in a sheet conveyance direction DP throughout an entire span of the fixing rotator **21** in the longitudinal direction thereof. According to the embodiment, the fixing nip N includes a center portion and both lateral end portions in the longitudinal direction of the fixing rotator **21**. The center portion has a width of 10 mm in the sheet conveyance direction DP. Each of the lateral end portions has a width of 10.5 mm in the sheet conveyance direction DP. The fixing nip N is applied with pressure of 25 kgf, for example.

The reflector **26** reflects thermal energy radiated from the heater **23** toward the fixing rotator **21**. As the heater **23** radiates thermal energy, the reflector **26** reflects the thermal energy toward the fixing rotator **21**, facilitating heating of the fixing rotator **21**. According to the embodiment, the reflector **26** is interposed between the heater **23** and the support **25**, preventing the heater **23** from supplying redundant thermal energy to the support **25**.

The slide aid **27** is interposed between the nip formation pad **24** and the fixing rotator **21** and is made of a low friction material. The slide aid **27** is made of polytetrafluoroethylene (PTFE) or the like, for example. Since the slide aid **27** is interposed between the nip formation pad **24** and the fixing rotator **21**, the slide aid **27** decreases sliding friction that generates between the nip formation pad **24** and the fixing rotator **21** that slides over the nip formation pad **24**.

The temperature detector **28** detects a temperature of the fixing rotator **21**. For example, the temperature detector **28** is disposed opposite an outer circumferential face of the fixing rotator **21** in a center portion of the fixing rotator **21** in the longitudinal direction thereof. For example, general temperature sensors such as a thermopile, a thermostat, a thermistor, and a normally closed (NC) sensor are used as the temperature detector **28**. The temperature detector **28** is a non-contact type temperature sensor that does not contact the outer circumferential face of the fixing rotator **21**. Alternatively, the temperature detector **28** may be a contact type temperature sensor that contacts the fixing rotator **21**.

A description is provided of operation of the fixing device **20** according to the embodiment.

As the image forming apparatus **1000** starts a print job, a driver starts driving and rotating the pressure rotator **22** clockwise in FIG. **2** in a rotation direction D**22**. The pressure rotator **22** drives and rotates the fixing rotator **21** in a rotation direction D**21**. The heater **23** starts generating heat, heating the fixing rotator **21**. As illustrated in FIG. **3**, the fixing device **20** further includes a controller **33**. The controller **33** controls the heater **23** based on a temperature of the fixing rotator **21**, that is detected by the temperature detector **28**, thus retaining the temperature of the fixing rotator **21** at a predetermined fixing temperature at which the fixing rotator **21** fixes the toner image T on the sheet P. Thereafter, the sheet P bearing the unfixed toner image T is conveyed to the fixing device **20**. As the sheet P enters the fixing nip N formed between the fixing rotator **21** and the pressure rotator **22**, the fixing rotator **21** and the pressure rotator **22** heat and press the sheet P and the unfixed toner image T on the sheet P, fixing the unfixed toner image T on the sheet P.

A description is provided of a configuration of a comparative fixing device that suppresses generation of flickers.

The comparative fixing device employs a half-wave control and a phase control as a control method for controlling a heater of the comparative fixing device.

However, the control method of the comparative fixing device may not suppress generation of flickers while improving fixing of a toner image on a sheet.

A description is provided of disadvantages of a temperature control of the comparative fixing device for controlling a temperature of a fixing rotator.

As the temperature control, the comparative fixing device performs a feedback control that controls heat generation of the heater based on a temperature of the fixing rotator, that is detected by a temperature detector. For example, the comparative fixing device includes a controller that calculates a duty cycle at which the heater is supplied with power based on the detected temperature. The controller controls power supplied to the heater based on the calculated duty cycle. The duty cycle (e.g., a duty cycle D) denotes a rate of an energization time W per control cycle C for energizing the heater (D=W/C). The duty cycle is also called a duty. The controller controls the heater under the feedback control based on the duty cycle calculated based on the detected temperature, thus retaining the temperature of the fixing rotator at a predetermined fixing temperature at which the fixing rotator fixes a toner image on a sheet.

However, when the sheet enters a fixing nip formed between the fixing rotator and a pressure rotator, the sheet may draw heat from the fixing rotator and the pressure rotator, causing temperature decrease of the fixing rotator at the fixing nip. For example, if the fixing rotator is a belt that has a thermal capacity smaller than a thermal capacity of a roller, the belt may suffer from substantial temperature decrease at the fixing nip when the sheet enters the fixing nip.

Hence, in order to prevent temperature decrease of the fixing rotator at the fixing nip, the comparative fixing device performs a feedforward control that supplies a predetermined amount of power to the heater at a predetermined time before the sheet enters the fixing nip.

Referring to FIGS. **16**, **17**, **18**, **19**A, and **19**B, a description is provided of the feedforward control.

FIG. **16** is a timing chart of the feedforward control as one example.

As illustrated in FIG. **16**, at a time T**2** that is prior to a nip entry time T**1** at which a leading end of the sheet enters the fixing nip by a predetermined time period, that is, a delay time period L, the feedforward control supplies predetermined power W**2** (e.g., a predetermined amount of power) to the heater. The predetermined time period, that is, the delay time period L, is from a time when the heater is supplied with power until heat generated by the heater is conducted to the fixing nip. Hence, the controller resets a start of a control cycle for supplying the predetermined power W**2** to the heater to the time T**2** that is prior to the nip entry time T**1** at which the leading end of the sheet enters the fixing nip by the delay time period L. Thus, the controller starts supplying the predetermined power W**2** to the heater at the time T**2** that is prior to the nip entry time T**1** by the delay time period L. Accordingly, heat in a proper amount is conducted to the sheet at the nip entry time T**1**, suppressing temperature decrease of the fixing rotator in response to the leading end of the sheet that enters the fixing nip.

