HEATING SYSTEM WITH ENHANCED TEMPERATURE CONTROL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to and claims priority under 35 U.S.C. § 119(e) from U.S. Patent Application No. 62/574,588, filed October 19, 2017, titled "MICROWAVE HEATING SYSTEM WITH ENHANCED TEMPERATURE CONTROL"; U.S. Patent Application No. 62/574,596, filed October 19, 2017, titled "MODULAR MICROWAVE HEATING SYSTEM"; and U.S. Patent Application No. 62/574,601, filed October 19, 2017, titled "MICROWAVE HEATING SYSTEM INCLUDING SPLIT CHAMBER VESSELS", the entire contents of which are incorporated by reference for all purposes.

TECHNICAL FIELD

[0002] Aspects of the present disclosure are directed to heating systems in which articles are heated, at least in part, by exposure to microwave energy. In particular, the present disclosure is directed to heating systems including improved systems for controlling temperature within microwave heating sections of such heating systems.

BACKGROUND

[0003] Microwave energy has been used as a source of energy to rapidly and effectively heat articles in many different applications. Because of its ability to quickly and thoroughly heat an article, microwave energy in particular may be employed in specific applications where the rapid achievement of a prescribed minimum temperature is desirable, such as, for example, pasteurization or sterilization processes. Additionally, because microwave energy is generally volumetric, it may be useful for heating many dielectrically and thermally sensitive articles, such as food and pharmaceuticals. However, to date, the complexities and nuances of safely and effectively applying microwave energy, particularly on a commercial scale, have severely limited its application in rapid thermal processing. Accordingly, a need exists for efficient and cost-effective industrial scale microwave energy heating systems suitable for use in a wide variety of end-use applications.

Summary

[0004] According to ~~a first~~an aspect of the present disclosure, there is provided a process for heating articles in a heating system, said process including: (a) passing an article in a carrier through a heating chamber that is at least partially filled with a liquid medium to form a liquid

bath; (b) heating said article in said carrier, wherein said article is at least partially submerged in said liquid bath during said heating, and wherein at least a portion of said heating is performed using microwave energy; (c) measuring a fluid temperature selected from the group consisting of an inlet fluid temperature, an outlet fluid temperature, and a combination thereof to provide at least one measured temperature value; (d) comparing said at least one measured temperature value to a target value for said liquid temperature measured in step (c) to determine a difference; and (e) one or more of adding fluid into and removing fluid from at least one location in said heating chamber until said difference is lower than a maximum allowable difference and to maintain a temperature profile across said heating chamber in which a temperature of said liquid bath at an inlet area of said heating chamber is at least 10°C cooler than a temperature of said liquid bath at an outlet area of said heating chamber.

[0005] ~~According to a second aspect of the present disclosure, there is provided~~ Disclosed herein is a heating system for heating, said heating system including: a heating chamber for heating articles using microwave energy, wherein said heating chamber is configured to be at least partially filled with a fluid forming a liquid bath; and a fluid distribution and temperature control system comprising: a heat transfer system comprising at least one heat transfer device for one or more of heating and cooling said fluid; and a plurality of nozzles for one or more of discharging fluid into said heating chamber and removing fluid from said heating chamber, wherein; each nozzle of said plurality of nozzles is in fluid flow communication with said heat transfer system, said plurality of nozzles is distributed along a length of said heating chamber, and said plurality of nozzles is configured such that a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near an inlet area of said heating chamber is greater than a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near an outlet area of said heating chamber.

