(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 900 864 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.03.2008 Bulletin 2008/12

(51) Int Cl.:
D06B 7/04 *(2006.01)*

(21) Application number: **07115878.6**

(22) Date of filing: **07.09.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **15.09.2006 IT MI20061767**

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(54) **Process and device for continuously mercerising spun yarn**

(57) Device and process for continuously mercerising yarn carried out on a plurality of threads (1) kept separate and parallel for the entire mercerisation, where the process fluids are fed directly to the individual threads (1) that run in a strip moved at high speed.

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Description

[0001] The present invention refers to the mercerising treatment of cotton yarn to give them the desired characteristics for their end use to produce fabrics or other manufactured products. In textile technology the treatment of yarn with liquid reactants uses a large variety of processes, for the various types of fibres like cotton, wool, silk, linen and so on, with which the yarn is given the desired characteristics or undesired components that decrease its worth and its possibilities of use are removed from it. With reference to cotton, such treatment is typically mercerisation, but it can also concern other treatments like dyeing, bleaching and so on.

[0002] In conventional industrial practice such treatment operations are generally carried out with discontinuous operations on discreet batches of yarn, which therefore must be suitably packed in reels or skeins, which after treatment must be unwound and repacked differently further on in the production line. Such discontinuous operations on the yarn are rather onerous and have problems due to the inconsistency in the quality of the product.

[0003] The overriding tendency of technology development is therefore in the direction of continuous processing in the overall yarn production process. For continuous mercerising technology the Applicant is the owner of European patent applications 1.369.519, 1.369.520 and 1.369.521. In them it is foreseen to work many threads together, picking them up from their reels, bringing them together in an integral bundle and subjecting them together to the mercerising processing, separating them once again and winding them each in a reel. The contact between the bundle of yarn and the process fluids is carried out with a series of Venturi nozzles, in which the process fluids also act as driving fluid of the bundle of yarn in the contact apparatuses. From the aforementioned European patent applications it is possible to obtain further details on mercerising technology.

[0004] In the description of the present invention we refer to mercerisation, but explicitly stating that the system for continuously treating yarn according to the present invention can also have advantageous uses for different treatments to be carried out on yarn in textile technology.

[0005] The mercerising treatment of cotton yarn improves its mechanical characteristics, improves it appearance, and enhances its absorption capacity and reactivity towards finishing products and the affinity towards dyes. In short, it consists of treating yarn with highly concentrated alkaline solutions followed by drawing and removal of the reactants with suitable washes. The treatment is carried out on individual fibres that make up the yarn in a semi-plastic state induced by the concentrated alkalis that imbibe them.

[0006] In conventional technique the mercerisation is typically carried out on the yarn in skeins, prepared with a reeling stage, subjected to discontinuous mercerisation, and then washed, neutralised, dried, unwound and repacked in reels.

[0007] In the prior art it has also been proposed to continuously treat yarn with mercerising solutions by first preparing the individual threads with winding in beams of hundreds of threads each. From such beams the threads are unwound in parallel, made to pass into a sequence of treatment baths, drawn by pairs of rollers and wound back up again. At the moment, such technical solutions have practically remained at the proposal stage due to the complications and the drawbacks that hinder its industrial practice. One of the requirements for industrial scale application of continuous mercerising techniques is the hourly productivity, in other words the ability to work a discreet number of threads simultaneously and with an acceptable speed, as productivity is linked to the product of these two parameters.

[0008] The purpose of the present invention is to make a system for continuously treating yarn with process fluids, and specifically mercerisation, which allows the drawbacks of the systems used or proposed in the state of the art to be overcome.

[0009] This purpose is accomplished according to the present invention with a mercerising process according to the more general definition of claim 1 and, for preferred embodiments or possible variants, dependent claims 2 to 8. The present invention also makes it possible to make a device for continuously treating yarn, and in particular mercerisation, according to claim 9 and the claims dependent upon it.

[0010] The characteristics and advantages of the present invention for continuously mercerising yarn, and more generally for continuously treating it with process fluids, can be seen more clearly from the following description thereof, given as a non-limiting example, referring to its application to the mercerisation of cotton, according to the plant scheme illustrated in figure 1A. Figure 1B for the sake of greater clarity - transparently shows the perspective view of the apparatuses in which the overall mercerising treatment is carried out, for simplicity's sake omitting the initial creel and the final reel-winding frame.

[0011] Figures 1A-B illustrate the general scheme of the system for continuously treating yarn with process fluids.

[0012] Figure 2 and the detail of figure 2A illustrate the relevant details of the first device for imbibing the threads subjected to mercerisation. Figure 3, on the other hand, illustrates the essential details of the container in which the mercerisation reaction takes place. Figure 4 on the other hand, illustrates the details of the hydro-extraction and drawing device after the mercerising reaction. Figure 5 then illustrates the details of the container 40 in which the drawing of the yarn and its first washing with water take place. Figure 6 illustrates the containers 40bis in which both the second washing and the neutralisation stages take place. Finally, figure 7 illustrates the details of the container 60 in which the drying and dehydration stage of the mercerised threads takes place.

[0013] In the general scheme of figures 1A-B, the yarn 1 to be treated is fed from a series of reels 2 arranged in parallel on a creel 3. The reels 2 yield a plurality of threads 1, which are kept separate and parallel during the entire process and along the entire sequence of mercerising apparatuses. In order to carry out the process and make the device according to the invention on an industrial scale the processing must be carried out on a congruous number of parallel threads 1, at least of the order of a few tens of threads at once, unwound with a speed at least of the order of 5-10 m/sec.

[0014] The return of the parallel threads 1 is carried out with the pair of main guide rollers 4 with horizontal axis, which rotate at controlled speed and that determine the linear flow rate of the threads being processed taken to the mercerising unit, operating as outlined above at a linear speed of at least 5-10 m/sec.

[0015] A relevant characteristic of the present invention lies in the operation of the treatment and in the structure of the mercerising reactor in which the treatment of the threads is carried out with sodium hydroxide alkaline solution. Such an operation is carried out in a closed parallelepiped-shaped container 5. Inside the closed container 5, in general shaped like a wardrobe that can be opened for the intervention of operators, it is possible to maintain a controlled atmosphere, just like for the other further containers foreseen in the unit. On its inside, the group of parallel threads 1 is deviated and guided firstly with rollers 7 with horizontal axis and worked with radial grooves that allow the threads to be kept separate and spaced apart during the entire mercerising reaction.

[0016] The strip of parallel and separated threads 1 is fed to a first imbibing device 8 illustrated in greater detail in figure 2, which shows plan, front and side section views. It consists of an imbibing plate 10 equipped with longitudinal grooves 11 that are independent and have constant pitch, which guide the threads 1 separately. The mercerising fluid consists of the alkaline solution, for example sodium hydroxide at 30° Be, and is sprayed on the plate 10 with sprayers 12 with nozzles at the grooves 11 in which the threads 1 run at a speed controlled by the initial guide rollers 4. The top part of the grooved plate 10 is protected with a cover 13.