FIG. **16** illustrates the half-wave control as a control method that controls the heater. As illustrated in FIG. **19**A, the half-wave control (e.g., a half-wave controlled rectifier) is the control method that supplies power to the heater per half wave shaded in FIG. **19**A (e.g., one-half of an alternating current cycle) of an alternating current from an alternating current power supply. Under the half-wave control, the controller supplies the predetermined power W**2** to the heater at the time T**2** that is prior to the nip entry time T**1**. However, when the comparative fixing device is in a heated state in which the comparative fixing device stores heat sufficiently, the controller may supply power in a decreased amount. Accordingly, an amount of power supplied to the heater may be below a power threshold Wh, degrading or breaking a filament of a halogen heater serving as the heater. Hence, when the comparative fixing device is in the heated state, in view of preventing degradation and breakage of the heater, in order to prevent the heater from being supplied with the amount of power that is below the power threshold Wh, the controller controls the duty cycle not greater than a predetermined value to zero. However, after the duty cycle is zero, when the alternating current power supply supplies the predetermined power W**2** to the heater, the amount of power may change sharply, generating flickers.

In order to suppress flickers, as illustrated in FIG. **17**, the comparative fixing device may employ the phase control, that is different from the half-wave control, to supply power to the heater. As illustrated in FIG. **19**B, the phase control (e.g., a phase-controlled rectifier) is the control method that supplies power to the heater per predetermined phase angle shaded in FIG. **19**B of one half wave (e.g., one-half of the alternating current cycle) of the alternating current from the alternating current power supply.

Under the phase control, the controller starts supplying power to the heater at a slight duty cycle. Hence, the controller disperses a rate of supply and interruption of power within one control cycle, suppressing flickers. However, slight power W**3** depicted in FIG. **17** supplied before the sheet enters the fixing nip is smaller than the predetermined power W**2**. Accordingly, temperature decrease may occur at the fixing nip, resulting in faulty fixing such as degradation of gloss of the toner image formed on the sheet.

As illustrated in FIG. **18**, if the controller resets the control cycle during the phase control, the controller suppresses flickers effectively. Hence, the phase control continues for a time period M that is not shorter than one control cycle Tperiod. For example, the one control cycle Tperiod defines 200 msec of 20 half waves at 50 Hz. After the controller starts the phase control, if the controller resets the control cycle for one half wave, the controller suppresses flickers insufficiently. Hence, the phase control continues for another control cycle Tperiod. However, the controller starts supplying power to the heater under the half-wave control at a power supply start time T**3** that is delayed from the time T**2** that is prior to the nip entry time T**1** by the delay time period L. Accordingly, heat in the proper amount is not conducted to the sheet at the nip entry time T**1**, causing temperature decrease at the fixing nip. For example, since the comparative fixing device is installed in an image forming apparatus that prints at a high speed, the comparative fixing device consumes an increased amount of heat per unit time. Additionally, as the power supply start time T**3** is delayed, heat conduction to the sheet may be delayed substantially from the leading end of the sheet. Accordingly, the comparative fixing device in the heated state may suffer from substantial temperature decrease.

To address the circumstance, the fixing device **20** according to the first embodiment of the present disclosure employs a construction and a temperature control method described below that suppress flickers and improve fixing of the toner image T on the sheet P. The following describes the construction and the temperature control method according to embodiments of the present disclosure.

A description is provided of a construction of a heating control device **30** incorporated in the fixing device **20**.

FIG. **3** is a block diagram of the heating control device **30** according to the first embodiment of the present disclosure.

As illustrated in FIG. **3**, the heating control device **30** according to the first embodiment of the present disclosure includes the temperature detector **28**, a switch **31**, a zero-crossing detector **32**, the controller **33**, and an alternating current power supply **40**. The heating control device **30** may be located inside the fixing device **20** or an apparatus body of the image forming apparatus **1000**.

The switch **31** switches between supply and interruption of power from the alternating current power supply **40** to the heater **23** according to an instruction from the controller **33**. When the switch **31** is turned on, the switch **31** starts supplying power from the alternating current power supply **40** to the heater **23**, causing the heater **23** to generate heat. Conversely, when the switch **31** is turned off, the switch **31** interrupts supplying power from the alternating current power supply **40** to the heater **23**, causing the heater **23** to interrupt generation of heat.

The zero-crossing detector **32** detects a zero-crossing time of the alternating current power supply **40**. For example, the zero-crossing detector **32** detects a zero-crossing time at which an alternating current (AC) voltage applied from the alternating current power supply **40** changes from a positive voltage to a negative voltage and a zero-crossing time at which the alternating current voltage changes from a negative voltage to a positive voltage. When the zero-crossing detector **32** detects the zero-crossing time, the zero-crossing detector **32** outputs a zero-crossing detection signal to the controller **33**.

Based on a temperature of the outer circumferential face of the fixing rotator **21**, that is detected by the temperature detector **28**, and a zero-crossing time of the alternating current voltage, that is detected by the zero-crossing detector **32**, the controller **33** determines a time at which the switch **31** switches the alternating current voltage. The controller **33** controls the switch **31** based on the determined time. For example, according to the embodiment, the controller **33** performs the phase control and the half-wave control. Under the phase control, the controller **33** controls the switch **31** to supply power to the heater **23** at a predetermined phase angle of one half wave (e.g., one-half of an alternating current cycle) of the alternating current generated by the alternating current power supply **40** based on the zero-crossing time. Under the half-wave control, the controller **33** controls the switch **31** to supply power fully or interrupt power supply to the heater **23** per one half wave of the alternating current generated by the alternating current power supply **40** based on the zero-crossing time. The controller **33** switches between the phase control serving as a first heating and the half-wave control serving as a second heating.