[0006] Disclosed herein is a process for heating articles that includes sequentially passing loaded carriers in a continuous manner through a first processing section and sequentially passing said plurality of loaded carriers in an incremental manner through a second processing section using an incremental convey segment. The incremental convey segment includes sequential carrier-receiving slots, each carrier-receiving slot configured to receive one of said loaded carriers and the incremental convey segment is configured to be moved incrementally at multiples of discrete intervals corresponding to the carrier-receiving slots. The process further includes sequentially passing the loaded carriers in a continuous manner through a third processing section and heating articles supported by the carriers with microwave energy in at least one of said first, second, and third processing sections, the heating of the articles

CLAIMS

1. A process for heating articles in a heating system, said process comprising:

(a) passing an article in a carrier through a heating chamber that is at least partially filled with a liquid medium to form a liquid bath;

(b) heating said article in said carrier, wherein said article is at least partially submerged in said liquid bath during said heating, and wherein at least a portion of said heating is performed using microwave energy;

(c) measuring a fluid temperature selected from the group consisting of an inlet fluid temperature, an outlet fluid temperature, and a combination thereof to provide at least one measured temperature value;

(d) comparing said at least one measured temperature value to a target value for said liquid temperature measured in step (c) to determine a difference; and(e) one or more of adding fluid into and removing fluid from at least one location in said heating chamber until said difference is lower than a maximum allowable difference and to maintain a temperature profile across said heating chamber in which a temperature of said liquid bath at an inlet area of said heating chamber is at least 10°C cooler than a temperature of said liquid bath at an outlet area of said heating chamber.

2. The process of claim 1, wherein passing said article in said carrier through said heating chamber includes transporting said carrier including said article using a conveyance system.

3. The process of claim 1, wherein said one or more of adding fluid and removing fluid of step (e) occurs simultaneously with at least a portion of said heating of step (b).

4. The process of claim 1, wherein a change in temperature per 0.305m (per linear foot) of said liquid bath remains substantially constant between said inlet area and said outlet area.

5. The process of claim 1, wherein the change in temperature per 0.305m (per linear foot) of said liquid bath is at least 1.64°C/m (0.50°C/ft).

6. The process of claim 1, wherein the temperature of said liquid bath at said inlet area of said heating chamber is at least 50°C.

7. The process of claim 1, wherein the temperature of said liquid bath at said outlet area of said heating chamber is at least 60°C.

8. The process of claim 1, wherein said heating of step (b) is sufficient to increase the temperature of a coldest portion of said article to a temperature at or above a target temperature, and wherein one or more of the temperature of said liquid bath at said inlet area and the temperature of said liquid bath at said outlet area is lower than said target temperature.

9. The process of claim 1, wherein said one or more of adding fluid and removing fluid of step (e) includes discharging a portion of said fluid into said heating chamber and withdrawing a portion of said fluid from said heating chamber, respectively, via a nozzle located along a length of said heating chamber between said inlet area and said outlet area.

10. The process of claim 9, wherein said nozzle is one of plurality of nozzles distributed along said length of said heating chamber between said inlet area and said outlet area.

11. The process of claim 10, wherein said plurality of nozzles includes at least one nozzle pair, said nozzle pair including a first nozzle for discharging warmed fluid and a second nozzle for discharging cooled fluid into the heating chamber.

12. The process of claim 11, wherein said warmed fluid has a temperature of at least 35°C and wherein said cooled fluid has a temperature of not more than 35°C.

13. The process of claim 10, wherein said plurality of nozzles includes a nozzle pair including an inlet nozzle and an outlet nozzle for respectively discharging fluid into and removing fluid from a portion of said heating chamber.

14. The process of claim 9, wherein said one or more adding and removing of step (c) includes simultaneously discharging fluid into said heating chamber and removing fluid from said heating chamber.

15. The process of claim 14, wherein a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near said inlet area is greater than a ratio of volumetric flow rate of fluid discharged into said

heating chamber to volumetric flow rate of fluid removed from said heating chamber near said outlet area.

16. The process of claim 1, wherein each of steps (c) through (e) is performed automatically by a computerized control system.

17. The process of claim 1 further comprising, prior to said passing of step (a), preheating said article in said carrier in a preheating chamber, wherein said preheating chamber is at least partially filled with another fluid to form a second liquid bath and said article is at least partially submerged in said second liquid bath during said preheating.

18. The process of claim 1 further comprising, subsequent to said heating of step (b), passing said article in said carrier through a holding zone, wherein a temperature of a coldest portion of said article is maintained at or above a target temperature for a period of time in said holding zone.