[0017] According to a preferred embodiment of the invention, at the entry of the strip of threads 1 into the imbibing device 8 a sealing device 15 is arranged. It consists of an elongated tank 16, fed with the same mercerising solution and kept at atmospheric pressure, with a lower slit that comes out onto the grooves that guide and contain the threads in movement from left to right in the drawing according to the arrows F. The liquid head of the tank 16 allows a first imbibition at atmospheric pressure of the threads 1 and avoids the entry of air into the second treatment area with the pressurised solution. In this second area the plate 10 is worked with V-shaped grooves, whereas the cover 13 is provided with one or more sprayers 12 consisting of a series of pressurised injection micro-nozzles 18, shown in the detail of figure 2A and each arranged at each individual groove 11 crossed by a single thread. Each sprayer 12 and the tank 16 are fed with fittings 17 from a general feeding duct, not shown in the figures, which takes the alkaline mercerising solution at constant pressure and at controlled temperature.

[0018] The temperature of the mercerising solution is kept at 30-35°C, whereas the injection overpressure is between 1 and 15 bars, preferably between 1.5 and 4 bars. Indeed, it has been found that the injection overpressure of the mercerising fluid causes a substantial increase in the mercerisation reaction kinetics, which can be attributed to a better exchange coefficient and a more efficient contact between the liquid phase and cellulose micelles, substantially accelerating the mercerising reaction. In conventional mercerisation techniques by immersion in baths or recipients at atmospheric pressure contact times of the order of minutes are required, whereas the technical solution according to the present invention allows such contact times to be drastically reduced, reducing them to the order of magnitude of 10 seconds.

[0019] Again inside the container 5, the strip of threads 1, after imbibition in the device 8, then passes onto the surface of two rotary drums 20, on which the strip of threads 1 is wound many times with incomplete 8-shaped spirals 21, whereas inside of them the mercerising reaction takes place between the imbibing solution and the cellulose.

[0020] The structure and the operation of the rotary drums 20 and of the other elements inside the container 5 is illustrated in greater detail in figure 3, in which they are shown in perspective view and transparently. The drums 20 are mounted parallel with substantially horizontal axis and they are equipped with a substantially smooth cylindrical surface. The incomplete 8-shaped spirals 21 are deposited on the surface of the drums 20. The deposit of the strip of threads 1 is guided with rotary combs 22, made up of a series of grooved ceramic bushings mounted with constant pitch on a shaft, and with the deviating rollers 24. The deviating rollers 24 have a substantially smooth surface, they are mounted with oblique rotation axis with respect to the axes of the drums 20 and they are equipped with means for varying their inclination. The inclination to the right or left of the axes of the deviating rollers 24 allows the progressive axial gauge between the 8-shaped spirals that wind on the drums 20 to be determined. Again with reference to figure 3, the whole of the threads 1 in a strip enters into the rear part at the main guide rollers 4, passes the imbibing device 8, winds - starting from the right-hand drum 20 - with 8-shaped spirals that advance towards the front part of the container 5, and discharges - from the left-hand drum 20 - through the hydro-extraction and drawing device 27. In the path between imbibing device 8 to the hydro-extraction device 27 the mercerising reaction between the cellulose micelles of the yarn and the solution that imbibes the yarn itself takes place.

[0021] The variation in inclination of the axes of the deviating rollers 24 allows the progressive axial gauge

to be generated between the 8-shaped spirals that wind on the drums 20 and allows the number of spirals that can be carried by the available length of the drums 20 to be varied, thus determining the length of the path of the strip of threads 1 and its treatment time with alkaline solution. For example, with substantially "square" cylindrical drums 20, with a diameter and length of about 1000 mm, it is possible to wind 50-100 m of strip of threads 1 and to carry out reaction times within the range of 8-15 seconds, which corresponds to the time of complete "re-entry", in other words the time for completion of the reactions between the cellulose and the alkaline solution, which result in the shortening of the yarn by values of 10-20% according to the type of yarn and the original cotton.

[0022] In the space contained between the two drums 20, i.e. in the free parts of the spirals 21 of the strip of threads 1, one or more series of further spray nozzles is arranged close to the surface of the drums themselves, to renew the contact between yarn and alkaline solution.

[0023] Such spray nozzles are placed on nozzle-carrying rods 25 and are analogous to those that equip the imbibing device 8, but operating at lower pressure, and the position of a pair of rods 25 thereof is shown as an example in figure 1A.

[0024] At the end of the path inside the container 5 for treatment with alkaline solution, the strip of threads 1 is discharged with the hydro-extraction and drawing device 27 after the mercerising reaction. It is shown in figure 4 with its essential components. The strip of mercerised threads 1 still imbibed with alkaline solution passes from idle deviating rollers 28 and reaches the hydro-extraction device 29 consisting of a motorised roller 30 against which two idle counter-rollers 31 are pressed, preferably made from polymeric elastic material. Such a roller 30 rotates at the linear speed of the strip of threads 1 fed, decreased by the expected percentage shrinkage for the mercerisation. In the part of the strip of threads 1 between the last spiral around the left-hand drum 20 and the device 27 the so-called shrinkage of the threads therefore takes place. In the contact between said rollers the alkaline solution still present in the threads is hydro-extracted and to a large extent recovered. The whole of the roller 30 and the counter-rollers 31 also acts as a seal against the shrinkage of the strip of threads hydro-extracted by the rotary drums 41A, B of the washing section arranged downstream, which operate at higher linear speeds than that of the roller 30. Such shrinkage generates the drawings of the mercerised yarn, tending both to recover the shrinkage undergone during the mercerisation step and to further stretch the threads of the strip, thus giving them the positive characteristics that derive from the mercerisation.

[0025] All of the motorisations of the shafts of the rotary members inside the container 5, in other words the drums 20, the rotary combs 22, the deviating rollers 24 and the roller 30, are controlled with independent actuations, for example through inverters, and the various angular speeds are synchronised with each other to obtain and keep the linear speeds for the drums 20 and the deviating rollers 24 coherent with that of the strip of threads 1 being processed. The rotation speed of the combs 22, on the other hand, is lower (2-10 revolutions per minute); it is carried out to limit the erosion phenomena of the ceramic bushes of which they consist.

[0026] According to a preferred embodiment of the invention, a device 35 for capturing the ends of the threads that have broken is arranged at the motorised roller 30 of the hydro-extraction device 29. Indeed, there is greater probability of breaking at the drawing of the mercerised threads and, in this case, the ends tend to stick and wind onto the roller 30.

[0027] The device 35, for example, can consist of a suction mouth 36 connected to a suction duct 37; the top edge of its suction slit 38 is made from polymeric material and is arranged to scrape the metallic surface of the roller 30. In this way, the possible end that winds onto the surface of said roller is stopped and sucked up by the mouth 36. Alternatively, the device 35 for capturing the ends can be made with a rotary brush of bristles made from polymeric material that, mounted in the same position as the mouth 36 and made to rotate at a high speed, clears the roller 30 of the possible ends that would otherwise wind onto its surface.