For example, the controller **33** is hardware equivalent to an information processing apparatus installed as a computer in which a central processing unit (CPU), a random access memory (RAM), a read only memory (ROM), and an input-output interface are connected through a bus. The controller **33** defines a function block created by the CPU as a hardware resource that reads and executes a program stored in the ROM.

A description is provided of the temperature control method according to the first embodiment of the present disclosure.

As illustrated in FIG. **4**, according to the embodiment, immediately after the image forming apparatus **1000** is powered on, the fixing device **20** is warmed up. In order to warm up the fixing device **20**, the controller **33** starts supplying power to the heater **23** so that the heater **23** heats the fixing rotator **21**. Accordingly, a temperature of an upstream portion Q of the fixing rotator **21** depicted in FIG. **2** increases gradually. FIG. **4** illustrates the temperature of the upstream portion Q of the fixing rotator **21**, that is disposed upstream from the fixing nip N in the sheet conveyance direction DP or the rotation direction D**21** of the fixing rotator **21**.

In order to control the heater **23** to warm up the fixing device **20**, the controller **33** performs the feedback control that determines a time for supplying power to the heater **23** based on a temperature of the fixing rotator **21**, that is detected by the temperature detector **28**. When the heater **23** heats the fixing rotator **21** to the predetermined fixing temperature, the controller **33** finishes warming up the fixing device **20** and the fixing device **20** enters a standby state (e.g., a standby mode). The standby state continues for a predetermined time period Δt**1**. After the time period Δt**1** elapses, the controller **33** starts conveying a sheet P. Accordingly, the feed roller **15** picks up the sheet P from the sheet tray **14**. The timing roller pair **16** conveys the sheet P to the secondary transfer nip where a toner image T is transferred onto the sheet P. The sheet P transferred with the toner image T is conveyed to the fixing device **20** that fixes the toner image T on the sheet P. FIG. **4** illustrates a predetermined time period Δt**2** from a time when the controller **33** starts conveying a first sheet P until the first sheet P enters the fixing nip N of the fixing device **20**. For example, when the predetermined time period Δt**2** elapses from the time when the controller **33** starts conveying the first sheet P, the first sheet P enters the fixing nip N of the fixing device **20** and the fixing device **20** fixes a toner image T on the first sheet P. Thereafter, a second sheet P and one or more following sheets P enter the fixing nip N with a predetermined interval therebetween. Similarly, the fixing device **20** fixes the toner images T on the second sheet P and the following sheets P, respectively.

According to the embodiment, in addition to the feedback control, in order to suppress temperature decrease of the fixing rotator **21** when the sheet P enters the fixing nip N, the controller **33** performs the feedforward control that supplies the predetermined amount of power to the heater **23** before the sheet P enters the fixing nip N. For example, at a time that is prior to the nip entry time T**1** at which a leading end of the first sheet P enters the fixing nip N by a predetermined time period Δt, the controller **33** performs the feedforward control that supplies the predetermined amount of power to the heater **23**. Before the fixing device **20** is in the heated state in which the fixing device **20** stores a predetermined amount of heat, the fixing device **20** is in a cool state in which the fixing device **20** stores heat in a decreased amount that is smaller than the predetermined amount of heat. While the fixing device **20** is in the cool state, the controller **33** performs the half-wave control, serving as the second heating, as the feedforward control and the feedback control. For example, the controller **33** performs the feedforward control by using a fixed duty cycle, changing a level of a start time to start the feedforward control, and comparing a profile of a temperature of the upstream portion Q of the fixing rotator **21**, that is disposed upstream from the fixing nip N in the sheet conveyance direction DP. Conversely, the controller **33** performs the feedback control by using a proportional-integral-differential controller (PID). The controller **33** determines a final duty cycle by calculating a total of a duty cycle of the feedforward control and a duty cycle of the feedback control. However, if the total of the duty cycles exceeds 100%, the controller **33** determines the final duty cycle of 100%.

FIG. **5** is a graph illustrating a relation between a start time at which the controller **33** starts the feedforward control and a temperature ripple (e.g., a temperature difference) in the upstream portion Q of the fixing rotator **21**.

In FIG. **5**, a horizontal axis represents the time period Δt taken after the feedforward control supplies the predetermined amount of power to the heater **23** until the first sheet P enters the fixing nip N. That is, the horizontal axis represents the start time of the feedforward control. A vertical axis represents a temperature ripple ΔR of the temperature of the upstream portion Q of the fixing rotator **21**. When the time period Δt is 0.5 sec, the temperature ripple ΔR is smallest. Hence, the time period Δt of 0.5 sec is equivalent to the delay time period L taken from a time when the heater **23** is supplied with power until heat generated by the heater **23** is conducted to the fixing nip N.

