

DEVOLATILIZATION APPARATUS AND METHOD FOR A POLYMER SOLUTION

BACKGROUND OF THE INVENTION

This invention relates to an apparatus and method for removing volatile components from a polymer. More particularly, this invention relates to an apparatus and method for treating a polymer solution containing large amounts of volatile components and separation of the volatiles from the polymer.

As is known, the removal of volatile components including unreacted monomers or solvents from a polymer or a polymer melt is referred to as “devolatilization”. A variety of processes are available for the separation of the volatile components from polymers by, for example, wiped film evaporation, increasing polymer surface renewal rate, increasing polymer surface area, flash devolatilization or combinations thereof.

In the process of flash devolatilization, the polymer solution is heated under pressure by means of a heat exchanger to a temperature higher than the boiling point of the volatile components, and then flows into a zone of reduced pressure, where a reduced pressure permits the volatile components to flash off and thereby causing the polymer to separate from the volatiles.

U.S. Pat. No. 7,942,955, for example, describes a devolatilization process, wherein a liquid containing a polymer is heated in a heat exchanger before flowing into a phase separation chamber under reduced pressure, where volatiles are vaporized and the polymer is discharged from the openings in its lower umbrella shaped portion or in a sloped perforated plate. U.S. Pat. No. 10,143,941 discloses a process, wherein a second devolatilization device below a phase separation chamber is utilized to increase the polymer surface area and residence time.

While such above-mentioned flash devolatilization processes allow to obtain a devolatilized polymer, one disadvantage is that the sizes of the openings in the phase separation chamber used for discharging polymers have to be relatively large so as to decrease the pressure drop caused by the polymer flowing through the openings, especially in cases where the polymer has a high viscosity. Since the main driving force for the polymer extruding through the openings is the static liquid height above them, i.e., a static liquid height has to be kept high enough to overcome the pressure drop. The use of relatively large openings facilitates a continuous flow of the polymer through the openings and also enables the formation of falling polymer strands. However, the volatile components are not released away so efficiently from the falling polymer

strands out of large openings as compared with those out of smaller ones because much more specific surface area provided by smaller strands are exposed to vacuum and heat.

Another disadvantage is that there exists a risk of solids formation in the phase separation chamber during flash devolatilization of a polymer solution containing large amounts of volatile components. As most of expansion evaporation of the volatiles needs to take place in the phase separation chamber, a large temperature drop will occur for the devolatilized polymer. The polymer with a low temperature has a negative impact on its flowability and is susceptible to accumulate and pile up in the phase separation chamber, which will also limit the disengagement of vapors from the polymers.

In the process of flash devolatilization the polymer solution is generally preheated to a temperature well below the degradation temperature of the polymer to be prevented from any discoloration or thermal degradation. In some cases of devolatilizing a volatile enriched polymer solution where solids formation or thermal degradation is concerned, multi-stage of devolatilization such as three to five stages are required to operate sequentially at a decreasing pressure to achieve a desired separation of volatiles from the polymer. During each stage of devolatilization, the polymer solution or partly devolatilized polymer is introduced to a heat exchanger to raise its temperature up to a value needed for the vaporization of a certain amount of volatiles. On the other hand, too many stages of devolatilization means a complicated process, where a long residence time is expected for the polymer being exposed to elevated temperatures.

In addition, a laminar flow regime with a parabolic flow profile is developed for the devolatilized polymer flowing in the horizontal phase separation chamber during flash devolatilization. The maldistribution in the flow speed occurs with the polymer in the center of the chamber having a higher speed and those near the interior walls having a relatively low speed. The low-speed will result in a long residence time for the polymer, which also leads to a risk of thermal degradation.