[0028] After passing into the container 5 in which the contact is made between the threads 1 in a strip and the alkaline mercerising solution, said strip is fed for washing with water. For example, the washing can be carried out in many stages with water in countercurrent and at decreasing temperature, according to methods already known in the field.

[0029] The first washing stage is carried out in the container 40, illustrated in figure 5 with its essential components. In it the washing operation of the yarn treated with the alkaline solution and coming from the container 5 takes place. The strip of threads 1 is guided and deviated by a series of idle rollers 28 up to the rotary cylindrical drums 41A, B made from metallic material and with a smooth surface. The strip of threads is inserted and held between the surface of the drums 41A, B and a series of idle cylindrical counter-rollers 42 that wrap around them and are kept pressed to grip said strip. At each passage under such counter-rollers the liquid contained by the strip of threads is thus squeezed out. Downstream of the counter-rollers 42 a series of spray nozzles 44 of the washing water is inserted. The washing consists of an alternating sequence of imbibition and squeezing of the threads 1 in a strip to remove the residues of the alkaline mercerising solution, thus discharging the strip of threads washed through the deviating idle roller 28 arranged downstream of the drum 41B. As already stated, in passing from the roller 30 of the squeezing group 29 to the contact between drum 41A and the first counter-roller 42 of the first washing unit in the container 40 the yarn is drawn as a consequence of the different linear actuation speed of the roller 30 and of the drum 41A, recovering

the lost length through "shrinkage" and giving the definitive tension required to fully obtain the mercerising effects.

[0030] The second washing stage is carried out in the container 40bis shown in figure 6 in its essential components, having the same structure and operations as the previous one, apart from the drawing function and the direction of the thread arriving from the previous stage. Therefore, the same reference numerals have been kept for the components present in the container 40bis.

[0031] The motorisation of the shafts of the drums 41A, B is also controlled with independent actuation, for example through an inverter, given that the various angular speeds of the mercerising device are synchronised to obtain and keep coherent speeds within the device.

[0032] The strip of threads 1 washed in the previous washing units is then subjected to neutralisation, for example with a diluted acetic or citric acid solution with pH of 2-2.5, inside the relative containers. In the embodiment illustrated here, again for illustrating and not limiting purposes, the neutralisation is shown in two stages: in the first neutralisation with acid is carried out, whereas in the second the final washing with water for greater purity is carried out. The neutralisation unit is totally analogous to the washing units and operates according to the same general scheme, apart from that the washing operates with water whereas neutralisation operates with acid solutions. It corresponds to the scheme of figure 6 in terms of its components and the path of the strip of threads 1, feeding with a pressurised flow of a diluted acetic or citric acid solution to remove the alkaline residue from the threads 1 of the strip that comes out from the previous washing. In the container 40bis of figure 6 the same reference numerals refer to components that are similar and have the same function as the container 40 of figure 5.

[0033] In the bottom part inside the container 5, 40 and 40bis plates 26, 46 for collecting the part of the various treatment fluids that is not held by the threads being treated are arranged, for its recovery and reuse, after a suitable reconditioning. As far as the washing waters are concerned, the criterion of countercurrent is used.

[0034] The washing and neutralisation operations of the strip of threads 1 are thus carried out inside the containers 40 and 40bis with S-shaped paths around the drums 41A, B, on which an alternating sequence of imbibition and squeezing is carried out with the washing waters and with the acid solution, respectively.

[0035] The strip of washed and neutralised threads 1 is then subjected to a drying and exsiccation stage, in the drying unit inside the container 60 shown in figure 7 in its essential components.

[0036] The drying and exsiccation unit has an analogous structure to that of the treatment unit with alkaline solution. The strip of threads 1 is made to pass onto the surface of two rotary drums 61, heated with steam or with diathermal oil to suitable temperature. The strip of threads 1 is wound many times onto the hot surface of the drums 61 always with incomplete 8-shaped spirals. The deposit of the strip of threads 1 is regulated with the deviating rollers 62, totally analogous to the deviating rollers 24 of the container 5, also with a rotation axis oblique to the axes of the drums 61. The variation in inclination of the axes of the deviating rollers 62 allows the progressive axial gauge between the 8-shaped spirals that wind onto the drums 61 to be generated and allows their number to be varied, thus determining the length of the path of the strip of threads 1 and its time spent inside the exsiccation unit. The strip of threads 1 is discharged from the drying and exsiccation unit of the container 60 with one or more pairs of discharging rollers 64. A suction hood 65 for the vapours developed during the course of the drying and exsiccation of the threads takes these vapours away.

[0037] The strip of threads 1 coming out from the exsiccation unit is then sent for the individual winding of each thread and does not require any particular operation to separate the threads 1 that make up the strip, since such threads have always kept their individuality. In the winder 70 a series of reels 72 is produced that each contain one of the threads 1 that have been mercerised in the plant upstream.

[0038] An important characteristic of the present invention is the way in which the threads make contact with the process fluids, alkaline solution, washing waters and neutralisation reagents, in the case of the mercerisation of cotton. The contact and the relative reactions are carried out by taking and feeding the process fluids directly to the single thread and avoiding the immersions in tanks or reactors of the prior art, which give a disadvantageous quantity ratio between the worked threads and the process fluids, In particular, the stage of reaction with the alkaline solutions takes place in a quite short time period. The use of the injector nozzles 12 in the imbibing device 8, which engage the threads 1 under treatment individually, injecting the alkaline solution under pressure, allows the mercerisation treatment to be completed in a time of around a tenth of a second and it does not require further reaction stages to achieve the desired result.

[0039] The mercerisation process described up to now allows significant advantages compared to the processes of the prior art. In addition to the advantage of carrying out the treatment with continuous operations, it is significant that the threads are worked as such and individually, without requiring them to firstly be joined in a package in an integral bundle, skeins or beams and later requiring their separation. The present invention allows work with good productivity since the strip of threads runs in the plant at a high speed going from the reels 2 and ending at the reels 72 for collecting the mercerised product.

[0040] A further advantage lies in the small amount of fluids used and their greater yield, reducing the environmental implications. Processing with individual threads means that each of the threads 1 being treated goes from a reel 2 of index N in the creel 3 and reaches a reel 72 of index N. In the case in which a thread breaks along the path, in the winder 70 the winding head of index N

indicates the absence of thread: it is quite simple and easy to indicate such an event to the creel 3 and consequently to thus automatically cause the relative end being fed to be cut and stop its winding head.

Claims

1. Process for continuously mercerising cellulose yarn comprising treatment of the yarn with alkaline solution, of drawing the yarn, the aqueous washing and the neutralisation of the residue of alkalinity still present in the yarn, starting from reels (2) of yarn and to produce reels (72) of mercerised yarn, **characterised in that** the process is carried out continuously on a strip consisting of a plurality of threads (1) kept separate and parallel along the entire mercerising apparatus, and **in that** the process fluids are fed directly to the individual threads (1) without immersion in treatment baths, said strip being moved from the reels (2) to the reels (72) at high speed.

