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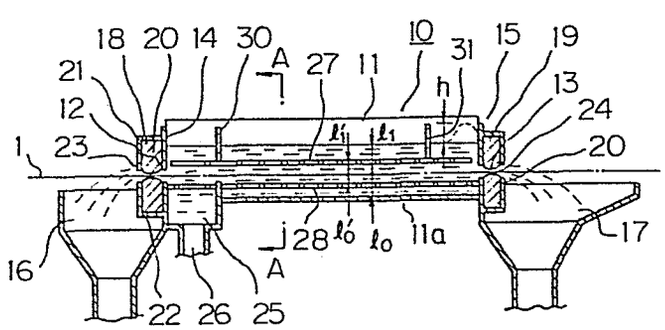
(54) **Apparatus for liquid bath treatment of synthetic fiber tows.**

(57) An apparatus for the liquid bath treatment of synthetic fiber tows, which comprises two driving rollers spaced from each other by a certain distance, a treating liquid circulating tank and a liquid bath tank arranged between the two driving rollers and communicating with the liquid circulating tank, wherein a treating liquid is supplied to the liquid bath tank and circulated therethrough and a synthetic fiber tow is treated by immersing and travelling the synthetic fiber tow in the treating liquid in the liquid bath tank, said liquid treatment apparatus being characterized in that a perforated plate having a number of holes is arranged at least above a tow passage connecting both the driving rollers in close proximity to said tow passage substantially in parallel thereto.

Fig. 4



EP 0 121 240 A2

APPARATUS FOR LIQUID BATH TREATMENT OF SYNTHETIC FIBER TOWS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an apparatus for a liquid bath treatment of synthetic fiber tows. More particularly, the present invention relates to a liquid bath treatment apparatus for a drawing treatment, heat treatment or oiling treatment of synthetic fiber tows.

Description of the Prior Art

A liquid bath treatment apparatus comprising weirs 2 and 2' on both the sides of a liquid bath tank 3 as shown in Fig. 1 has been used for performing drawing of a synthetic fiber tow in a liquid bath or carrying out a heat treatment or oiling treatment of a synthetic fiber tow in a liquid bath. In this apparatus, a tow 1 passes below the weirs 2 and 2', that is, below the liquid surface defined by the weirs 2 and 2'. However, if the treatment speed is increased in this apparatus so as to improve the productivity, the liquid 4 in the liquid bath treatment apparatus is caused to flow while accompanying the tow and is forwarded toward the tow discharge side, with the result that the liquid level on the tow supply side becomes lower than that on the tow discharge side in the liquid bath treatment apparatus. Accordingly, the tow 1 is not sufficiently immersed in the liquid 4 on the tow supply side and the liquid bath treatment becomes insufficient, and consequently, the temperature is not sufficiently elevated and treatment unevenness such as drawing unevenness, heat treatment unevenness or unevenness of application of an oiling agent is caused.

Furthermore, if the treatment speed is increased, the liquid impinging against the weir 2' is scattered outside the liquid bath, as indicated by dot lines

in Fig. 1, resulting in impairment of the operation adaptability and safety. Therefore, it is very difficult to perform the liquid bath treatment at a treatment speed higher than 150 m/min and the practical utility of this conventional treatment apparatus is very low.

As means for avoiding the above disadvantage, there has been proposed an apparatus in which a liquid stopping weir plate is arranged above the tow to block the liquid accompanying the tow (see Japanese Examined Utility Model Publication (Kokoku) No. 47-15628, Japanese Examined Patent Publication (Kokoku) No. 56-42683 and Japanese Examined Utility Model Publication (Kokoku) No. 42-6244). In this apparatus, however, as shown in Fig. 2, it has been found that the liquid is more likely to stay on the weir plate 5 as the treatment speed is increased, and therefore, the temperature of the liquid before the weir plate 5 reduced and because of the temperature difference between the upper and lower portions of the tow, treatment unevenness is readily caused. Furthermore, as the treatment speed is increased, the liquid adheres to the surface of the weir plate and a discontinuous portion is formed in the liquid between the two weir plates 5 and the tow 1 is not sufficiently immersed in the liquid, with the result that temperature unevenness is produced in the tow.

SUMMARY OF THE INVENTION

The present invention has been completed under the above-mentioned background. It is therefore a primary object of the present invention to provide an apparatus in which even if a liquid bath treatment of a synthetic fiber tow is carried out at a high speed especially at a speed higher than 200 m/min, the liquid bath treatment can be carried out stably without exhaustion of a treating liquid in the tow, scattering of the liquid from a liquid bath or disturbance of the liquid in the liquid bath.

Another object of the present invention is to

provide an apparatus in which if a liquid bath treatment of a synthetic fiber tow is carried out at such a high speed as at least 200 m/min, a homogeneous product excellent in the properties can be obtained.

Still another object of the present invention is to enhance the productivity by treating a synthetic fiber tow at a high efficiency.