Accordingly, as illustrated in FIG. **6**A, in a case that the controller **33** starts the feedforward control at a time prior to the nip entry time T**1** by the delay time period L, that is, the optimal time period Δt of 0.5 sec (Δt=L), the heater **23** conducts the predetermined amount of heat to the fixing rotator **21** when the sheet P enters the fixing nip N, minimizing the temperature ripple ΔR. Conversely, as illustrated in FIG. **6**B, in a case that the controller **33** starts the feedforward control at a time earlier than the time prior to the nip entry time T**1** by the delay time period L that is shorter than the time period Δt (Δt>L), the heater **23** conducts the predetermined amount of heat to the fixing rotator **21** before the sheet P enters the fixing nip N. Hence, the temperature of the upstream portion Q of the fixing rotator **21** increases, thus increasing the temperature ripple ΔR. As illustrated in FIG. **6**C, in a case that the controller **33** starts the feedforward control at a time later than the time prior to the nip entry time T**1** by the delay time period L that is longer than the time period Δt (Δt<L), the heater **23** conducts the predetermined amount of heat to the fixing rotator **21** after the sheet P enters the fixing nip N. Hence, the temperature of the upstream portion Q of the fixing rotator **21** decreases, thus increasing the temperature ripple ΔR (e.g., temperature decrease). To address the circumstances, according to the embodiment, the time period Δt taken from the start time when the controller **33** starts the feedforward control until the first sheet P enters the fixing nip N is equivalent to the delay time period L of 0.5 sec.

As described above, the feedforward control starts supplying power to the heater **23** at the time that is prior to the nip entry time T**1** of the first sheet P by the delay time period L, thus suppressing temperature decrease of the fixing rotator **21** after the first sheet P enters the fixing nip N. However, while the fixing device **20** is in the heated state in which the fixing device **20** stores heat sufficiently, if the controller **33** performs the half-wave control to supply power to the heater **23**, flickers may occur. Conversely, in order to suppress flickers, if the controller **33** switches from the half-wave control to the phase control, temperature decrease of the fixing rotator **21** may occur, resulting in faulty fixing such as degradation of gloss of the toner image T formed on the sheet P.

To address the circumstances, even if the fixing device **20** according to the first embodiment of the present disclosure is in the heated state, the controller **33** performs a temperature control of the fixing rotator **21** as described below to improve fixing of the toner image T on the sheet P while suppressing flickers.

FIG. **7** is a timing chart of the temperature control according to the first embodiment of the present disclosure while the fixing device **20** is in the heated state.

As illustrated in FIG. **7**, the controller **33** according to the first embodiment of the present disclosure starts supplying power to the heater **23** under the phase control at a time T**4** that is prior to the time T**2** by the one control cycle Tperiod or longer. The time T**2** is prior to the nip entry time T**1** of the first sheet P by the delay time period L. After the controller **33** continues supplying power to the heater **23** under the phase control for the time period M that is not shorter than the one control cycle Tperiod, the controller **33** starts supplying power to the heater **23** under the half-wave control at the time T**2** that is prior to the nip entry time T**1** of the first sheet P by the delay time period L.

As described above, the controller **33** starts the half-wave control at the time T**2** that is prior to the nip entry time T**1** of the first sheet P by the delay time period L. Hence, under the half-wave control, the controller **33** supplies the predetermined amount of power to the heater **23** at a proper time, that is, the time T**2**. Additionally, the controller **33** starts supplying power to the heater **23** under the phase control at the time T**4** that is prior to the time T**2** by the one control cycle Tperiod or longer. The time T**2** is prior to the nip entry time T**1** of the first sheet P by the delay time period L. Hence, the controller **33** continues supplying power to the heater **23** under the phase control for the one control cycle Tperiod or longer before the half-wave control. Accordingly, while the controller **33** suppresses flickers effectively, the controller **33** supplies the predetermined amount of power to the heater **23** at the proper time, suppressing temperature decrease of the fixing rotator **21** and improving fixing of the toner image T on the sheet P. Consequently, according to the first embodiment of the present disclosure, the controller **33** achieves both suppressing flickers and improving fixing of the toner image T on the sheet P.

A description is provided of a second embodiment of the present disclosure.

As illustrated in FIG. **8**, the controller **33** continues the phase control for a time period that is twice as long as the one control cycle Tperiod. For example, immediately before the half-wave control, the controller **33** starts the phase control at the time T**4** that is prior to the time T**2** by the time period that is twice as long as the one control cycle Tperiod. The time T**2** is prior to the nip entry time T**1** of the sheet P by the delay time period L. Alternatively, instead of the time T**4**, at which the controller **33** starts the phase control, that is prior to the time T**2** by the time period that is twice as long as the one control cycle Tperiod, the time T**4** may be prior to the time T**2** by a time period that is defined by an arbitrary integral multiple, such as three or four times, of the one control cycle Tperiod.

A description is provided of comparison tests.

In order to confirm advantages of the embodiments of the present disclosure, the comparison tests were performed as described below. In the comparison tests, embodiments of the present disclosure and comparative examples were prepared and glossiness of a toner image formed according to each of the embodiments of the present disclosure and the comparative examples was measured.

A description is provided of the comparison test with an embodiment 1 of the present disclosure and a comparative example 1.

The embodiment 1 and the comparative example 1 employed different temperature control methods, respectively. However, the embodiment 1 and the comparative example 1 used fixing devices having an identical construction, respectively. Sheets were conveyed through the fixing devices under an identical condition to fix toner images on the sheets, respectively. For example, the fixing devices having the construction of the fixing device **20** depicted in FIG. **2** were used. Plain paper having a letter size (e.g., standard paper having a paper weight of 20 lb) was used as the sheets and fed in landscape orientation through the fixing devices at a linear velocity of 300 m/sec or 60 copies per minute (CPM). From the cool state of each of the fixing devices, the sheets for 30 jobs were conveyed with an interval of 20 seconds for 3 sheets. The toner image formed on the sheet was a red patch image having a length of 50 mm in portrait orientation and a length of 50 mm in landscape orientation. In order to fix the red patch image on the sheet while a fixing belt serving as a fixing rotator and having a diameter of 30 mm rotated for one rotation, the red patch image was transferred onto the sheet in an area that was on a center on the sheet in a width direction thereof and created a margin of 20 mm from a leading edge of the sheet in a sheet conveyance direction. The red patch image was adhered with toner in an amount defined by mass per unit area (M/A) of 0.8 mg/cm^2 (M/A=0.8 mg/cm^2).