2. Process for mercerising yarn according to claim 1, **characterised in that** in the treatment with alkaline solution the strip of threads (1) is firstly subjected to imbibition with said solution in an imbibing device (8) and then passes onto the surface of rotary drums (20), being wound many times with incomplete 8-shaped spirals (21), thus determining with the number of spirals the length of the path of the strip of threads (1) and its treatment time with alkaline solution, whilst the mercerising reaction between the imbibing solution and the cellulose mixtures takes place inside of them.

3. Process for mercerising yarn according to claim 2, **characterised in that** the imbibition of the threads (1) is carried out with a series of pressurised injector micro-nozzles (1), each arranged at a groove (11) crossed by a single thread (1).

4. Process for mercerising yarn according to claim 3, **characterised in that** the injection overpressure in the micro-nozzles (18) is between 1 and 15 bars, and preferably between 1.5 and 4 bars.

5. Process for mercerising yarn according to claim 2, **characterised in that** between the drums (20), in the free parts of the spirals (21) of the strip of threads (1), the contact between yarn and alkaline solution is renewed with further spray nozzles arranged on nozzle-carrying rods (25).

6. Process for mercerising yarn according to claim 2, **characterised in that** at the end of the treatment with alkaline solution the strip of threads (1) is removed with a roller (30) rotating at the linear speed of the strip of threads (1) being fed, decreased by the expected percentage shrinkage for the mercerisation, thus allowing the threads to shrink in the part of free strip of threads (1) between the last spiral and the roller (30).

7. Process for mercerising yarn according to claim 1, **characterised in that** the washing and neutralisation treatments are carried out by winding the strip of threads (1) with S-shaped paths about rotary drums (41A, B) on which an alternating imbibition and hydro-extraction sequence takes place with washing water and with acid solution, respectively.

8. Process for mercerising yarn according to claim 7, **characterised in that** in passing from the roller (30) to the drum (41A) and the first counter-roller (42) of the first washing unit the drawing of the yarn takes place as a result of the different linear actuation speed of the roller (30) and the drum (41A).

9. Device for continuously mercerising cellulose yarn comprising devices for treating the yarn with alkaline solution, for drawing the yarn, for aqueous washing and neutralisation of the residue of alkalinity still present in the yarn, starting from reels (2) of yarn and to produce reels (72) of mercerised yarn, **characterised in that** such devices operate continuously on a strip consisting of a plurality of threads (1) kept separate and parallel along the entire mercerising apparatus, feeding the process fluids directly to the individual threads (1) without immersion in treatment baths.

10. Device for continuously treating yarn with process fluids according to claim 9, **characterised in that** the device for treating the strip of threads (1) with alkaline solution comprises an imbibing device (8) and two rotary drums (20), on which the strip of threads is wound many times with incomplete 8-shaped spirals (21), thus determining the length of the path along which the mercerising reaction between the imbibing solution and the cellulose micelles takes place.

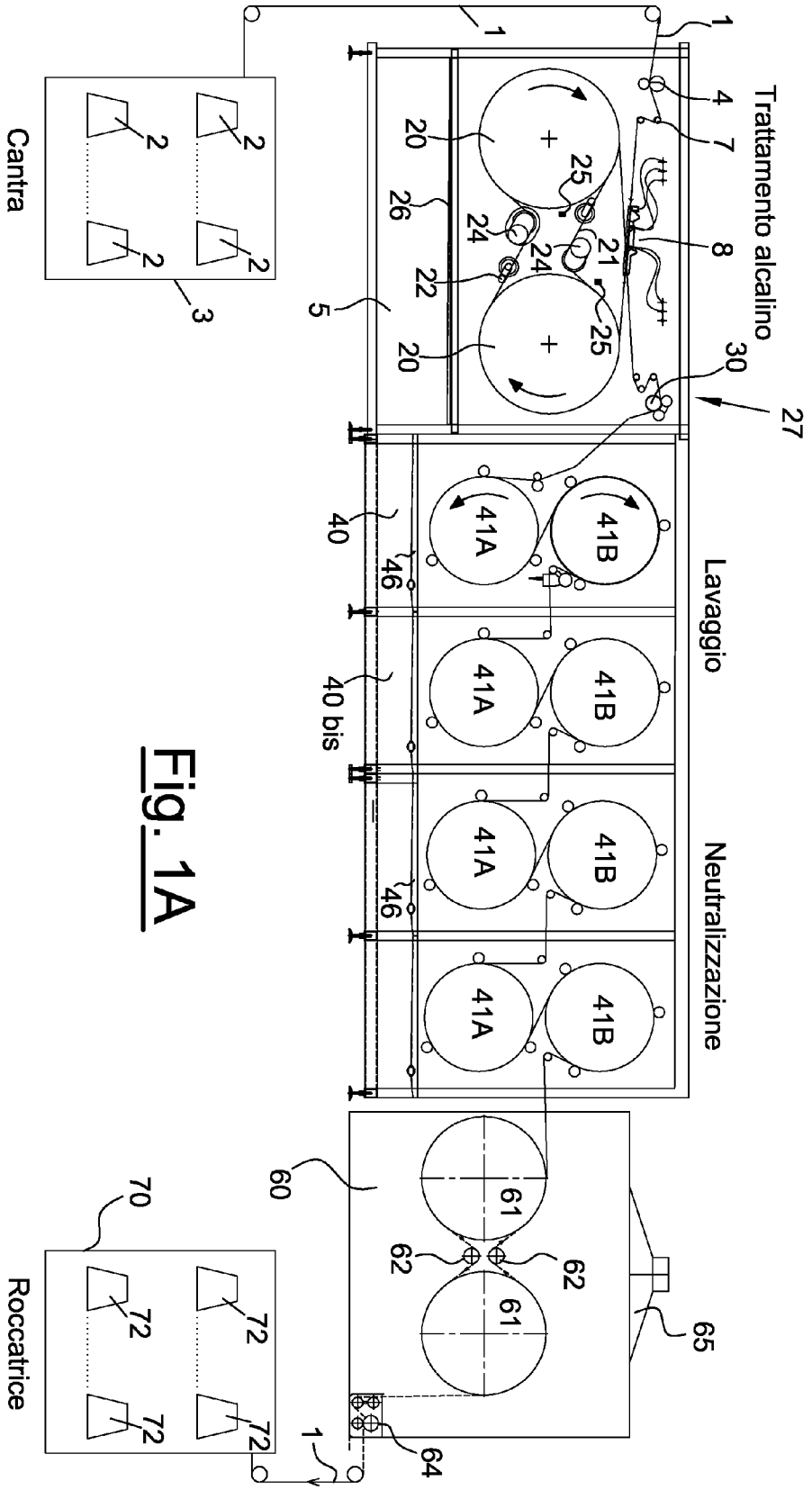
11. Device for continuously treating yarn with process fluids according to claim 10, **characterised in that** the two rotary drums (20) are provided with means for determining the gauge of the incomplete 8-shaped spirals, and for varying the number of spirals that can be carried by the available length of the drums (20), thus determining the length of the path of the strip of threads (1) and its treatment time with alkaline solution.

