

1 MICROWAVE HEATING DEVICE FOR A PRINTING PRESS

BACKGROUND OF THE INVENTION

The present invention relates to heating devices for a web printed by a printing press.

In the past, heating devices of a conventional nature have been utilized to heat a web printed by a printing press to dry the ink. In order to fix heat set ink during printing, the printed web is passed through a drier which uses hot air convection heat transfer. This process is relatively slow, and therefor long tunnels are needed to provide the residence time needed for heat transfer and solvent removal. As a result, the tunnels to provide heat are both costly and energy inefficient, and large quantities of heated air must be circulated to heat the web and capture the solvent and water in the ink. In addition, the prior heating devices require an excessive amount of space in the press room due to their inefficiency.

A microwave heating device was disclosed in White 3,739,130, but is not adequate for the heat set process needed by a printing press.

The microwave cavities for heating webs to evaporate the solvent from heat set inks must be used in pairs. This is required because the power density across the web

varies as $\cos^2 (n \pi x/L)$, where n is an integral number, x is the position along the length of the cavity, and L is the cavity length. As a result, two cavities must be used in which one is shifted by a distance of $L/2n$ so that the phase of one standing wave pattern in the cavity is $\pi/2$ relative to the other cavity. When this condition is met, the power distribution across the web is constant [$\cos^2 (n \pi x/L) + \sin^2 (n \pi x/L) = 1$]. Small differences in tuning or matching can result in non uniform energy across the web.

SUMMARY OF THE INVENTION

A principal feature of the present invention is the provision of an improved heating device for a printed web from a printing press.

The heating device of the present invention comprises, a microwave heating device having a chamber for heating a printed web, means for collecting information from the microwave heating device and press, and means for controlling the microwave heating device and press responsive to the collected information.

Thus, a feature of the invention is that operation of the microwave heating device is controlled in conjunction with operation of the press.

Yet another feature of the invention is that the power in the microwave heating device is controlled in accordance with the speed of the printing press.

A further feature of the invention is that operation of the microwave heating device is coordinated with the operation of a chiller for cooling the web after passing through the heating device.

Another feature of the invention is that operation of

the microwave heating device may be immediately stopped in the case of a web break in the press or an emergency shut down of the press.

Still another feature of the invention is that the type of paper and ink used in the press may be supplied to the controlling device of the microwave drier.

A further feature of the invention is that the temperature of the web may be monitored by the controlling device.

Another feature of the invention is that the power supplied by the microwave may be controlled in accordance with the temperature of the web, the relative humidity in the chamber, the solvent vapor content of the chamber, or any combination thereof.

Yet another feature of the invention is that a solvent may be monitored by the controlling means in the chamber.

Still another feature of the invention is that an indication of a failure in a zone of the heating device may be supplied by the controlling device to the press, and the speed of the press may be slowed responsive to this condition in the microwave heating device. Also, in

this event, the energy (heat) supplied by other zones may be increased, or an inactive (reserve) zone is activated while the power of other zones are readjusted to maintain the optimal heating profile.

A feature of the invention is that the controlling device may inform the press when it is ready to receive the printed web, and that the ink on the web is being properly heat set.

Another feature of the invention is that a stream of air may be directed towards the web in order to penetrate a boundary layer of gas adjacent a surface of the web.

Still another feature of the invention is that the stream of air may be controlled by the controlling device.

Another feature of the invention is that the air may be preheated by gas or electricity.

Another feature of the invention is that the microwave heating device has a plurality of heating zones, and the controlling device controls operation of the device in each of the zones.

A feature of the invention is that the microwave heating device is expected to be $1/4$ or shorter than the

length of conventional heaters, and thus requires much less space in the press room as compared to prior heating devices.

Another feature of the present invention is that a cavity in the device provides a uniform energy across the web being printed.

Further features will become more fully apparent in the following description of the embodiments of this invention, and from the appended claims.

DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1 is a diagrammatic view of a microwave heating device of the present invention;

Fig. 2 is a sectional view of a plurality of a pair of heating zones in the microwave heating device of Fig. 1;

Fig. 3 is a sectional view of cylindrical cavities creating a uniform electric field across a web passing through the cavities in the heating device in another embodiment of the present invention; and

Fig. 4 is a diagrammatic view of a cavity for creating a uniform electric field across a web passing through the cavity in another.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Fig. 1, there is shown a microwave heating device generally designated 10 having a plurality of applicators or heating zones 12 in order to heat inks on a printed web 18 from a printing press 20. The heating zones are individually controlled by a master control unit 14 comprising a computer. As shown, the heating device 10 has a power unit 16 controlled by the computer 14, with each of the power units 16 being associated with each of the heating zones 12.

The number of heating zones 12 depends on the energy required by the heating process, press speed, and the microwave frequency. Typical microwave frequencies for industrial heating are 915 and 2450 MHz. As examples, at 2450 MHz the maximum power output is 15 kW per power station, while at 915 MHz the maximum power output is 60-75 kW per power station. Thus, there may be 10 to 20 zones for 2450 MHz while there may be 3 to 4 zones for 915 MHz. If desired, the individual cavities or chambers 30 in an applicator 12 may be powered from either side of a web 18 printed by a printing press 20 to ensure uniform heating across a wide web 18.

Another example of this device when 2450 MHz is selected as the microwave frequency is to power each

resonant cavity by its microwave generator. In this case, the microwave source will generate 2 to 3 kW. In such cases, a large number of sources are used to generate the required power. However, in some applications this approach may have economical and practical advantages over dividing the power among many stations.

The computer 14 collects information and monitors the individual heating zones 12, the press 20, and a chiller 22 which cools the web 18 after the ink has been heated in the microwave heating device 10. In turn, the computer 14 controls the applicators 12, the press 20 and the chiller 22, with the computer 14 monitoring a temperature sensor 23 in the chiller 22, such as a temperature sensor fiberoptic sold by Luxtron. The information supplied from the press 20 to the computer 14 includes the type of paper, ink, the amount of ink coverage on the web, the press speed, an emergency shut down condition, and sensed web breaks. In the case of an emergency shut down condition or web break, the computer 14 immediately inhibits power to the power units 16 in order to immediately stop heating in the heating device 10. In contrast to previous heating devices, power may be applied to the heating device 10 in order to start immediate heating of the web 18, and power may be removed from the heating device 10 in order to prevent heating of the web 18 that could damage the ink or char or burn the paper.

The computer 14 in turn supplies information to the press 20 to inform the press 20 that the microwave drier can receive paper, when the ink on the paper is properly being heat set, and a failure condition in any of the power units 16 or zones 12. The individual microwave units 12 are controlled by the computer 14 based upon a desired heat set profile. In addition, any malfunction of one of the power units 16 can cause the control unit 14 to redistribute the loads for drying without shutting down the press, or, if necessary, may cause the press speed to change so that proper drying can be maintained while the specific unit is being repaired. Since the units 16 are essentially independent, many types of repairs can be made while the press 20 is still operational.

With reference to Fig. 2, the device 10 has a plurality of temperature sensors 24 adjacent the web 18, such as a fiberoptic Model 790 sold by Luxtron, or part NOEMI-TS sold by Nortech, and along the path of the web 18, an effluent solvent sensor 26, such as model Nos. TGS 822 and 823 sold by Figaro of Winnetka, Illinois, and a water vapor sensor 28, such as Models TF- and M-series sold by Panametrics. The microwave power at each zone 12 is also monitored for proper control, along with the other sensors by the computer 14 for proper control of the device 10. The primary control functions for each

applicator 12 that are controlled by the computer are the air flow, air temperature, and microwave power.