A commercial power having a voltage of 120 V and a frequency of 60 Hz supplied power to a heater. As illustrated in FIG. **4**, a controller controlled the heater basically under the feedback control and the feedforward control. While the fixing device was in the heated state, the controller retained a duty cycle of 20% under the phase control.

According to the embodiment 1, the controller started supplying power to the heater under the phase control at a first time that was prior to a second time by one control cycle. The second time was prior to a nip entry time at which a sheet entered a fixing nip by a delay time period. For example, the one control cycle was 167 msec. Conversely, according to the comparative example 1, the controller started supplying power to the heater under the phase control at the second time that was prior to the nip entry time at which the sheet entered the fixing nip by the delay time period. The delay time period was 0.5 seconds.

The fixing devices according to the embodiment 1 and the comparative example 1 fixed the toner images on the sheets, respectively, with the constructions and conditions described above. The glossiness of each of the toner images fixed on the sheets was measured. The glossiness was measured with a photometer PG-1 that measured an angle of 60 degrees and was manufactured by Nippon Denshoku Industries Co., Ltd. FIG. **9** illustrates the temperature of the fixing belt, that changes depending on a number of jobs according to the embodiment 1 and the comparative example 1. FIG. **10** illustrates the glossiness of the toner image formed on the sheet, that changes depending on the number of jobs according to the embodiment 1 and the comparative example 1. FIG. **9** illustrates a proper temperature of zero degree of the fixing belt. The temperature of the fixing belt depicted in FIG. **9** is a relative value of a temperature of an upstream portion of the fixing belt, that is disposed upstream from the fixing nip in the sheet conveyance direction. The relative value is defined by temperature deviation from the proper temperature. In FIGS. **9** and **10**, a solid line represents the embodiment 1 and a dotted line represents the comparative example 1.

As illustrated in FIGS. **9** and **10**, while the fixing devices performed a first job to a fifteenth job, the fixing devices were in the cool state in which the fixing devices stored heat insufficiently. While the fixing devices were in the cool state, a substantial difference in the temperature of the fixing belt and the glossiness of the toner image did not appear between the fixing device according to the embodiment 1 and the fixing device according to the comparative example 1. Conversely, while the fixing devices performed a twentieth job and following jobs, the fixing device according to the comparative example 1 suffered from substantial temperature decrease of the fixing belt, resulting in decrease in the glossiness of the toner image. While the fixing devices performed the twentieth job and the following jobs, the fixing devices were in the heated state in which the fixing devices stored heat sufficiently. Hence, the fixing belt of each of the fixing devices retained a fixing temperature at which the fixing belt fixed the toner images on the sheets properly, generating a section having a duty cycle of zero. Accordingly, as described above, if the controller resets a control cycle as the sheet enters the fixing nip under the phase control at a duty cycle of 20%, the controller may supply power to the heater in a decreased amount. For example, according to the comparative example 1, the controller started supplying power to the heater under the phase control at the time that was prior to the nip entry time of the sheet by the delay time period. Accordingly, the controller did not start supplying power to the heater under the half-wave control following the phase control at the time that was prior to the nip entry time by the delay time period. Consequently, according to the comparative example 1, the controller did not conceivably supply a predetermined amount of power to the heater at a proper time, causing temperature decrease of the fixing belt. Conversely, according to the embodiment 1, after the controller continued supplying power to the heater under the phase control for one control cycle, the controller started supplying the predetermined amount of power to the heater under the half-wave control at the time that was prior to the nip entry time at which the sheet entered the fixing nip by the delay time period, thus suppressing temperature decrease of the fixing belt and improving the glossiness of the toner image on the sheet.

A description is provided of the comparison test with an embodiment 2 of the present disclosure and a comparative example 2.

Unlike the embodiment 1 and the comparative example 1, the embodiment 2 and the comparative example 2 used a commercial power having a frequency of 50 Hz. According to the embodiment 2, the controller started supplying power to the heater under the phase control at a first time that was prior to a second time by two control cycles of 400 msec. The second time was prior to a nip entry time at which a sheet entered the fixing nip by a delay time period. Conversely, according to the comparative example 2, the controller started supplying power to the heater under the phase control at the second time that was prior to the nip entry time at which the sheet entered the fixing nip by the delay time period. Other construction and conditions were equivalent to the construction and the conditions of the embodiment 1 and the comparative example 1.

FIG. **11** illustrates the temperature of the fixing belt, that changes depending on the number of jobs according to the embodiment 2 and the comparative example 2. FIG. **12** illustrates the glossiness of the toner image formed on the sheet, that changes depending on the number of jobs according to the embodiment 2 and the comparative example 2. The temperature of the fixing belt depicted in FIG. **11** is also the relative value of the temperature of the upstream portion of the fixing belt, that is disposed upstream from the fixing nip in the sheet conveyance direction. The relative value is defined by temperature deviation from the proper temperature. In FIGS. **11** and **12**, a solid line represents the embodiment 2 and a dotted line represents the comparative example 2.