12. Device for continuously treating yarn with process fluids according to claim 10, **characterised in that** the imbibing device (8) consists of an imbibing plate (10) equipped with independent longitudinal grooves

(11), which separately guide the threads (1) on which the alkaline solution is sprayed with sprayers (12) with nozzles (18) at the grooves (11) in which the threads (1) run.

13. Device for continuously treating yarn with process fluids according to claim 12, **characterised in that** at the entry of the strip of threads (1) into the imbibing device (8) a sealing device (15) is arranged consisting of a tank (16), fed with the same mercerising solution, with a lower slit that comes out onto the grooves (11) that gives a liquid head at the start of said grooves and a first impregnation of the threads (1).

14. Device for continuously treating yarn with process fluids according to claim 11, **characterised in that** the means for determining the gauge of the spirals wound on the rotary drums (20) consist of deviating rollers (24) mounted with oblique rotation axis with respect to the axes of the drums (20) and equipped with means for varying their inclination, to generate the progressive axial gauge between the incomplete 8-shaped spirals that wind on the drums (20).


Trattamento alcalino
Lavaggio
Neutralizzazione
Cantra
Roccatrice
1
2
3
4
5
7
8
20
21
22
24
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40 bis
41A
41B
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72

Fig. 1A

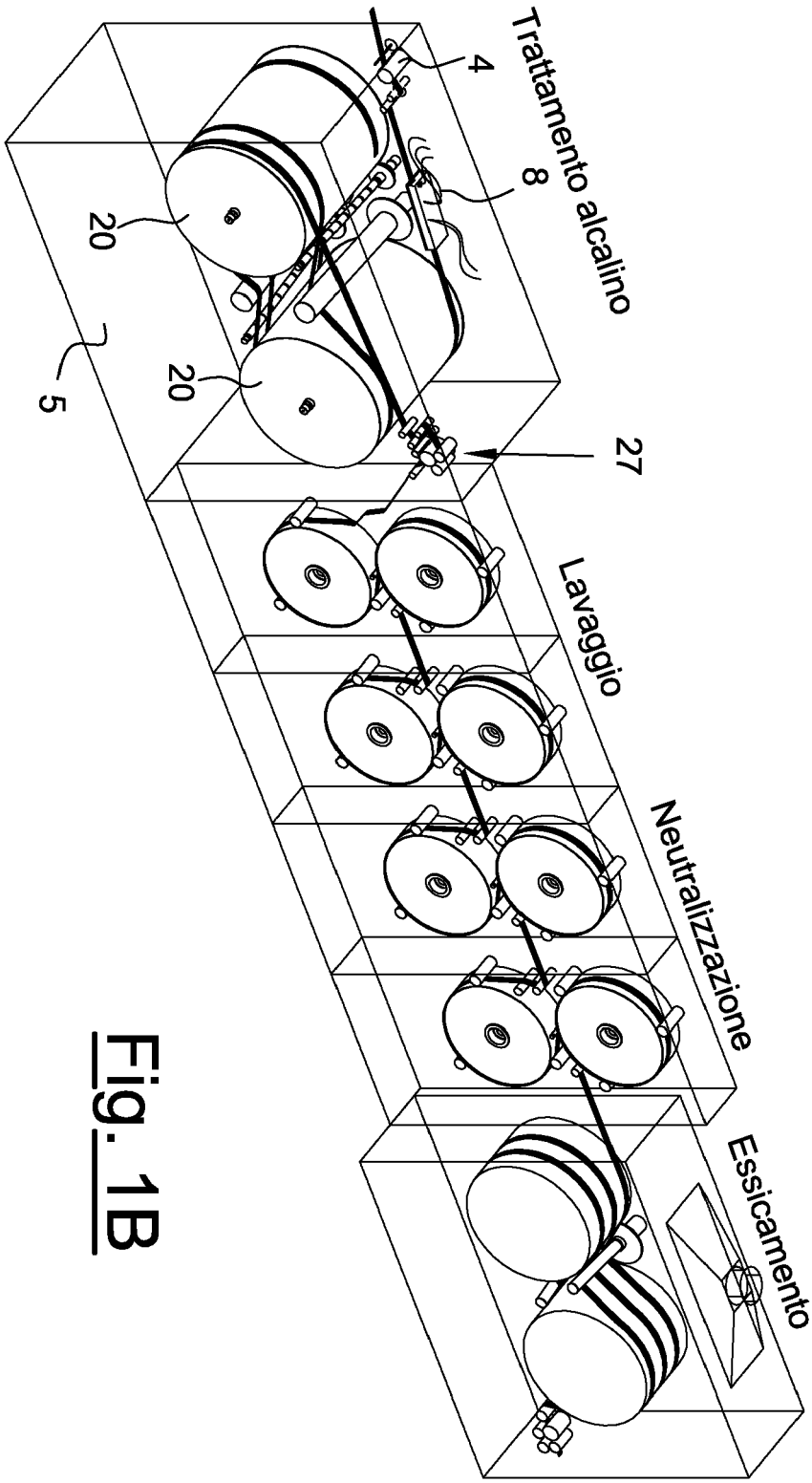
Trattamento alcalino
Lavaggio
Neutralizzazione
Essicamento
4
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Fig. 1B