An example of a microwave heating zone or applicator 12 is shown in Fig. 2. Each zone 12 may have any number of pairs of microwave cavities 30, and the example of Fig. 2 shows two pairs of cavities 30. Each pair is arranged so that the maximum electric field in one cavity is precisely in line along the web direction with the minimum of the second. If the cavities in each pair are in resonance with the source, and they are tuned identically, the power distribution across the web is an integral number of half cycles that exhibit a power distribution proportional to $\sin^2(2n \pi y/W)$, where y is the web position, L is the cavity length, and n is the number of wavelengths along the cavity length. In order to obtain a uniform heating distribution, one cavity is offset from the other by a distance that corresponds to a phase shift of $\pi/2$. In Fig. 2, the difference in the electric field intensity, and therefor microwave power density, between each cavity in the pair is designated by the short and long arrows on either side of the web. Thus, over two cavities, the energy received by the moving web is proportional to $\sin^2(2n \pi y/L) + \cos^2(2n \pi y/L) = 1$. Thus, each location on the web receives an equal amount of energy, and the applied energy is configured to conform with the shape of the web 18.

The microwave energy in each zone 12 is supplied by the source, which, in turn, is controlled by the control unit 14 based upon preprogrammed information and the sensors located on the press 20, microwave generators, and applicators 12. Temperature is the most critical measurement since it has a direct effect on the quality of the print, paper coating, and paper quality. Fiber optic temperature sensors 24 can be placed in holes 34 through the walls 32 separating the cavities or chambers 30. These sensors 24 should be placed so that the maximum and minimum temperatures can be determined, and the operation of the heater 10 can be maintained in the proper range.

In the applicator 12 shown, air is forced through slots 36 in the wall 38 between the microwave cavities 30 and exits through openings 48 in the top wall 40 and the bottom wall 42 of the cavity 30. The solvents in the air may be collected in a suitable manner, and may be burned or collected and retained for later disposal. As the web 18 passes through the cavity 30, the boundary layer of solvents and water vapor adjacent the web 18 is sheared by the gap 44 through which the web passes. This gap 44 may be 1/8" to 1/4" for 2450 MHz microwave energy, and somewhat larger for 915 MHz. This shearing effect causes turbulence which facilitates removing the evaporated solvent. To ensure that the solvent is removed, dry

preheated air passed through ducts 46 is used to penetrate the boundary along the web 18. This excess air will cause additional turbulence in the expanded area inside the microwave cavity 30, and cause the vapors to be purged from the system. In addition, the air supports the web, and prevents the wet ink from contacting the metal around the slot. The solvent sensors 26 and water vapor sensors 28 can be placed at key locations, as shown, adjacent openings 48 in the top wall 40, in order to determine the amount of solvents and water vapor released from the inks when heated. The amount of solvent or water vapor being removed is related to temperature, power, air flow, and dwell time, whereas the temperature is primarily dependent on the power and speed of the web 18.

Thus, in accordance with the present invention, the inks on the printed web 18 from the press 20 are heated in the microwave heating device 10 in order to dry the inks on the web 18. The control unit 14 coordinates operation of the press 20 and heating device 10. In addition, the control unit 14 coordinates operation between the microwave heating device 10 and chiller 22 in order to cool the web 18 and inks after they pass through the microwave heating device 10. In accordance with the present invention, the microwave heating device 10 is greatly more efficient than prior convention heating devices, and significantly reduces the amount of floor

space required in the press room.

In one modification of this invention, the microwave cavities for heating webs to evaporate the solvent from heat set inks must be used in pairs. This is required because the power density across the web varies as $\cos^2 (n \pi x/L)$, where n is an integral number, x is the position along the length of the cavity, and L is the cavity length. As a result, two cavities must be used in which one is shifted by a distance of $L/2n$ so that the phase of one standing wave pattern in the cavity is $\pi/2$ relative to the other cavity. When this condition is met, the power distribution across the web is constant [$\cos^2 (n \pi x/L) + \sin^2 (n \pi x/L) = 1$]. Small differences in tuning or matching can result in non uniform energy across the web. The solution to this problem is to design a cavity that can provide a uniform energy across the web in accordance with alternate embodiments of the invention which are shown in Figs. 3 and 4.