In accordance with the present invention, these objects can be attained by an apparatus for the liquid bath treatment of synthetic fiber tows, which comprises two driving rollers spaced from each other by a certain distance, a treating liquid circulating tank and a liquid bath tank arranged between the two drivig rollers and communicating with the liquid circulating tank, wherein a treating liquid is supplied to the liquid bath tank and circulated therethrough and a synthetic fiber tow is treated by immersing and travelling the synthetic fiber tow in the treating liquid in the liquid bath tank, said liquid treatment apparatus being characterized in that a perforated plate having a number of holes is arranged at least above a tow passage connecting both the driving rollers in close proximity said tow passage substantially in parallel thereto.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram illustrating an example of the conventional liquid bath treatment apparatus.

Fig. 2 is a diagram illustrating another example of the conventional liquid treatment apparatus.

Fig. 3 is a diagram illustrating the entire arrangement of one embodiment of the liquid bath treatment apparatus according to the present invention.

Fig. 4 is a sectional view showing the liquid bath tank zone in the apparatus illustrated in Fig. 3.

Fig. 5 is a view showing the section taken along the line A-A in Fig. 4.

Fig. 6 is a sectional view illustrating the main portion of another embodiment of the liquid bath

treatment apparatus according to the present invention, in which one of the driving rollers is arranged within the liquid bath tank.

Fig. 7 is a sectional view showing the main portion of still another embodiment of the liquid bath treatment apparatus according to the present invention, in which both of the two driving rollers are arranged within the liquid bath tank.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described in detail with reference to embodiments illustrated in the accompanying drawings.

Referring to Figs. 3 through 5, reference numeral 10 represents a (hot) liquid bath treatment tank according to the present invention, which is located between a set of a feed roller 39 and a draw roller 40, and a tow 1 is subjected to predetermined drawing while the tow 1 is passed through the liquid bath treatment tank 10 along a substantially linear tow travel passage connecting the rollers 39 and 40.

The liquid bath treatment tank comprises a tank proper 11 having a rectangular cross-section and front and rear receivers 16 and 17 communicating with the tank proper 11, and weirs 14 and 15 having slits 12 and 13 for passage of the tow 1, respectively, are arranged on the front end portion of the tank 10, that is, on the side of the feed roller 39, and on the rear end portion of the tank 10, that is, on the side of the draw roller 40, respectively. Sealing members 18 and 19 are arranged on the front and rear weirs 14 and 15 of the tank proper 11 on the sides of the receivers 16 and 17, respectively. Each sealing member comprises a seal 20 and frames 21 and 22 arranged above and below the seal 20 to hold the seal 20, and tow passing openings 23 and 24 are formed substantially on the same level as that of the slits 12 and 13 so as to define such clearance that the tow 1 is travelled while having contact with the seals 20 or in

close proximity to the seals 20 without having contact therewith, whereby the amount of the liquid flowing out from the slits 12 and 13 is controlled. The liquid level in the tank proper 11 can be adjusted by changing the sizes of the openings 23 and 24. It is ordinarily preferred that such sealing members 18 and 19 be disposed, but arrangement of the sealing members 18 and 19 is not particularly indispensable and other sealing means may be adopted. A hot liquid supply chamber 25 projecting downward is arranged in the front end portion of the tank proper 11, and a hot liquid is supplied from an inlet 26 formed in the lower portion of the chamber 25.

Upper and lower perforated plates 27 and 28 are horizontally arranged at positions lower than those of the weirs 14 and 15 in close proximity to the tow travel passage so that the tow travel passage is interposed between the upper and lower perforated plates 27 and 28, and the lower perforated plate 28 is attached to a bottom plate 11a of the tank proper 11 through a spacer 29. Buffle plates 30 and 31 are vertically arranged on the front and rear portion of the upper perforated plate 27, and the front buffle plate 30 also acts as a member defining the upper portion of the hot liquid supply chamber 25. The buffle plate 30 enhances the effect of contacting the tow with the hot liquid by preventing the hot liquid from flowing above the perforated plate 27 and avoiding the decrease of the amount of the hot liquid flowing between the upper and lower perforated plates 27 and 28, and the rear buffle plate 31 moderates the shock of impingement of the hot liquid to the weir 15. It is preferred that perforated plates be used as the buffle plates 30 and 31, and in some cases, the buffle plates 30 and 31 may be omitted. The clearance between the upper perforated plate 27 and the tow is changed according to the diameter of holes formed on the perforated plate 27 and the amount of an oiling agent contained in the hot

liquid (though the hot liquid does not always contain an oiling agent). However, in case of warm water hardly containing an oiling agent, the above clearance is ordinarily adjusted to less than 10 mm. In order to reduce the accompanying stream of the liquid, it is preferred that the clearance between the tow and the lower perforated plate 28 or bottom plate 11a be adjusted to less than 20 mm.