SUMMARY OF THE INVENTION

It is, therefore, the object of this invention to provide a devolatilization apparatus for a treatment of a polymer solution containing large amounts of volatile components, by means of which the above-mentioned disadvantages or deficiencies are overcome, diminished or at least mitigated. This object is achieved, according to the invention, by using a horizontal perforated housing being equipped with a bundle of coiled tubes, which serves as a heat exchanger for heat

input into the polymer solution, and at the same time as a static guider designed to cause the polymer solution a forced convection and direct its flow towards to interior walls of the housing

Further objects of the invention include providing a method for using the devolatilization apparatus in treating a polymer solution containing large amounts of volatile components, wherein the apparatus comprises at least one horizontal perforated housing located in the upper regions of a container, inside of which housing is equipped with a bundle of tubes being arranged in parallel to one another. Each such tube is coiled into a number of identical loops connected in series, each of which loop consists of bendings and straight portions. The loops from the same tube are arranged in a single plane perpendicular to a common center plane and allocated evenly and symmetrically on both sides of the center plane in the axial direction of said housing. The heating medium from an inlet head flowing to the bundle of tubes transfers heat into the polymer solution which is guided by the straight portions of loops towards the interior walls of the housing. The perforated section in the horizontal perforated housing consists of sets of holes, which are located respectively in its lower portion for discharging the partly devolatilized polymer downwardly towards to the sump regions of the container, and in its upper portion for vapors escaping upwardly to the top regions of the container.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is one schematic depiction of a devolatilization apparatus with one horizontal perforated housing in accordance with the invention;

FIG. 2 is a partial top plan view of a devolatilization apparatus of FIG 1A;

FIG. 3 is a schematic depiction of a single coiled tube from the tube bundle in a horizontal perforated housing in accordance with the invention;

FIG. 4 is a partial sectional side view of a devolatilization apparatus of FIG 1A;

FIG. 5A is a partial cutaway drawing of a horizontal perforated housing in the upper regions of a devolatilization apparatus in accordance with the invention;

FIG. 5B is a partial cutaway drawing of two horizontal perforated housings in the upper regions of a devolatilization apparatus in accordance with the invention;

FIG. 6 is a partial cross-sectional view of a horizontal perforated housing in accordance with the invention;

FIG. 7A is a partial side plan view of a supporting bar in accordance with the invention;

FIG. 7B is a partial top plan view of a supporting bar in accordance with the invention; and

FIG. 8 is a schematic depiction of two stage of devolatilization in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will be understood more readily from the following detailed description of preferred embodiments of the invention and the accompanying examples included herein.

Referring to FIG. 1, the devolatilization apparatus 100 includes a container 101 serving as a buffer tank where the generated vapors are disengaged from the liquid polymer. The interior space of the container 101 includes an upper region 102 for accommodating vapor enriched fraction 201, a lower sump region 103 for collecting polymer enriched fraction 202 and a central region 104 for accommodating the falling polymer strands 203, all disposed on a vertical axis. A gear pump 105 is located at the bottom of the container 101 for discharging the devolatilized polymer 204 via line 112 to a subsequent process and a vapor line 106 is located at the top of the container 101 for removing the vapors 205 therefrom.

A horizontal perforated housing 107 is placed in the upper region of the container 101 which housing includes a polymer solution feed inlet 108, a heating medium inlet head 109 and a heating medium outlet head 110, all of which are located outside the container 101. A bundle of tubes 111 is installed inside the housing 107, each of which is coiled into a number of identical loops connected in series in the axial direction of the housing 107. All the loops of a single tube are arranged in the same plane perpendicular to the common center plane 200. It is therefore inferred that each such tube of the tube bundle 111 is positioned in parallel to one another. One end of each tube is connected to the inlet head 109 for heating medium flowing in and the other end is connected to the outlet head 110 for heating medium flowing out. As the heating medium inlet head 109 and outlet head 110 are at the same side of the housing 107, each tube of the bundle 111 can be considered as a coiled U-tube having a number of connected loops. The polymer solution is fed from the inlet 108 into the housing 107, passing around the bundle of tubes 111 and exchanging heat with the heating medium flowing in the individual tubes. The outer diameter of the tube in the bundle 111 can be different and

selected from the range from 6 to 25 mm. However, the use of the same size of tubes enables a more structured bundle and a more predictable heat transfer rate into the polymer.

As shown in FIG. 2, the horizontal perforated housing 107 is an end-enclosed pipe. One portion of the housing 107 with the feed inlet 108 is located outside the container 101 and the remaining portion with the closed end extends to the inside of the container 101. As the bundle of tubes 111 is filled with flowing heating medium which emit heat to its surroundings, thermal jacketing is thus not necessary for the housing 107.