As illustrated in FIGS. **11** and **12**, while the fixing device according to the comparative example 2 performed the twentieth job and the following jobs, the fixing device according to the comparative example 2 suffered from substantial temperature decrease of the fixing belt compared to the fixing device according to the embodiment 2, resulting in decrease in the glossiness of the toner image. Additionally, the fixing device according to the comparative example 2 suffered from temperature decrease and glossiness degradation that were greater than temperature decrease and glossiness degradation of the fixing device according to the comparative example 1. The fixing device according to the comparative example 2 used the commercial power having the frequency of 50 Hz. Hence, compared to the fixing device according to the comparative example 1 that used the commercial power having the frequency of 60 Hz, the fixing device according to the comparative example 2 increased the control cycle and a time period for which the phase control continued. Additionally, under the half-wave control, the controller according to the comparative example 2 did not conceivably supply the predetermined amount of power to the heater at a proper time. Conversely, the fixing device according to the embodiment 2 suppressed temperature decrease of the fixing belt and improved the glossiness of the toner image on the sheet. After the controller according to the embodiment 2 continued the phase control for two control cycles, the controller conceivably started supplying the predetermined amount of power to the heater under the half-wave control at the time that was prior to the nip entry time at which the sheet entered the fixing nip by the delay time period.

A description is provided of the comparison test with an embodiment 3 of the present disclosure and a comparative example 3.

In the comparison test with the embodiment 3 and the comparative example 3, when 50 sheets as plain paper having a B4 size were conveyed through the fixing devices from a time at which the fixing devices were in the cool state, the temperature of the fixing belt of each of the fixing devices and the glossiness of toner images formed on the sheets were measured.

FIG. **13** is a timing chart illustrating conveyance of sheets as plain paper having the B4 size through the fixing device and the temperature control of the fixing device.

The sheet having the B4 size has a width smaller than an entire width of a heat generation portion of the heater in a direction perpendicular to the sheet conveyance direction.

Hence, the sheet is not conveyed over a non-conveyance span disposed in each lateral end portion of the fixing belt in the direction perpendicular to the sheet conveyance direction. Accordingly, the fixing belt in the non-conveyance span may suffer from substantial temperature increase. Consequently, the fixing belt may not fix the toner image on the sheet properly. Additionally, the fixing belt may suffer from degradation or damage. To address the circumstance, while the sheets are conveyed continuously, an interval with which the sheets are conveyed increases from an interval D**1** to an interval D**2** that is greater than the interval D**1** by decreasing a conveyance speed defined by pages per minute (PPM), thus suppressing temperature increase in the non-conveyance span on the fixing belt. For example, according to the embodiment 3 and the comparative example 3, a first sheet to a fourteenth sheet were conveyed at 25 PPM. A fifteenth sheet and following sheets were conveyed at 17 PPM. During the interval D**2** when the fifteenth sheet and the following sheets were conveyed at the decreased PPM, the controller controlled the heater under the feedback control to prevent the heater from supplying heat excessively. At a time when the following sheet passed through the fixing nip, the controller performed the feedforward control and the feedback control at a fixed duty cycle.

Like the controller according to the embodiment 1, the controller according to the embodiment 3 started supplying power to the heater under the phase control at a first time that was prior to a second time by one control cycle. The second time was prior to a nip entry time at which a sheet entered the fixing nip by a delay time period. Conversely, according to the comparative example 3, the controller started supplying power to the heater under the phase control at the second time that was prior to the nip entry time at which the sheet entered the fixing nip by the delay time period. Other construction and conditions were equivalent to the construction and the conditions of the embodiment 1 and the comparative example 1.

FIG. **14** illustrates the temperature of the fixing belt, that changes depending on a number of sheets conveyed through the fixing device according to the embodiment 3 and the fixing device according to the comparative example 3. FIG. **15** illustrates the glossiness of the toner image formed on the sheet, that changes depending on the number of sheets conveyed through the fixing device according to the embodiment 3 and the fixing device according to the comparative example 3. The temperature of the fixing belt depicted in FIG. **14** is also the relative value of the temperature of the upstream portion of the fixing belt, that is disposed upstream from the fixing nip in the sheet conveyance direction. The relative value is defined by temperature deviation from the proper temperature. In FIGS. **14** and **15**, a solid line represents the embodiment 3 and a dotted line represents the comparative example 3.

As illustrated in FIGS. **14** and **15**, after conveyance of the sheets started, from the first sheet to the twentieth sheet, a substantial difference in the temperature of the fixing belt and the glossiness of the toner image did not appear between the fixing device according to the embodiment 3 and the fixing device according to the comparative example 3. Conversely, while the fixing devices conveyed a twenty-fifth sheet and following sheets, the fixing device according to the comparative example 3 suffered from substantial temperature decrease of the fixing belt, resulting in decrease in the glossiness of the toner image. While the fixing devices conveyed the twenty-fifth sheet and the following sheets, an amount of heat stored in the fixing devices increased substantially. For example, heat was not conducted to the sheets during the interval D**2**. As heat was conducted from the non-conveyance span to a sheet conveyance span where the sheets were conveyed over the fixing belt, the controller might supply power to the heater at a decreased duty cycle, generating a section having a duty cycle of zero. Hence, according to the comparative example 3, after generation of the section having the duty cycle of zero while the twenty-fifth sheet and the following sheets were conveyed, the controller conceivably failed to change to the phase control and start supplying power to the heater under the half-wave control following the phase control at the time that was prior to the nip entry time of the sheet by the delay time period, causing temperature decrease of the fixing belt. Conversely, according to the embodiment 3, after the controller continued supplying power to the heater under the phase control for one control cycle, the controller started supplying the predetermined amount of power to the heater under the half-wave control at the proper time that was prior to the nip entry time at which the sheet entered the fixing nip by the delay time period, conceivably suppressing temperature decrease of the fixing belt and improving the glossiness of the toner image on the sheet.