It is preferred that as the speed of the tow is increased or the viscosity of the bath liquid is increased, the distance between the tow and the upper or lower perforated plate 27 or 28 (which may be regarded as the distance between the tow travel passage and the perforated plate because the thickness of the running tow is ordinarily smaller than 1 mm) be reduced within the range preventing the contact with the tow.

Arms 32 are arranged in the upper portions of one sides of the buffle plates 30 and 31, and each arm 32 is rotatably pin-connected to a bracket 11b of the tank proper 11 so that the arm 32 is opened upward. Namely, the arm 32 is opened and closed, according to need, while the tow is set to be treated or when a trouble takes place. Reference numeral 33 represents a handle for opening and closing the arm 32. Incidentally, the method for opening and closing the perforated plate 27 is not limited to the above-mentioned method, but needless to say, an optional mechanism may be adopted. Furthermore, the perforated plate 27 may be independently arranged vertically movably so that the distance between the perforated plates 27 and 28 can be adjusted. In the case where the distance to the bottom of the tank proper 11 can be reduced, the lower perforated plate 28 may be omitted. Holes 27a and 28a of the perforated plates 27 and 28 may have optional shape and size. Ordinarily, circular holes having a diameter of about 1 to about 10 mm are uniformly distributed at equal pitches of about 1 to about 10 mm, or they are arranged in a

zigzag or lattice pattern. It is preferred that as the tow speed is increased or the viscosity of the bath liquid is increased, both the hole diameter and pitch be reduced.

Reference numeral 38 represents a thermostat heater arranged in the lower portion of the liquid bath tank 10, and the heater 38 is connected to the inlet 26 of the liquid supply chamber 25 through a pump 37 and a pipe 34 and to the front and rear receivers 16 and 17 through pipes 35 and 36.

In the foregoing embodiment, the two driving rollers are located on the outside of the liquid bath tank 10. However, as shown in Fig. 6, the roller on the front end side may be located within the liquid bath tank 10 so that a part or all of the roll is immersed in the liquid, or both the rollers may be located within the liquid bath tank 10, as shown in Fig. 7. In this case, arrangement of a pair of driving rollers as shown in Fig. 3 is not particularly necessary, but one driving roller is preferably arranged. In the case where a roller 41 is arranged within the liquid bath tank 10 on the front end side thereof as shown in Fig. 6, especially good results are attained when the tow is drawn at a high draw ratio, because fluctuation of the draw point is controlled and the draw point is fixed at a certain position on the circumference of the end portion of the roller on the tow discharge side. In the embodiment illustrated in Fig. 6, a front chamber 42 where the driving roller 41 is located is arranged in the front end portion of the tank proper 11, the liquid is supplied from an inlet 43 on the front end side and an inlet located at an intermediate position, and buffle plates 45, 46 and 47 having many small holes are arranged so as to enhance the liquid dispersing effect. In the embodiment shown in Fig. 6, since the front chamber is formed, weirs are not arranged. Of course, weirs may be arranged according to need.

The embodiment shown in Fig. 7 is different from the embodiment shown in Fig. 6 in the point where another driving roller 48 is further arranged on the rear receiver 17 so that the tow is taken out upward. In this embodiment, the weir 15 may be omitted. The embodiment shown in Fig. 7 where driving rollers are arranged within the liquid bath tank 10 on both the sides thereof is advantageously adopted when an oiling treatment or other chemical treatment is carried out.

When the roller 41 is immersed in the liquid bath as shown in Fig. 6 or 7, if the space S below the roller 41 is narrow, the guiding operation of the tow becomes difficult. Accordingly, it is preferred that the space S of the liquid bath tank 10 (tank proper 11) be increased as shown in Fig. 7. In this case, it is preferred that a perforated plate 49 be arranged below the tow travel passage so as to prevent generation of accompanying flows in the portion of space S and this perforated plate 49 be turnable or movable in the vertical direction so as to facilitate the tow guiding operation.

In the embodiment illustrated in Fig. 7, the perforated plate 49 is attached to a turnable shaft 50 and the shaft 50 is moved to the upper or lower position by a lever 51 arranged on the outside of the tank 10. Of course, the method for moving the perforated plate 49 is not limited to this method. In the case where the lower perforated plate 28 shown in Fig. 4 is arranged in the embodiments shown in Figs. 6 and 7, the above-mentioned perforated plate 49 may be arranged in communication with or independently from the perforated plate 28. In the embodiment shown in Fig. 7, if the weir 15 on the rear end side and the sealing member 19 are not disposed and the roller 48 is immersed in the liquid bath, it is preferred that a similar perforated plate be vertically movably arranged on the rear end side as well as the perforated plate 49 arranged on the

front end side.