With reference to FIG. 3, a representative coiled tube 206 from the tube bundle 111 has 26 loops positioned in one plane, which loops are allocated evenly and symmetrically on both sides of the center plane 200 in the axial direction of the housing 107, i.e., the first 13 loops which are above the center plane 200 are the mirror image of the remaining 13 ones which are below the center plane 200. The connections 209 which connect the 13 loops above the center plane 200 and the 13 mirrored ones below the center plane 200 consists of straight tube fittings, elbows and any combinations thereof. Each loop consists of two bendings 207 and two straight portions 208, with the straight portions 208 extending towards the interior walls of the housing 107. A gap is observed between the bottommost part of the loops above the center plane 200 and the uppermost part of the mirrored ones below the center plane 200, which gap is in the ranges of 0.5 to 10 mm so as to accommodate tube thermal expansion. Each loop is inclined at the same angle with reference to the common center plane 200. The angle is preferably in the range of 20° to 80°, more preferably of 30° to 60° to direct the flow of the polymer solution towards to the interior walls of the housing 107, e.g., a representative angle of 45° is shown in FIG. 3. To obtain a more structured bundle 111 it is preferred that the same size of bendings 207 is used throughout the bundle 111, which indicates that the length of the loop is only dependent on the length of the straight portions 208. As the straight portions 208 of each tube are expected to extend fully and approach to the interior walls of the housing 107, the cross-sectional area of the tube bundle 111 is thereby slightly smaller than that of the horizontal perforated housing 107 so that the polymer solution is prevented from channeling a course through the gap between the periphery of the tube bundle 111 and the interior walls of the housing 107.

FIG. 4 is a schematic sectional side view of a devolatilization apparatus with one horizontal perforated housing 107 installed. The perforated sections of the housing 107 are located respectively in its lower portion 301 for discharging partly devolatilized polymer downwardly towards to the sump regions of the container 101 and in its upper portion 302 for

vapors removal to the top regions of the container 101. The portion 301 is made of a set of holes 303 with gradually increasing diameters along the length of the housing 107 in the flow direction of the polymer solution. The diameters of the holes 303 are in the range of 0.5 to 50 mm, and more preferably of 1 to 30 mm. It can be advantageous to distribute the holes 303 in an irregular manner so that a variable hole density is available, for example a low density with large hole diameters is desired for the partly devolatilized polymer having a relatively high viscosity near the closed end of the housing 107, in a purpose of facilitating its flowing through the holes 303. In the upper portion 302 above the center plane 200 located at least one row of holes 304 for the release of the vapors from the polymer. Similarly, it is beneficial to enlarge the holes 304 stepwise along the length of the housing 107 till its end to expedite the removal of the vapors through them. The diameters of the holes 304 are in the range of 0.5 to 50 mm, and more preferably of 1 to 30 mm. It is preferred that the distribution of holes 304 can be irregular, for example a large hole density with small hole diameters is preferred at the beginning of the perforations.

With reference to FIG. 5A, a partial cutaway drawing of a horizontal perforated housing 107 shows a tube bundle 111 consists of four coiled tubes arranged in parallel to one another, each of which has the same number of loops. The sizes of the loops are the same for a single tube but may differ in other tubes, with the tube being disposed in the center of the housing 107 having the largest loop benefiting from its longest straight portions.

In cases where a horizontal perforated housing 107 cannot handle a polymer solution, e.g., the heating surface area of the tube bundle 111 is not large enough to provide necessary heat for the evaporation of contained volatiles or the flow rate of the polymer solution is too high, two or more horizontal perforated housing can be simultaneously employed to achieve a desired devolatilization. As shown in FIG. 5B, two horizontal perforated housings 107 and 107' are located in the upper regions of the container 101, each of which has a heating medium inlet head 109 or 109', an outlet head 110 or 110' and a tube bundle 111 or 111'. The polymer solution is evenly divided into two streams, each of which is fed to the inlet 108 or 108' respectively located in the corresponding housing 107 or 107', where two sets of holes 303 and 303' are used for discharging partly devolatilized polymer downwardly and two sets of holes 304 and 304' are used for removing generated vapors upwardly.