In another modification of the invention, cavities that generate a uniform electric field across the web are used. Only two cavity modes can meet the condition. One of these cavities is cylindrical with the mode designation TM_{0m0} , as shown in Fig. 3, and the other is rectangular, as shown in Fig. 4, with the mode designation TE_{10n} , where n is an integer. These mode designations are standard

microwave practice.

As shown in Fig. 3, the TM_{0m0} mode cavity 60 is cylindrical. TM represents a cavity with a magnetic field transverse to its axis. The subscripts l, m, and n, represent the half wavelengths of electric field, respectively in the circumference, radius, and length. In this case, the electric field is constant in the direction parallel to the axis, and is zero in the radial direction. Thus, a web 18 fed through the cylindrical portion of the cavity will experience a constant electric field perpendicular to the direction in which the web 18 moves. If the Q factor (power storage) in the cavity is reasonably large (e.g. $Q > 100$) which means that the electromagnetic wave will decrease to $1/e$ of its initial strength after 100 cycles, the web 18 will be heated uniformly as it passes through the cavity. Since this mode is a stable mode, it is easily introduced through an opening at either end of the cavity 30, or through an opening in the cylinder.

Fig. 3 shows a cross section of a series of cavities that could constitute a web drying system. There should be inlets and outlets for heated gas to both support the web, purge the solvent, and sample the vapor and solvent composition. These features were previously described which describes rectangular TE_{10n} mode cavities. However,

the resonant frequency of the TM_{0m0} mode cavity cannot be adjusted by changing the axial length of the cavity. Rather, some tuning adjustments need to be made by inserting a metal conductor 52 or Teflon dielectric through slots along the cavity axis. These should be symmetrical about the web 18.

As shown in Fig. 4, the TE_{10n} mode is rectangular. TE represents a cavity with a magnetic field transverse to its length, in this case, the length L, in Fig. 4 is not the longest direction of the cavity. The dimensions a (x-direction), b (y-direction), and L (z-direction) represent the dimensions in which there are respectively one, zero, and any integer, n, half-wavelengths of the magnetic field. In this cavity 62, the electric field, which is needed to heat the web 18, is constant along the y-direction as shown in Fig. 3, reaches a maximum in the center of the cavity, and falls to zero at either wall (half wavelengths in x and z direction). As a result, paper passing through the cavity in the direction a' to O' will experience a uniform field along its width, and the web will be uniformly heated as long as the Q of the cavity is greater than about 100. Since this mode is not a stable mode, some induction must be added to the cavity to prevent the electric field in the cavity from being orientated in other directions. To accomplish this, metal rods 54 are inserted into the cavity 62, as shown in Fig.

4. These rods 54 induce a current parallel to the electric field which, in turn, generates a magnetic field perpendicular to the electric field to stabilize this geometry. Coupling the power into the cavity 62 would require an opening 56 in the wall of the cavity, as shown.

As disclosed previously, various air inlets and outlets are required. These would be configured in a similar manner to the drawings in the previous disclosure. In this orientation there is no way to adjust the frequency to make the cavity resonant with the microwave source. As a result, tuning elements similar to those shown for the cylindrical cavity of Fig. 3 and described above could be used.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

Claims:

What is claimed is:

1. A heating device for a printed web of a printing press, comprising:

a microwave heating device having a chamber for heating the web;

means for passing the web through the chamber while heating the web; and

means for passing a high speed stream of a gas against the web to support the web and to penetrate a boundary layer caused by the moving web.