In each of the foregoing embodiments, the upper portion of the liquid bath tank is opened. Needless to say, a liquid bath tank having a lid or a closed liquid bath tank can similarly be used in the present invention. In case of the liquid bath tank having the opened upper portion or the liquid bath tank which has a lid but is not closed, it is preferred that weirs be arranged on both the ends as in the foregoing embodiments. The reason is that when the hot liquid is caused to overflow from the liquid bath tank for any reason, the liquid is prevented from flowing to the outside over the side wall, whereby the operation safety is maintained and contamination or damage of surrounding articles and devices can be prevented. It is preferred that the perforated plate 27 or 28 be arranged along the tow travel passage through the substantially entire length of the liquid bath tank 10. However, it is not absolutely necessary that the perforated plate should be extended along the entire length of the liquid bath tank but it may be omitted in the vicinity of the liquid supply opening or both the end portions of the tank. The position for supply of the treating liquid is not limited to the front end portion, but the treating liquid may be supplied from other position, for example, the central portion, or the treating liquid may be showered from above.

The operation and effects of the apparatus of the present invention will now be described.

In the apparatus having a structure as shown in Figs. 3 through 5, the tow 1 is introduced into the tank proper 11 through the slit 12 from the opening 23 of the sealing member 18 and is travelled between the perforated plates 27 and 28 located in the hot liquid, and the tow 1 is passed through the slit 13 and the opening 24. While the tow 1 is thus passed through the (hot) liquid bath tank, predetermined drawing of the tow 1 is effected

between the feed roller 39 and the draw roller 40.

The hot liquid in the liquid bath tank 10 is adjusted to a predetermined temperature by the thermostat heater 38 located in the lower portion of the liquid bath tank 10, and the hot liquid is raised up by the pump 37 and supplied into the liquid supply chamber 25 of the liquid bath tank 10 through the pipe 34. A part of the hot liquid poured into the tank 10 flows out through the sealig member 18 and the remainder of the hot liquid passes through the clearance between the buffle plate 30 and the liquid supply chamber 25, that is, the clearance between the upper and lower perforated plates 27 and 28. The supplied hot liquid flows out through the opening 24 of the sealing member 19 in the rear portion of the tank proper 11 so that the amount supplied of the hot liquid is balanced with the amount of the liquid flowing out from the sealing members 18 and 19 and the level of the liquid in the tank proper 11 is kept substantially constant. The hot liquid flowing out to the receivers 16 and 17 is returned to the thermostat heater 32 through the pipes 35 and 36, and by this circulation of the hot liquid, the hot liquid in the liquid bath tank 10 is always maintained at a certain temperature. Since the hot liquid is decreased by the amount taken away by the tow, the decreased amount is supplemented.

In the case where a running tow is treated in an ordinary liquid bath treatment tank, as pointed out hereinbefore, as the travelling speed of the tow is increased, the amount of the liquid accompanying the tow (hereinafter referred to as "accompanying stream") is increased and also the speed of the accompanying stream is increased, a discontinous portion is caused in the liquid in the inlet portion of the liquid bath tank or the accompanying stream impinges and scatters to the weir in the outlet portion of the liquid bath tank. This disadvantage becomes conspicuous when the travelling

speed is 150 m/min or higher, and even if a plurality of weirs are arranged, this disadvantage cannot safisfactorily be eliminated.

The present invention is different from the above-mentioned conventional technique in the point where forcible blocking of the accompanying stream by the weirs is not intended but growth of the accompanying stream is controlled. For attaining this control of growth of the accompanying stream, according to the present invention, perforated plates are arranged in close proximity to the travelling tow, as pointed out hereinbefore. The liquid stream accompanying the tow is produced at the inlet of the liquid bath tank and is allowed to grow while the tow freely travels in the tank 10. However, since the perforated plate 27 is located just above the tow along the tow, the thickness of the boundary layer for forming the accompanying stream is controlled and the accompanying stream is prevented from growing beyond the clearance between the travelling tow 1 and the perforated plate 27, with the result that excessive growth of the accompanying liquid is prevented and such troubles as break-off, scattering, impingement and fluctuation of the liquid are not caused.

In the conventional liquid bath tank, as the immersion depth of the tow is increased, the amount of the accompanying stream in the upper portion of the tow is increased. However, when perforated plates are immersed in the liquid bath tank according to the present invention, as will be apparent from the foregoing description, the immersion depth of the tow can freely be increased. This feature is very advantageous. More specifically, if the immersion depth of the tow is increased, the amount of the liquid in the bath tank becomes large and in case of a hot liquid, the heat capacity is increased and the heat treatment can be performed stably. Furthermore, since the liquid is

freely continuous above the perforated plate, the pressure in the liquid bath tank is uniformalized and the liquid level is stably maintained.

Similarly, the temperature in the liquid bath tank is uniformalized. This is another advantage attained by the present invention.

In principle, the same effects attained by the upper perforated plate can similarly be attained by the lower perforated plate. However, so far as the liquid is present in the upper portion of the tow, break-off of the liquid is not caused in the lower portion. Accordingly, if the clearance between the travelling tow and the bottom of the bath tank is reduced so that growth of the accompanying stream is prevented, the lower perforated plate may be omitted.

The effects attained by the present invention will now be described in detail with reference to the following Example.