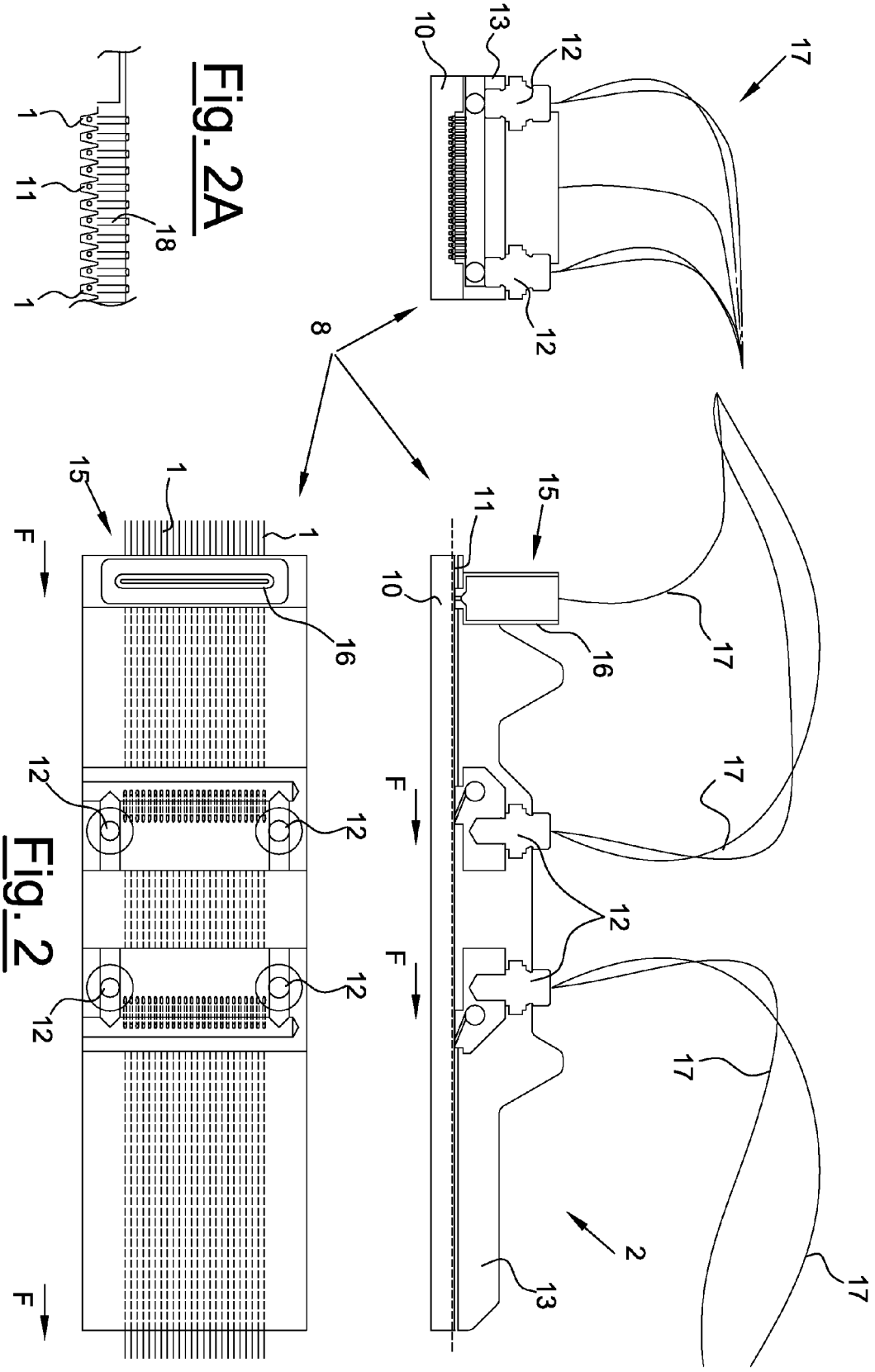
1
11
18
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Fig. 2A
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Fig. 2
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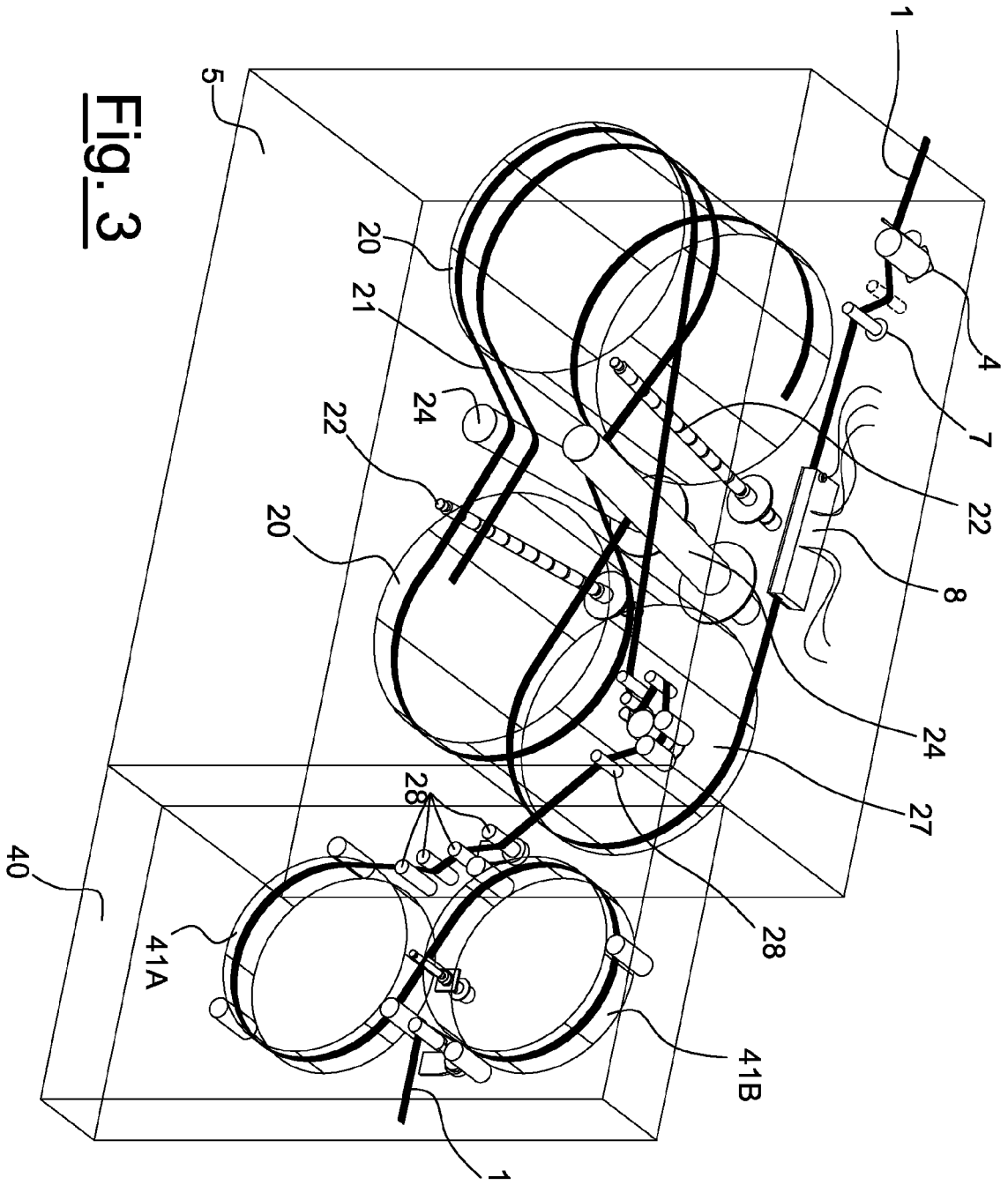
Fig. 3