Referring to FIG. 6, a partial cross-sectional view of a horizontal perforated housing 107 is displayed with a row of holes 304 above the center plane 200 placed for each side of the housing 107. A plurality of guiding elements 305 are positioned vertically and separately welded below holes 304 on the two intersection lines of the center plane 200 and the housing 107. The length of the guiding element 305 is preferably in the range of 5 to 80 mm, more preferably of 10 to 50 mm. A set of holes 303 are located in the lower portion of the housing 107, which are kept at a

certain distance apart from the above-mentioned two intersection lines so as to prevent the falling polymer strands out of the holes 303 from entangling with each other.

With reference now to FIG. 5A, during devolatilization the polymer solution is heated and guided by the straight portions of loops towards the interior walls of the housing 107. The vapors are generated stepwise and removed through holes 304, where a small amount of partly devolatilized polymer will be entrained by escaping vapors, flow along the outer surface of the housing 107 and then diverted by the elements 305 towards to the sump regions of the container 101. With the progress of the devolatilization, the polymer solution is gradually heated in the housing 107 to control the amount of vapors generated. As the bundle of tubes 111 are structured and aligned tightly with very small distance between one another and the holes 303 and 304 are set small, the pressure drop caused by the flowing of the polymer solution has to be overcome mainly by the driving force provided by a gear pump (not shown in FIG. 5A) upstream of the housing 107. It indicates that the size of the holes 303 in the present invention can be designed so small that the polymer strands coming out of the holes 303 have a large specific surface area being exposed to heat and reduced pressure, which therefore accelerates the releasing of vapors from the falling polymer strands.

As illustrated in FIG. 7A, multiple grooves 402 in a representative supporting bar 401 are used for tube loops to be fit in and soldered. FIG. 7B displays the supporting bar 401 having grooves 402 on its both sides. The supporting bar 401 is located in between two adjacent tubes, i.e., for every two coiled tubes there exists two supporting bars 401 respectively for the loops above the center plane 200 and those below the center plane 200. The purpose of the supporting bars 401 are to support each coiled tube and stabilize the tube bundle 111.

As seen in FIG. 8, a devolatilization process consisting of two stages is utilized for a treatment of a polymer solution. The polymer solution is fed into the horizontal perforated housing 107 via inlet 108 for the first stage of devolatilization, where the heating medium is fed via inlet head 109 to the tube bundle 111 for heat input to the polymer solution. The vaporized volatiles are removed from the holes 304 while the partly devolatilized polymer is discharged through the holes 303 to the sump regions of the container 101. A gear pump 105 is installed at the bottom of the container 101 and used for transferring the partly devolatilized polymer to the horizontal perforated housing 107" of the second stage of devolatilization. The heating medium is fed via inlet head 109" to the tube bundle 111", heat exchanging with the polymer which passes around the bundle of tubes 111". The remaining volatiles are released from the holes 304" and the polymer strands out of the holes 303" are deposited at the bottom of the container 101". A gear

pump 105" is installed at the bottom of the container 101" and used for transferring the polymer product 204 substantially free of volatiles to a subsequent process for further treatment.

EXAMPLES

Two stages of devolatilization according to an embodiment of the invention as shown in FIG. 8 were performed for varying feed and process conditions to demonstrate the functioning of the devolatilization apparatus.

The first devolatilization apparatus comprises of one horizontal perforated housing 107 with an inner diameter of 400 mm. A tube bundle 111 in the housing 107 is composed of 36 tubes, each of which has an outer diameter of 10 mm. Each such tube is coiled into 28 identical loops connected in series, each of which consists of bendings and straight portions. The loops from the same tube are arranged in a single plane perpendicular to a common center plane 200 and allocated evenly and symmetrically on both sides of the center plane 200 in the axial direction of the housing 107. The perforated sections in the lower portion of the housing 107 comprises of 68 holes 303 ranging from 3 to 10 mm along the polymer flow direction. The perforated sections in the upper portion of the housing 107 comprises of 82 holes 304 ranging from 3 to 10 mm, 41 holes of which are placed on each side along the length of the housing 107. A total of 36 supporting bars 401 are used for the tube bundle 111. A total of 44 guiding plates 305 are welded below the holes 304 on each side of the housing 107.