Example

A liquid bath treatment apparatus having a structure as shown in Figs. 3 through 5 (buffle plates 30 and 31 were not arranged) was used, and warm water at 70°C was circulated at a rate of 250 l/min. A polyethylene terephthalate tow having a size of 1,000,000 deniers (after drawing) and a width of 800 mm was immersed along a depth of 60 mm and was subjected to a drawing treatment. The liquid bath tank proper had a length of 1000 mm and a width of 800 mm. The sizes of holes of the upper and lower perforated plates and the tow speed were changed as shown in Table 1. The obtained results are shown in Table 1.

Incidentally, the symbols used in Table 1 have the following meanings:

l_1: distance (= 60 mm) between top face of tow (travelling passage) and liqid surface

l'_1: distance between top face of tow and upper perforated plate

l_0: distance between lower face of tow and tank bottom surface

l'_0: distance between lower face of tow and lower perforated plate

h: height of the wave by accompanying stream on tank end

These symbols are shown in Fig. 4.

The apparatus used at Runs Nos. 1 and 2 was a conventional apparatus in which the perforated plates were not disposed.

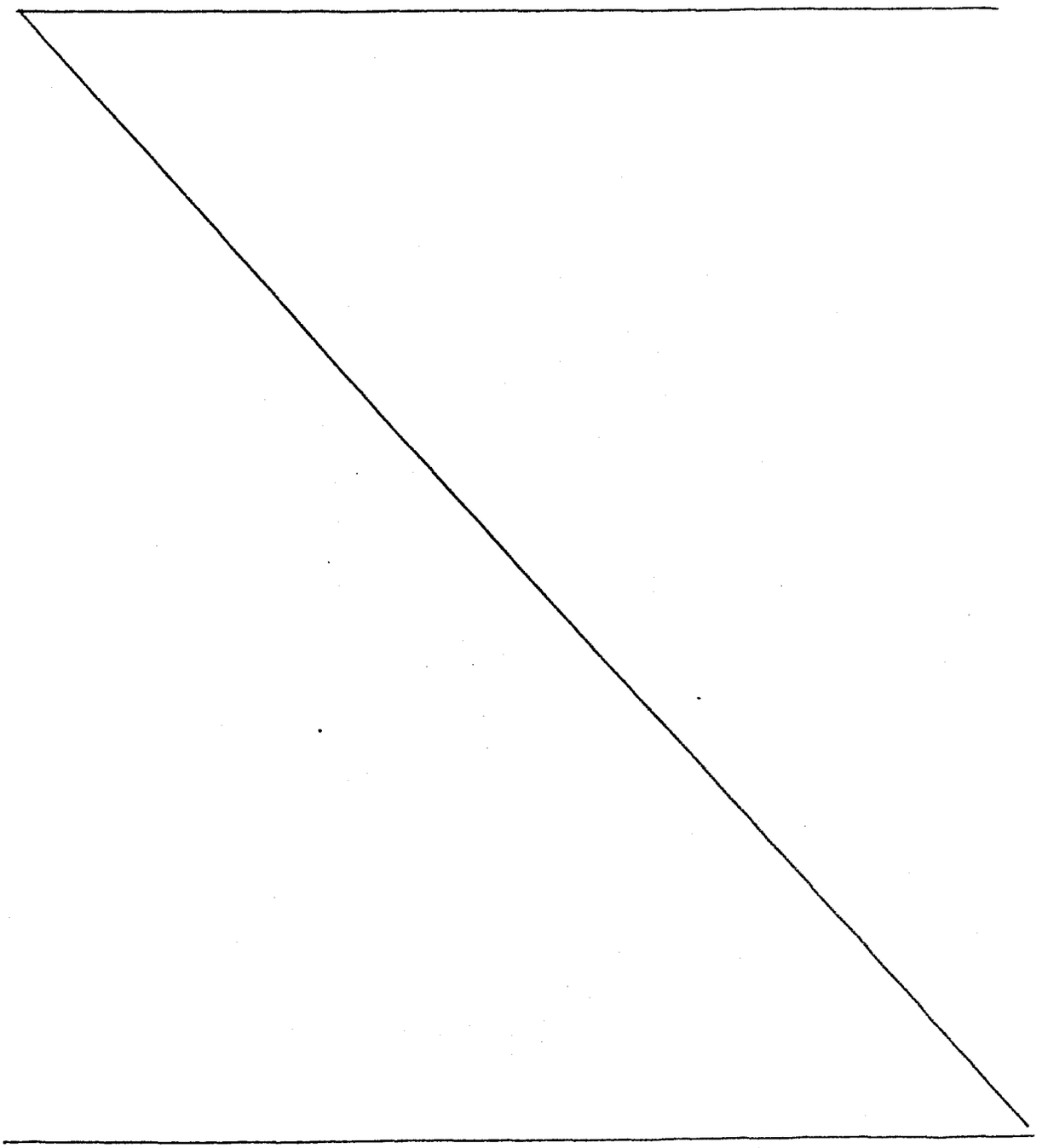


Table 1

Run No.	Treating Speed (m/min)	Liquid Bath Tank: Upper Perforated Plate hole diameter (mm)	Upper Perforated Plate hole pitch (mm)	Upper Perforated Plate clearance l_1, (mm)	Lower Perforated Plate hole diameter (mm)	Lower Perforated Plate hole pitch (mm)	Lower Perforated Plate clearance l_0, (mm)	Distance l_0 (mm)	State of Liquid in Tank: Scattering at Outlet	Height h (mm) of Wave by Accompanying Stream	Break-off of Liquid in Tow
1	200	not disposed			not disposed			80	observed	60	not observed
2	300	not disposed			not disposed			80	observed	above 200	observed
3	300	8	10	5	8	10	10	80	not observed	40	not observed
4	300	2	3.5	5	8	10	10	80	not observed	10	not observed
5	300	2	3.5	5	not disposed			10	not observed	20	not observed
6	300	2	3.5	10	not disposed			10	not observed	30	not observed
7	300	2	3.5	5	not disposed			20	not observed	30	not observed

In Runs Nos. 3 through 7, if the buffle plates 30 and 31 were arranged, the height h of the accompanying stream was reduced to some extent.

When the test was repeated by using the apparatuses shown in Figs. 6 and 7, substantially similar results were obtained.

Each of the drawn polyethylene terephthalate tows obtained in Runs Nos. 1 through 7 was cut into lengths of 50 mm, and the undrawn fiber contents in the obtained short fibers were examined. The obtained results are shown in Table 2.

Table 2

Run No.	Undrawn Fiber Content (number of undrawn fibers per 100,000 filaments)
1	0.25
2	2.38
3	0.12
4	0
5	0.12
6	0.12
7	0

It is seen that if the tow is exposed from the hot liquid as in Run No. 2, temperature unevenness is generated in the thickness direction of the tow and the undrawn fiber content is increased.

CLAIMS