As described above, according to the embodiments of the present disclosure, in a case that the controller **33** switches from the phase control serving as the first heating to the half-wave control serving as the second heating immediately before the sheet P enters the fixing nip N, the controller **33** starts the half-wave control at the time T**2** that is prior to the nip entry time T**1** at which the sheet P enters the fixing nip N by the delay time period L. Thus, the controller **33** supplies the predetermined amount of power to the heater **23** at the proper time, suppressing temperature decrease of the fixing rotator **21** and improving fixing of the toner image T on the sheet P. Additionally, according to the embodiments of the present disclosure, the controller **33** continues the phase control immediately before the half-wave control for one control cycle or longer at a duty cycle not greater than 40%, suppressing flickers effectively.

An upper limit of the duty cycle of the phase control is not greater than 40%. The controller **33** performs the phase control at the duty cycle not greater than 40%, suppressing flickers effectively. Conversely, a lower limit of the duty cycle is preferably not smaller than 10%. In a case that the halogen heater as the heater **23** is turned on and off repeatedly in shortened cycles at the duty cycle smaller than 10%, a halogen cycle may be incomplete, shortening a life of a filament. The halogen cycle defines a thermochemical cyclic reaction between evaporated tungsten from the filament and halogen gas filling a halogen lamp. Hence, the lower limit of the duty cycle under the phase control is not smaller than 10% that achieves a proper halogen cycle.

As the control cycle of each of the phase control serving as the first heating and the half-wave control serving as the second heating, continuous 20 half waves generated by the alternating current power supply **40** may be one control cycle. In a case that the alternating current power supply **40** has the frequency of 50 Hz, the control cycle of each of the phase control serving as the first heating and the half-wave control serving as the second heating may be 200 msec. In a case that the alternating current power supply **40** has the frequency of 60 Hz, the control cycle of each of the phase control serving as the first heating and the half-wave control serving as the second heating may be 167 msec. Accordingly, the controller **33** achieves both suppressing flickers and improving fixing of the toner image T on the sheet P regardless of a frequency band.

Application of the embodiments of the present disclosure is not limited to the fixing device **20** depicted in FIG. **2**, that incorporates the single heater **23**. The embodiments of the present disclosure are also applied to a fixing device incorporating a plurality of heaters. For example, the embodiments of the present disclosure are also applied to a fixing device that includes, as heaters, a first halogen heater and a second halogen heater. The first halogen heater is disposed opposite and heats a center span of the fixing rotator **21** in the longitudinal direction thereof. The second halogen heater is disposed opposite and heats both lateral end spans of the fixing rotator **21** in the longitudinal direction thereof. The fixing device that incorporates the plurality of heaters and is applied with any one of the embodiments of the present disclosure also achieves both suppressing flickers and improving fixing of the toner image T on the sheet P.

With the embodiments of the present disclosure described above, the technology of the present disclosure encompasses a fixing device (e.g., the fixing device **20**) and an image forming apparatus (e.g., the image forming apparatus **1000**) that have at least one of aspects described below.

A description is provided of a first aspect of the technology of the present disclosure.

As illustrated in FIGS. **2** and **3**, the fixing device includes a pair of rotators, that is, a first rotator (e.g., the fixing rotator **21**) and a second rotator (e.g., the pressure rotator **22**), a heater (e.g., the heater **23**), and a controller (e.g., the controller **33**). The second rotator contacts the first rotator to form a nip (e.g., the fixing nip N) between the first rotator and the second rotator. The heater heats at least one of the first rotator or the second rotator. The controller controls the heater to switch between a first heating and a second heating. The first rotator and the second rotator fix an image (e.g., the toner image T) on a recording medium (e.g., the sheet P) that enters the nip under heat. As illustrated in FIG. **7**, immediately before the recording medium enters the nip, the controller controls the heater to switch from the first heating to the second heating. The controller starts the second heating at a time (e.g., the time T**2**) prior to a nip entry time (e.g., the nip entry time T**1**) at which the recording medium enters the nip by a delay time period (e.g., the delay time period L) taken for the heater to conduct heat to the nip. The controller controls the heater to continue the first heating immediately before the second heating for at least one control cycle (e.g., the one control cycle Tperiod) at a duty cycle of power supplied to the heater. The duty cycle is not greater than 40%.

A description is provided of a second aspect of the technology of the present disclosure.

As illustrated in FIG. **7**, in the fixing device according to the second aspect based on the first aspect, the controller controls the heater to continue the first heating immediately before the second heating for at least one control cycle at a duty cycle of the power supplied to the heater. The duty cycle is not smaller than 10% and not greater than 40%.

A description is provided of a third aspect of the technology of the present disclosure.

As illustrated in FIG. **3**, the fixing device according to the third aspect based on the first aspect or the second aspect further includes an alternating current power supply (e.g., the alternating current power supply **40**), a switch (e.g., the switch **31**), and a zero-crossing detector (e.g., the zero-crossing detector **32**). The switch switches between supply and interruption of the power from the alternating current power supply to the heater. The zero-crossing detector detects a zero-crossing time of an alternating current generated by the alternating current power supply. The first heating defines a phase control under which the controller controls the switch to supply the power to the heater at a predetermined phase angle of one half wave of the alternating current generated by the alternating current power supply based on the zero-crossing time. The second heating defines a half-wave control under which the controller controls the switch to perform one of full power supply and interruption of power supply to the heater per one half wave of the alternating current generated by the alternating current power supply based on the zero-crossing time.