The second devolatilization apparatus comprises of one horizontal perforated housing 107" with an inner diameter of 190 mm. A tube bundle 111" in the housing 107" is composed of 14 tubes, each of which has an outer diameter of 10 mm. Each such tube is coiled into 26 identical loops connected in series, each of which consists of bendings and straight portions. The loops from the same tube are arranged in a single plane perpendicular to a common center plane 200" and allocated evenly and symmetrically on both sides of the center plane 200" in the axial direction of the housing 107". The perforated sections in the lower portion of the housing 107" comprises of 79 holes 303" ranging from 3 to 7 mm along the polymer flow direction. The perforated sections in the upper portion of the housing 107" comprises of 50 holes 304" ranging from 3 to 7 mm, 25 holes of which are placed on each side along the length of the housing 107". A total of 14 supporting bars 401" are used for the tube bundle 111". A total of 44 guiding plates 305" are welded below the holes 304" on each side of the housing 107".

Example 1

A flow rate of 2000 kg/h of the polymer solution at a pressure of 38 bar and a temperature of 190° C, composed of 16% by weight of ethylene/octene copolymer, 1.2% by weight of ethylene, 5.8% by weight of 1-octene and 77% by weight of cyclohexane, was continuously fed to the first devolatilization through feed inlet 108. The heating medium with a flow rate of 9,400 kg/h flowed to the inlet head 109, where the heating medium was distributed into the 36 tubes. While heat exchanging with the polymer solution the heating medium was circulated in each tube and eventually entered the outlet head 110. The operating pressure for the first devolatilization was set as 6.6 bar. The polymer solution was heated up to a temperature of 230° C and most of the volatiles contained in the polymer solution were released stepwise from the housing 107. The generated vapors 205 were removed outside the container 101 via line 106. The partly devolatilized polymer with 88.07% by weight of copolymer was transferred by gear pump 105 via line 112 to the inlet of the housing 107" in the second devolatilization. As the partly devolatilized polymer had a relatively high temperature of 230° C, the heating medium was not needed and the tube bundle 111" was only used for directing the polymer towards the interior walls of the housing 107". The operating pressure for the second devolatilization was set as 15 mbar. The volatiles contained in the partly devolatilized polymer were further evaporated and removed from the housing 107". The generated vapors 205" were removed outside the container 101" via line 106". The devolatilized polymer 204 with 99.96% by weight of copolymer was transferred by gear pump 105" via line 112" to a subsequent process.

Example 2

A flow rate of 2000 kg/h of the polymer solution at a pressure of 38 bar and a temperature of 190° C, composed of 17% by weight of ethylene/octene copolymer, 1% by weight of ethylene, 4% by weight of 1-octene and 78% by weight of cyclohexane, was continuously fed to the first devolatilization through feed inlet 108. The heating medium with a flow rate of 8,900 kg/h flowed to the inlet head 109, where the heating medium was distributed into the 36 tubes. While heat exchanging with the polymer solution the heating medium was circulated in each tube and eventually entered the outlet head 110. The operating pressure for the first devolatilization was set as 7 bar. The polymer solution was heated up to a temperature of 220° C and most of the volatiles contained in the polymer solution were released stepwise from the housing 107. The generated vapors 205 were removed outside of the container 101 via line 106. The partly devolatilized polymer with 84.87% by weight of copolymer was transferred by gear pump 105 via line 112 to the inlet of the housing 107" in the second devolatilization. The operating pressure for the second devolatilization was set as 15 mbar. The heating medium with a flow rate of 2,200 kg/h flowed to the inlet head 109", where the heating medium was distributed into the 14 tubes.