1. An apparatus for the liquid bath treatment of synthetic fiber tows, which comprises two driving rollers spaced from each other by a certain distance, a treating liquid circulating tank and a liquid bath tank arranged between the two driving rollers and communicating with the liquid circulating tank, wherein a treating liquid is supplied to the liquid bath tank and circulated therethrough and a synthetic fiber tow is treated by immersing and travelling the synthetic fiber tow in the treating liquid in the liquid bath tank, said liquid treatment apparatus being characterized in that a perforated plate having a number of holes is arranged at least above a tow passage connecting both the driving roller in close proximity to said tow passage substantially in parallel thereto.

2. A liquid bath treatment apparatus as set forth in claim 1, wherein the two driving rollers are arranged on the outside of the liquid bath tank and slit-like openings for passage of the tow are formed on each of the front and rear end walls of the liquid bath tank so that the tow passage connecting the driving rollers is interposed between the slit-like openings.

3. A liquid bath treatment apparatus as set forth in claim 1, wherein the front driving roller is arranged within the liquid bath tank and the rear driving roller is arranged on the outside of the liquid bath tank, and slit-like openings for passage of the tow are formed on the rear end wall of the liquid bath tank so that the tow passage connecting the driving rollers is interposed between the slit-like openings.

4. A liquid bath treatment apparatus as set forth in claim 1, wherein the two driving rollers are arranged within the liquid bath tank.

5. A liquid bath treatment apparatus as set forth in any of claims 1 through 4, wherein perforated plates are arranged below and above the tow passage in close

proximity thereto.

6. A liquid bath treatment apparatus as set forth in any of claims 1 through 5, wherein the small holes of the perforated plate have a circular section and a diameter of 1 to 10 mm and are arranged in a zigzag or lattice pattern at pitches of 1 to 10 mm.

7. A liquid bath treatment apparatus as set forth in any of claims 1 through 4, wherein the upper perforated plate located above the tow passage is vertically turnably secured to the side wall of the liquid bath tank so that the upper perforated plate is opened upward.

8. A liquid bath treatment apparatus as set forth in any of claims 1 through 4 and 7, wherein a buffle plate is arranged on the upper perforated plate confronting a liquid supply opening to disperse the supplied liquid.

9. A liquid bath treatment apparatus as set forth in any of claims 1 through 4 and 7, wherein a buffle plate for controlling an acccompanying stream is arranged on the upper perforated plate arranged in the rear portion of the liquid bath tank.

10. A liquid bath treatment apparatus as set forth in any of claims 1 through 4, wherein the distance between the upper perforated plate and the travelling tow is less than 10 mm and the distance between the lower perforated plate or tank bottom and the travelling tow is less than 20 mm.

11. A liquid bath treatment apparatus as set forth in any of claims 1 through 4, wherein a weir and a receiver for the overflowing stream are arranged on the front or rear end of the liquid bath tank.

12. A liquid bath treatment apparatus as set forth in any of claims 1 through 4, wherein a liquid supply opening is arranged in the front end portion of the liquid bath tank and a liquid receiver is located below a slit-like opening.