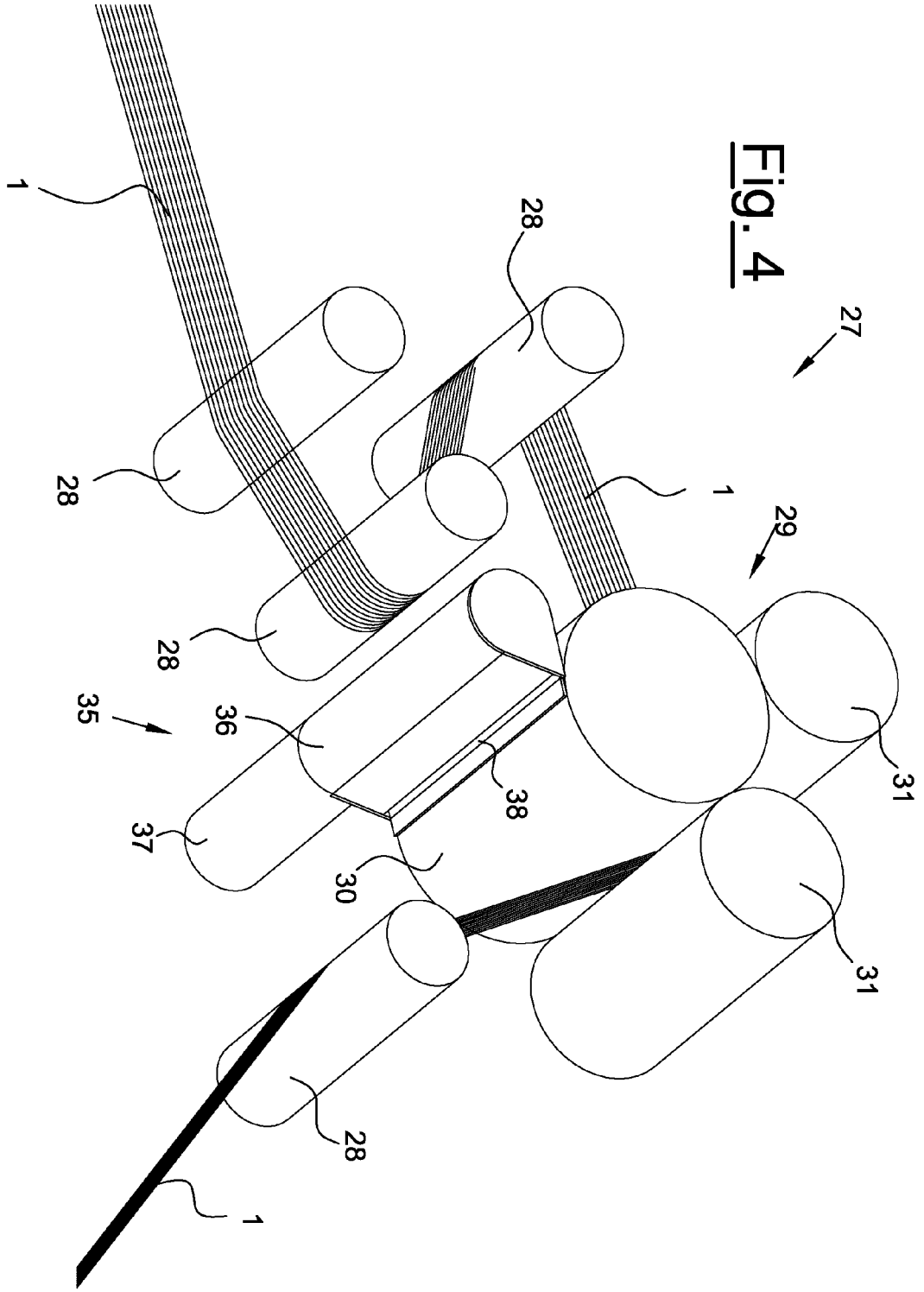


Fig. 4

Fig. 5

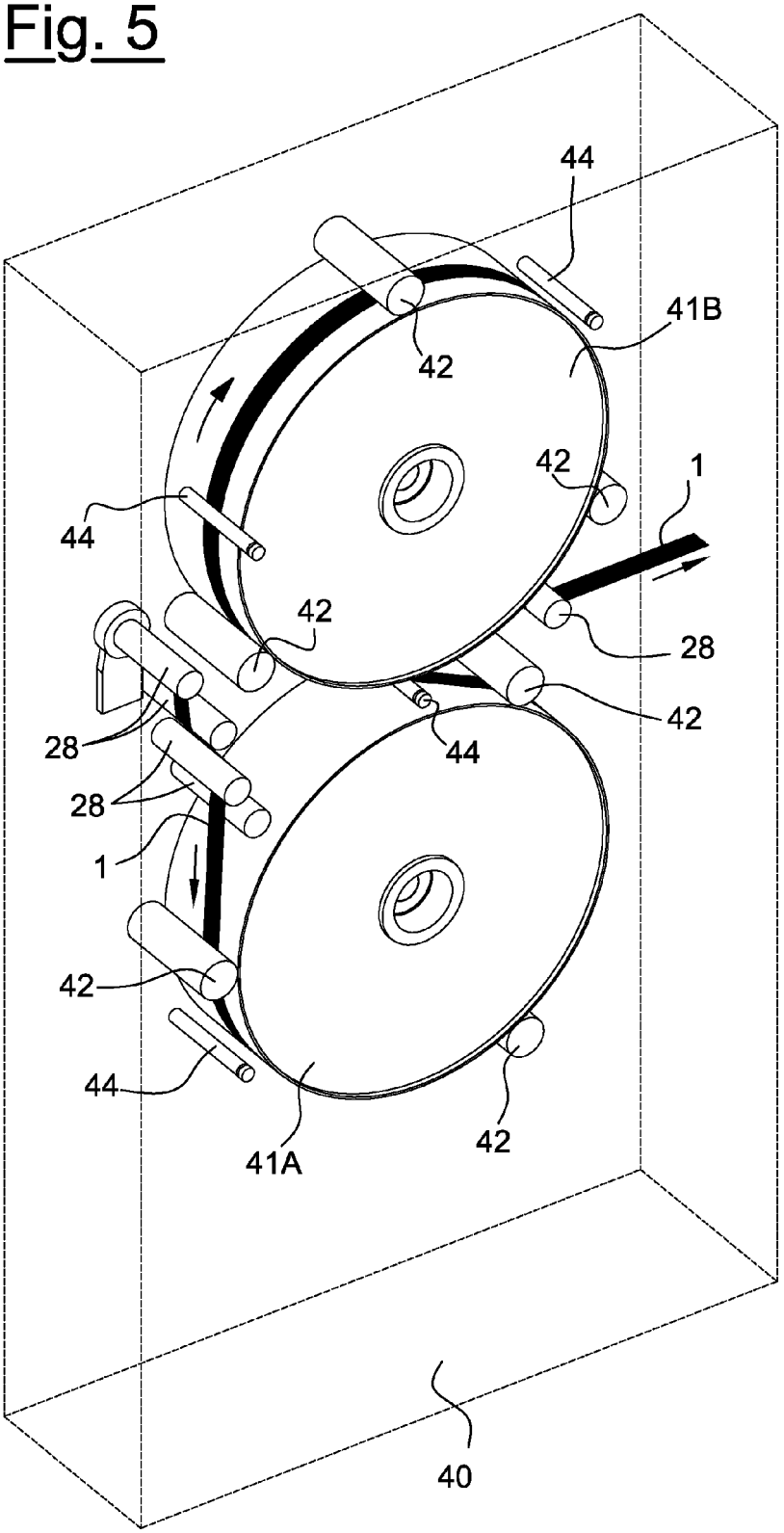


Fig. 6

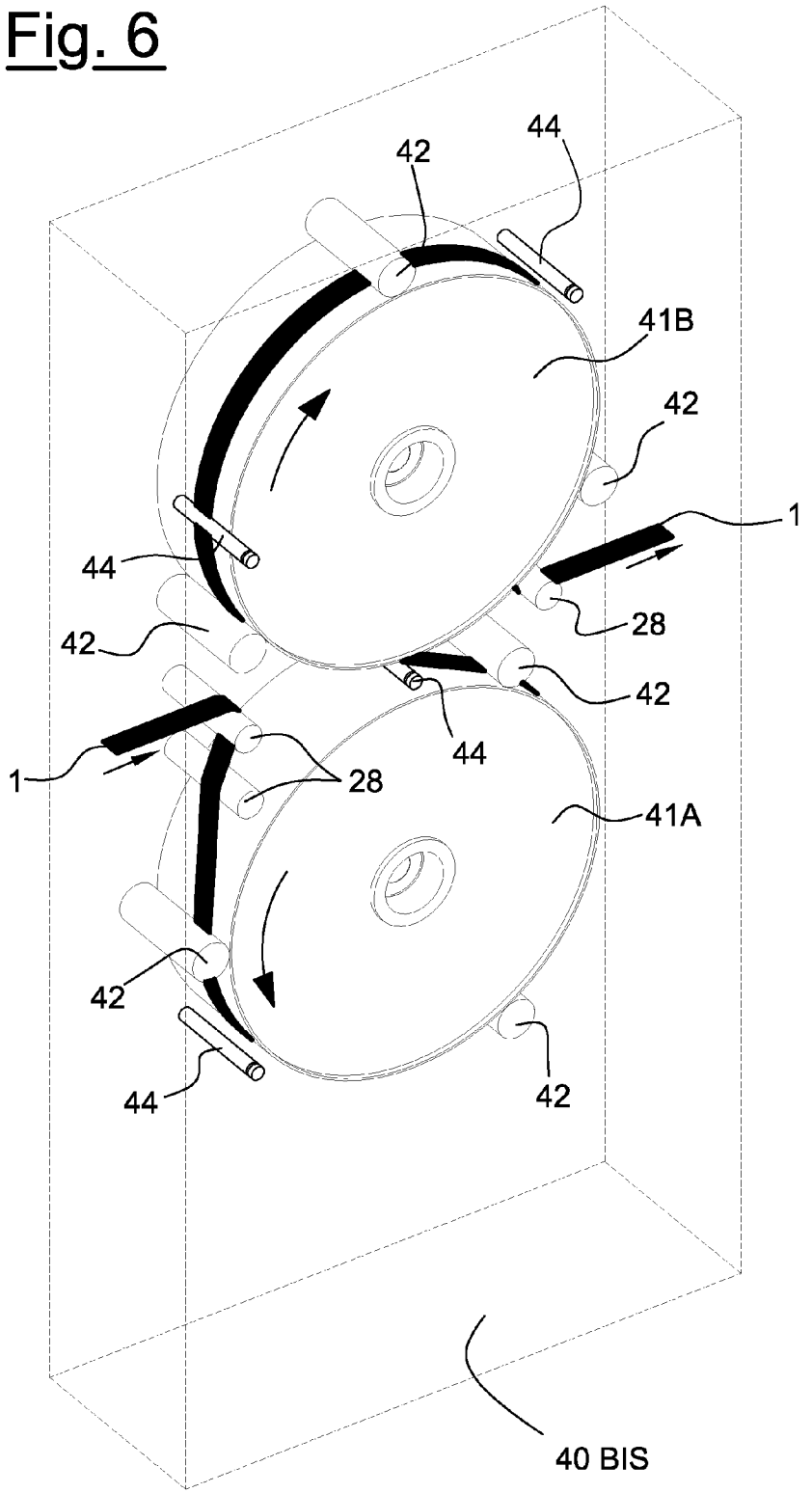