After heat exchanging with the polymer solution the heating medium from each tube eventually flowed into the outlet head 110". The polymer solution was heated up to a temperature of 230° C and the remaining volatiles contained in the partly devolatilized polymer were gradually taken out from the housing 107". The generated vapors 205" were removed outside of the container 101" via line 106". The devolatilized polymer 204 with 99.97% by weight of copolymer was transferred by gear pump 105" via line 112" to a subsequent process.

Although the invention has been described in detail with reference to specific embodiments, it will be understood that such detail is solely for the purpose of illustration and that various modifications may be made therein by those skilled in the art without departing from the scope of the invention.

The invention claimed is:

1. A devolatilization apparatus for a treatment of a polymer solution, comprising at least one horizontal perforated housing located in the upper regions of a container, inside of which said housing being equipped with a bundle of tubes, each said tube being coiled into a number of identical loops connected in series each of which said loop consists of bendings and straight portions, said loops of a single said tube being arranged in the same plane perpendicular to the common center plane and being allocated evenly and symmetrically on both sides of said center plane in the axial direction of said housing.
2. A devolatilization apparatus of claim 1, wherein said horizontal perforated housing is an end-enclosed pipe extending to the inside of said container, said pipe having a feed inlet outside said container for receiving a polymer solution.
3. A devolatilization apparatus of claim 1, wherein said plane where each said tube lies is arranged in parallel to one another.
4. A devolatilization apparatus of claim 1, wherein said horizontal perforated housing has a heating medium inlet head and an outlet head outside said container for passing the heating medium to said bundle of tubes for heat exchanging with said polymer solution.
5. A devolatilization apparatus of claim 1, wherein one end of each said tube connects to said inlet head for heating medium flowing in and the other end connects to said outlet head for heating medium flowing out.
6. A devolatilization apparatus of claim 1, wherein said loops of each said tube are inclined at the same angle with reference to said common center plane.
7. A devolatilization apparatus of claim 6, wherein said same angle is preferably in the range of 20° to 80°, more preferably of 30° to 60°.
8. A devolatilization apparatus of claim 1, wherein said horizontal perforated housing has perforated sections respectively both in its lower portion for discharging partly devolatilized polymer downwardly towards to the sump regions of said container and in its upper portion for releasing vapors upwardly to the top regions of said container.
9. A devolatilization apparatus of claim 8, wherein the perforations in said perforated section are made of sets of holes with gradually increasing diameters ranging more preferably from 1 to 30 mm along the length of said horizontal perforated housing in the polymer flow direction.

10. A devolatilization apparatus of claim 8, wherein a plurality of guiding elements is separately welded on the two intersection lines of said center plane and said horizontal perforated housing, each said guiding element being positioned vertically to guide partly devolatilized polymer to flow downwardly to the sump region of said container.

11. A devolatilization apparatus of claim 1, wherein the outer diameter of said tube lies in the range of 6 to 25 mm.

12. A devolatilization apparatus of claim 1, further comprising supporting bars each of which is located in between two adjacent said tubes to support said tubes and stabilize said tube bundle.

13. A method for devolatilizing a polymer solution comprising volatile components using the devolatilization apparatus of claim 1, wherein the method comprises: passing a polymer solution to at least one horizontal perforated housing through an inlet located outside of a container, which housing is equipped with a bundle of tubes being arranged in a parallel configuration, each such tube being coiled into a number of identical loops connected in series each of which loop consists of bendings and straight portions, the loops being arranged in a single plane perpendicular to a common center plane and allocated evenly and symmetrically on both sides of the center plane in the axial direction of said housing;

wherein a heating medium is passed to the bundle of tubes for heat exchanging with the polymer solution being guided by the straight portions of the loops towards the interior walls of the horizontal perforated housing, and wherein perforated sections of the horizontal perforated housing are located respectively both in its lower portion for discharging partly devolatilized polymer downwardly towards the sump regions of the container and in its upper portion for discharging vapors upwardly to the top regions of the container.

14. The method of claim 13, wherein a plurality of guiding elements is separately welded on the two intersection lines of said center plane and said horizontal perforated housing, each said guiding element being positioned vertically to guide partly devolatilized polymer to flow downwardly to the sump region of said container.

15. The method of claim 13, wherein said polymer solution is a polyolefin elastomer solution.