13. A liquid bath treatment apparatus as set forth in any of claims 1 through 4, wherein the two driving rollers are a feed roller and a draw roller.

14. A liquid bath treatment apparatus as set forth in claim 3 or 4, wherein the perforated plate located below the driving rollers is arranged so that it can be turned downward.

Fig. 1

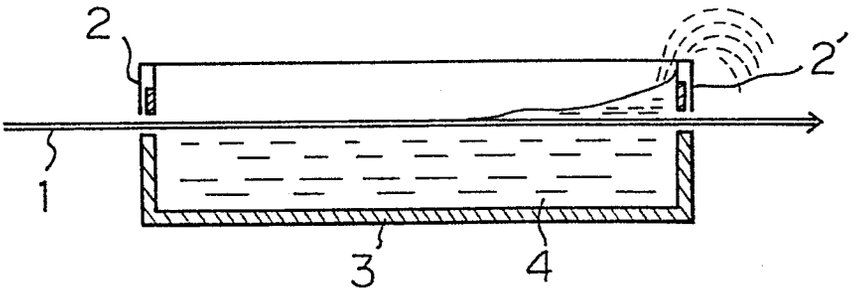


Fig. 2

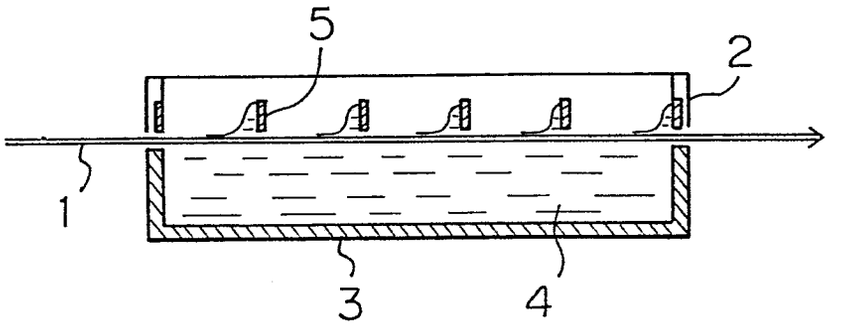


Fig. 3

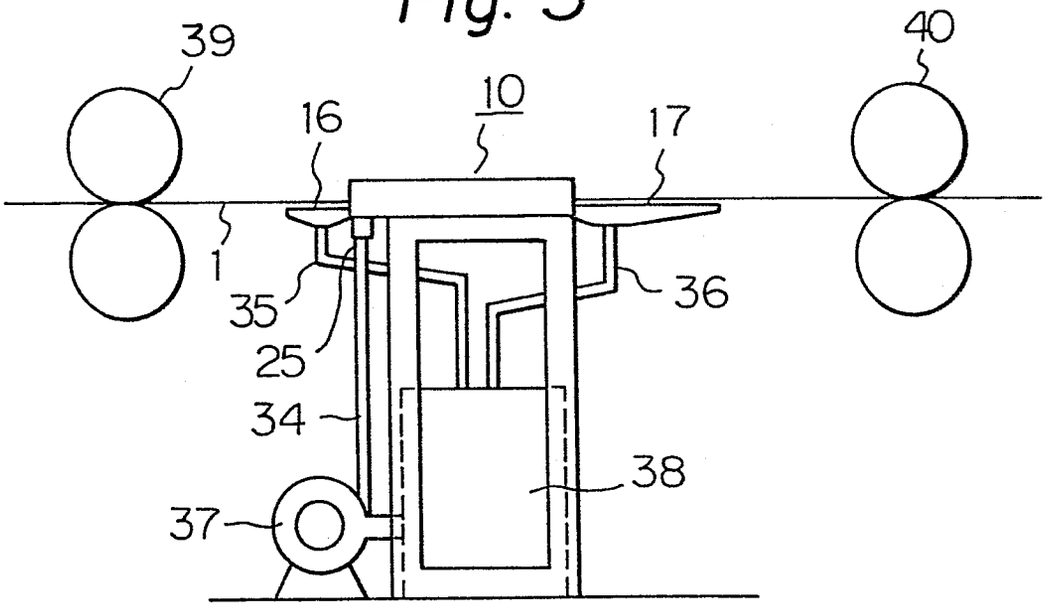


Fig. 4

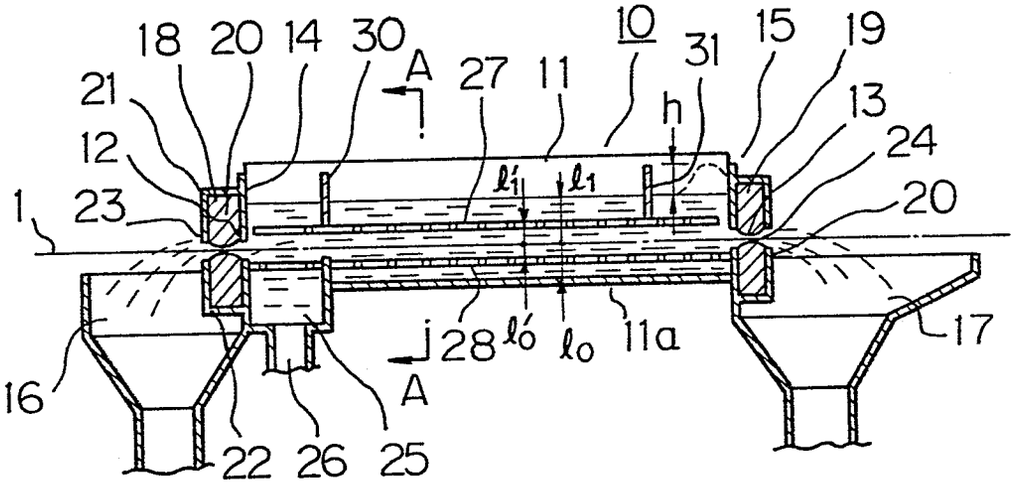

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Fig. 5

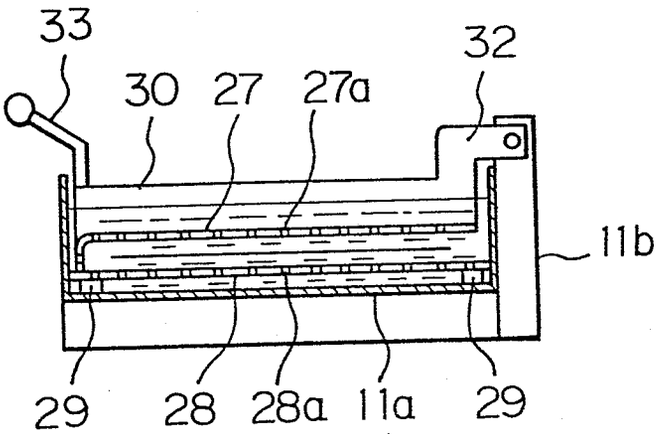
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Fig. 6

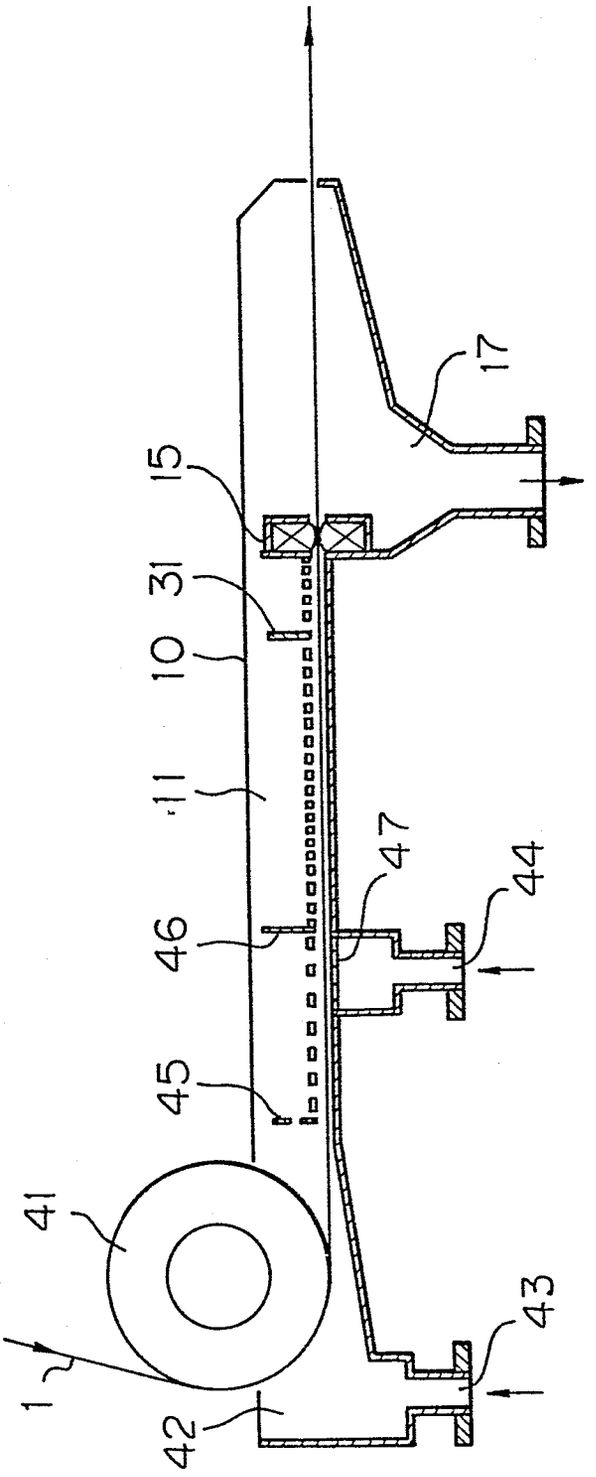

Fig. 7