19. The process of claim 18, wherein said heating of step (c) and said holding are sufficient to at least one of pasteurize and sterilize said article.

20. The process of claim 1, wherein said article comprises packaged foodstuffs or a beverage.

21. The process of claim 1, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.

~~22. A heating system for heating, said heating system comprising:~~

~~a heating chamber for heating articles using microwave energy, wherein said heating chamber is configured to be at least partially filled with a fluid forming a liquid bath; and~~

~~a fluid distribution and temperature control system comprising:~~

~~a heat transfer system comprising at least one heat transfer device for one or more of heating and cooling said fluid; and~~

~~a plurality of nozzles for one or more of discharging fluid into said heating chamber and removing fluid from said heating chamber,~~

~~wherein;~~

~~each nozzle of said plurality of nozzles is in fluid flow communication with said heat transfer system,~~

~~said plurality of nozzles is distributed along a length of said heating chamber, and~~

~~said plurality of nozzles is configured such that a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near an inlet area of said heating chamber is greater than a ratio of volumetric flow rate of fluid discharged into said heating chamber to volumetric flow rate of fluid removed from said heating chamber near an outlet area of said heating chamber.~~

~~23. The heating system of claim 22, wherein said fluid distribution system is configured to maintain a temperature profile along said heating chamber in which a temperature of said liquid bath at said outlet area of said heating chamber is at least 10°C higher than a temperature of said liquid bath at said inlet area of said heating chamber and a change in temperature per 0.305m (per linear foot) of said liquid bath through said heating chamber remains substantially constant between said inlet area and said outlet area.~~

~~24. The heating system of claim 23 further comprising, an automatic control system for selectively regulating a flow of fluid of said plurality of nozzles and said at least one heat transfer device to maintain said temperature profile along said heating chamber.~~

~~25. The heating system of claim 22 further comprising a carrier configured to hold said articles.~~

~~26. The heating system of claim 25 further comprising a convey line for transporting said carrier in a convey direction.~~

~~27. The heating system of claim 22 further comprising a microwave generator for generating said microwave energy and a microwave distribution system for directing said microwave energy from said generator into said heating chamber, wherein said microwave distribution system includes at least one pair of microwave launchers for discharging microwave energy into said heating chamber.~~

~~28. The heating system of claim 27, wherein said pair of launchers is disposed on an upper side of said heating chamber.~~

~~29. The heating system of claim 27, wherein said pair of microwave launchers includes an upper microwave launcher and a lower microwave launcher, the upper microwave launcher and the lower microwave launcher positioned on opposite sides of said heating chamber.~~

~~30. The heating system of claim 22, wherein said plurality of nozzles includes at least two pairs of nozzles spaced apart from one another along the length of said heating chamber, wherein each of said pairs of nozzles includes one discharge nozzle for adding fluid to said heating chamber and one withdraw nozzle for removing fluid from said heating chamber.~~

~~31. The heating system of claim 22, wherein the plurality of nozzles includes adjacent pairs of nozzles, the system further comprising a divider disposed between said adjacent pairs of nozzles.~~

~~32. The heating system of claim 22, wherein said heat transfer system comprises a first heat transfer device to provide heated fluid to a first nozzle of said plurality of nozzles and a second heat transfer device to provide cooled fluid to a second nozzle of said plurality of nozzles, said first nozzle and said second nozzle being disposed adjacent to each other along the length of said heating chamber.~~

~~33. The heating system of claim 22, wherein said plurality of nozzles includes at least two pairs of nozzles positioned on opposite sides of said heating chamber.~~

~~34. The heating system of claim 22 further comprising a preheating chamber located prior to said heating chamber for preheating said articles to a preheat temperature.~~

~~35. The heating system of claim 22 further comprising a holding chamber located after said heating chamber for maintaining said articles at a hold temperature such that a coldest portion of each of said articles is at or above a target temperature for a hold time.~~

~~36. The heating system of claim 22, wherein said heating system is at least one of a pasteurization or sterilization system.~~

~~37. The heating system of claim 22, wherein said heating system has an average production rate of at least 20 packages per minute equivalent.~~