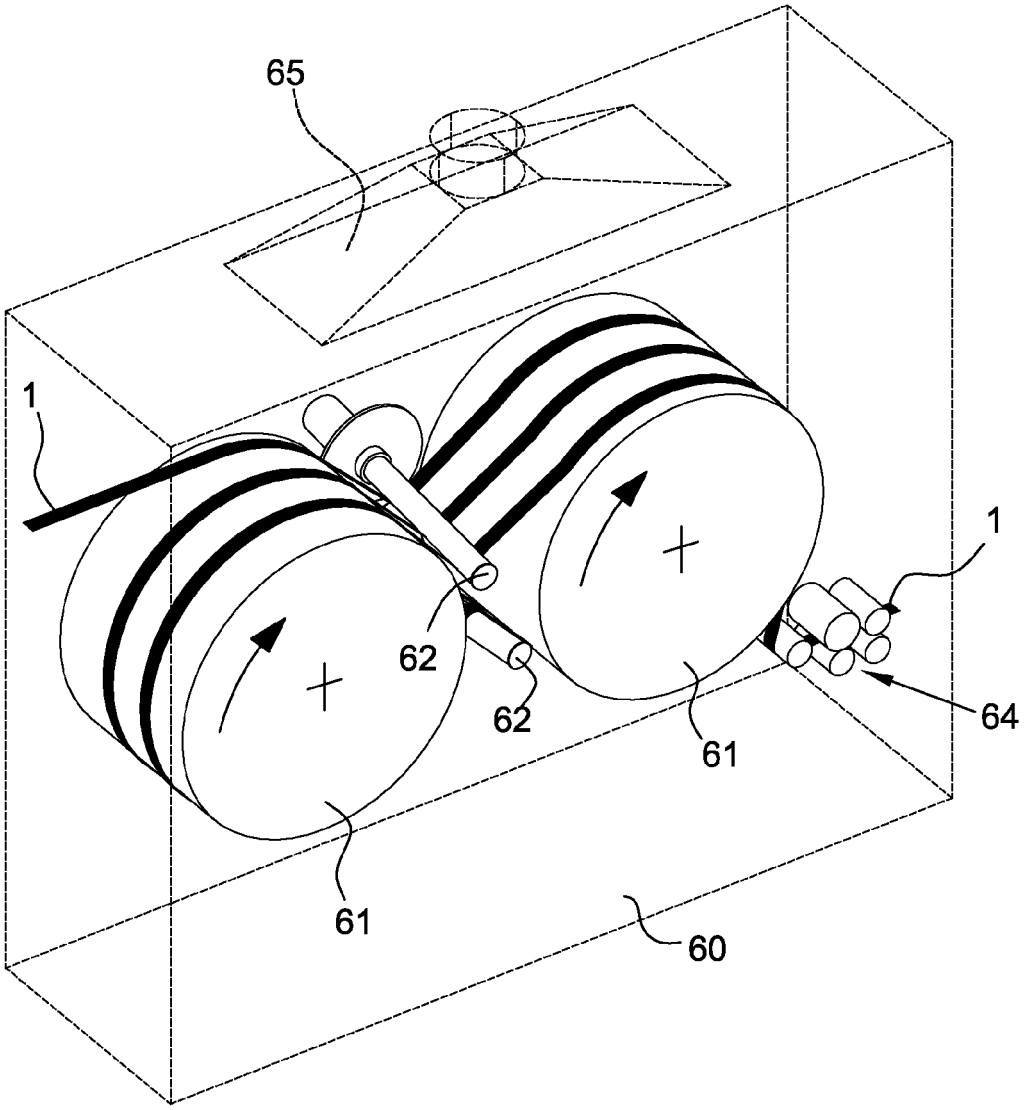


Fig. 7



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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