A description is provided of a fourth aspect of the technology of the present disclosure.

In the fixing device according to the fourth aspect based on any one of the first aspect to the third aspect, as a control cycle of each of the first heating and the second heating, continuous 20 half waves of the alternating current generated by the alternating current power supply define one control cycle. In a case that the alternating current power supply has a frequency of 50 Hz, the control cycle of each of the first heating and the second heating is 200 msec. In a case that the alternating current power supply has a frequency of 60 Hz, the control cycle of each of the first heating and the second heating is 167 msec.

A description is provided of a fifth aspect of the technology of the present disclosure.

In the fixing device according to the fifth aspect based on any one of the first aspect to the fourth aspect, the controller controls the heater to continue the first heating immediately before the second heating for a time period defined by an arbitrary integral multiple of one control cycle at a duty cycle of the power supplied to the heater. The duty cycle is not greater than 40%.

A description is provided of a sixth aspect of the technology of the present disclosure.

As illustrated in FIGS. **1** and **2**, an image forming apparatus (e.g., the image forming apparatus **1000**) according to the sixth aspect includes an image forming device (e.g., the image forming portion **100**) and the fixing device according to any one of the first aspect to the fifth aspect. The image forming device forms an image (e.g., the toner image T) on a recording medium (e.g., the sheet P). The fixing device fixes the image on the recording medium.

Accordingly, the fixing device suppresses flickers and improves fixing of the image on the recording medium.

The above-described embodiments are illustrative and do not limit the present invention. Thus, numerous additional modifications and variations are possible in light of the above teachings. For example, elements and/or features of different illustrative embodiments may be combined with each other and/or substituted for each other within the scope of the present invention. Any one of the above-described operations may be performed in various other ways, for example, in an order different from the one described above.

The functionality of the elements disclosed herein may be implemented using circuitry or processing circuitry which includes general purpose processors, special purpose processors, integrated circuits, application specific integrated circuits (ASICs), digital signal processors (DSPs), field programmable gate arrays (FPGAs), conventional circuitry and/or combinations thereof which are configured or programmed to perform the disclosed functionality. Processors are considered processing circuitry or circuitry as they include transistors and other circuitry therein. In the disclosure, the circuitry, units, or means are hardware that carry out or are programmed to perform the recited functionality. The hardware may be any hardware disclosed herein or otherwise known which is programmed or configured to carry out the recited functionality. When the hardware is a processor which may be considered a type of circuitry, the circuitry, means, or units are a combination of hardware and software, the software being used to configure the hardware and/or processor.

The invention claimed is:

1. A fixing device comprising:

a first rotator;

a second rotator to contact the first rotator to form a nip between the first rotator and the second rotator, the first rotator and the second rotator to fix an image on a recording medium that enters the nip under heat;

a heater to heat at least one of the first rotator or the second rotator; and

a controller to:

control the heater to switch between a first heating and a second heating;

control the heater to switch from the first heating to the second heating before the recording medium enters the nip;

control the heater to start the second heating at a time prior to a nip entry time at which the recording medium enters the nip by a delay time period taken for the heater to conduct heat to the nip; and

control the heater to continue the first heating before the second heating for at least one control cycle at a duty cycle of power supplied to the heater, the duty cycle being not greater than 40%.

2. The fixing device according to claim **1**,

wherein the duty cycle is not smaller than 10%.

3. The fixing device according to claim **1**,

wherein the controller controls the heater to continue the first heating for a time period defined by an arbitrary integral multiple of one control cycle.

4. The fixing device according to claim **1**, further comprising:

an alternating current power supply to supply the power to the heater;

a switch to switch between supply and interruption of the power from the alternating current power supply to the heater; and

a zero-crossing detector to detect a zero-crossing time of an alternating current generated by the alternating current power supply.

5. The fixing device according to claim **4**,

wherein the first heating defines a phase control under which the controller controls the switch to supply the power to the heater at a predetermined phase angle of one half wave of the alternating current generated by the alternating current power supply based on the zero-crossing time, and

wherein the second heating defines a half-wave control under which the controller controls the switch to perform one of full supply and interruption of the power to the heater per one half wave of the alternating current generated by the alternating current power supply based on the zero-crossing time.

6. The fixing device according to claim **4**,

wherein continuous 20 half waves of the alternating current generated by the alternating current power supply define one control cycle as a control cycle of each of the first heating and the second heating,

wherein the control cycle of each of the first heating and the second heating is 200 msec in a case that the alternating current power supply has a frequency of 50 Hz, and

wherein the control cycle of each of the first heating and the second heating is 167 msec in a case that the alternating current power supply has a frequency of 60 Hz.

7. The fixing device according to claim **1**,

wherein each of the first rotator and the second rotator includes one of a belt and a roller.

8. An image forming apparatus comprising:

an image forming device to form an image on a recording medium; and

a fixing device to fix the image on the recording medium,

the fixing device including:

a first rotator;

a second rotator to contact the first rotator to form a nip between the first rotator and the second rotator, the first rotator and the second rotator to fix the image on the recording medium that enters the nip under heat;

a heater to heat at least one of the first rotator or the second rotator; and

a controller to:

control the heater to switch between a first heating and a second heating; control the heater to switch from the first heating to the second heating before the recording medium enters the nip;

control the heater to start the second heating at a time prior to a nip entry time at which the recording medium enters the nip by a delay time period taken for the heater to conduct heat to the nip; and

control the heater to continue the first heating before the second heating for at least one control cycle at a duty cycle of power supplied to the heater, the duty cycle being not greater than 40%.

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