2. The device of claim 1 wherein the gas comprises air.

3. A heating device for a printed web of a printing press, comprising:

a microwave heating device having a chamber for heating the web;

means for collecting information from the press;

means for controlling the microwave heating device;



and

means for providing the collected information from the press to the controlling means for controlling the microwave heating device.

4. The device of claim 3 wherein the information comprises a break in the web of the printing press.

5. The device of claim 4 in which the controlling means inhibits operation of the microwave heating device responsive to a web break.

6. The device of claim 3 wherein the information comprises a shut down of the press.

7. The device of claim 4 in which the controlling means inhibits operation of the microwave heating device responsive to the shut down of the press.

8. The device of claim 3 in which the information comprises the operational speed of the press.

9. The device of claim 8 in which the controlling means modifies power to the microwave heating device responsive to the speed of the press.



10. The device of claim 3 in which the information comprises the type of paper or ink used as the web.

11. A heating device for a printed web of a printing press, comprising:

a microwave heating device having a chamber to heat the web;

means for monitoring information pertaining to operation of the microwave heating device; and

means for controlling the microwave heating device responsive to the monitored information.

12. The device of claim 11 wherein the monitored information comprises the temperature of the web.

13. The device of claim 11 wherein the monitored information comprises the vapor pressure of a released solvent from a heated ink on the web.

14. The device of claim 11 wherein the monitored information comprises a released water vapor in the chamber from a heated ink on the web.

15. A heating device for a printed web of a printing



press, comprising;

a microwave heating device having a chamber for heating an ink on the web; and

means for disposing of a solvent released from the ink responsive to heating of the web.

16. A heating device for a printed web of a printing press, comprising:

a microwave heating device having a chamber for heating the web;

means for collecting information from the microwave heating device;

means for controlling the press; and

means for providing the collected information from the microwave heating device to the controlling means.

17. The device of claim 16 wherein the collected information comprises power applied to the microwave heating device.

18. The device of claim 16 wherein the collected



information comprises the heating profile in the microwave heating device.

19. The device of claim 16 wherein the collected information comprises a failure in the microwave heating device.

20. The device of claim 19 wherein the controlling means slows the speed of the press responsive to a failure in the microwave heating device.

21. The device of claim 19 wherein including means for redistributing microwave power in the microwave heating device responsive to a failure in the microwave heating device.

22. The device of claim 16 wherein the collected information comprises an approval that the microwave heating device is ready to accept the printed web for drying.

23. The device of claim 16 wherein the collected information comprises the proper heat set of an ink on the web.

24. A heating device for a printed web of a printing press, comprising:



a microwave heating device having a chamber for heating the web;

means for collecting information from the microwave heating device or press; and

means for controlling the microwave heating device or the press responsive to the collected information.

25. The device of claim 24 wherein the controlling means comprises a variation of power responsive to the speed of the press.

26. The device of claim 24 wherein the controlling means controls the passage of air towards the web.

27. The device of claim 24 wherein the collected information comprises the air temperature adjacent the web in the chamber and the web temperature, and in which the controlling means comprises the power profile in the microwave heating device.

28. A heating device for a printed web of a printing press, comprising:

a microwave heating device having a plurality of



heating zones; and

means for controlling the power in each of the heating zones.

29. A heating device for a printed web of a printing press, comprising:

a microwave heating device having a chamber for heating the web;

a chiller for cooling the web subsequent to being heated; and

means for controlling the balance between the chiller and the power to the microwave heating device.

30. A microwave heating device for a printed web of a printing press, comprising:

a microwave heating device having a cavity for heating the web;

means for passing the web through the cavity while heating the web; and

means for providing a uniform energy of the



microwaves across the web.

31. The device of claim 30 wherein the providing means comprises at least one induction rod in the cavity.

32. The device of claim 30 wherein the providing means comprises at least one tuning stub extending into the cavity.

33. The device of claim 30 wherein the providing means comprises means for forming an electric field of the microwaves parallel to the web and extending across the web.