United States Patent [19]

Francia

[11] **3,774,829**

[45] **Nov. 27, 1973**

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[54] **YARN FEEDING DEVICE**

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[73] Assignee: **L.I.R. S.p.A. Laboratorio Italiano Ricerche**, Genova, Italy

[22] Filed: **Mar. 8, 1972**

[21] Appl. No.: **232,846**

[30] **Foreign Application Priority Data**

Mar. 8, 1971 Italy 9402A/71

[52] **U.S. Cl.** **226/97**, 226/195

[51] **Int. Cl.** **B65h 17/32**

[58] **Field of Search** .... 226/7, 97, 195; 83/402, 98; 29/114, 121 R

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Primary Examiner—Richard A. Schacher

Attorney—Clifton T. Hunt

[57] **ABSTRACT**

A yarn is wrapped around a portion of a rotary element which is rotating in the direction of feed. The periphery of the rotary element includes a plurality of openings through which an air stream is induced, the air stream tending to urge the yarn out of engagement with the rotary element, whereby the tension and frictional effect on the yarn around the rotary element may be varied in response to downstream conditions in order to obtain constant tension in the yarn being delivered to downstream machines regardless of the tension on the yarn as it is received at the rotary element from a supply source.

7 Claims, 16 Drawing Figures

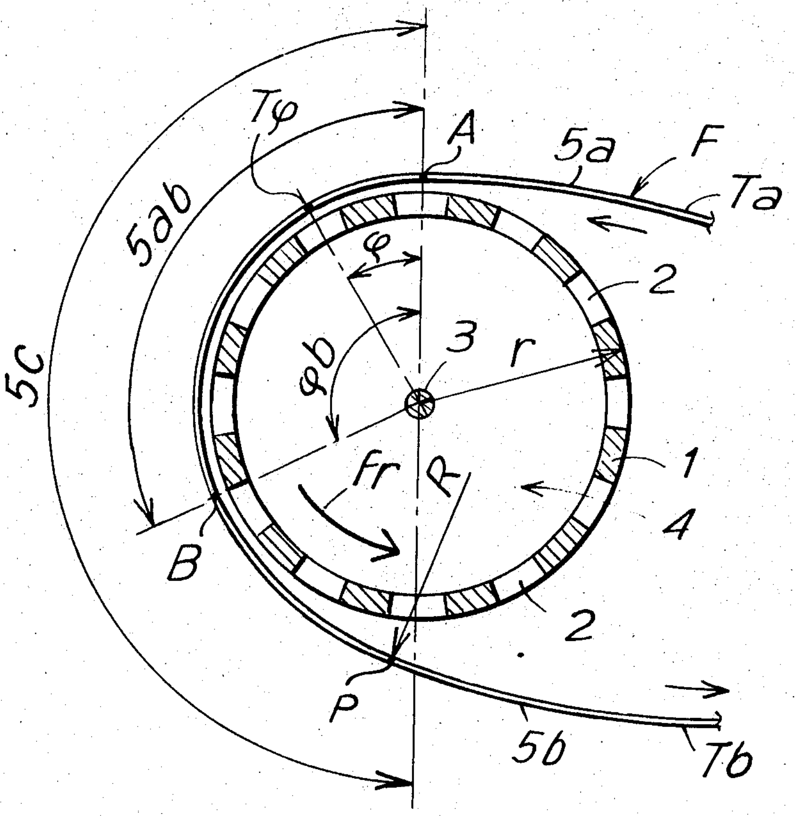
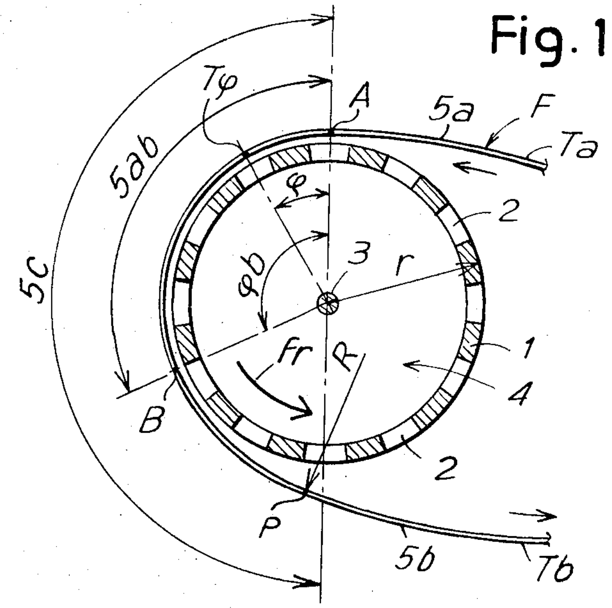


Fig. 1



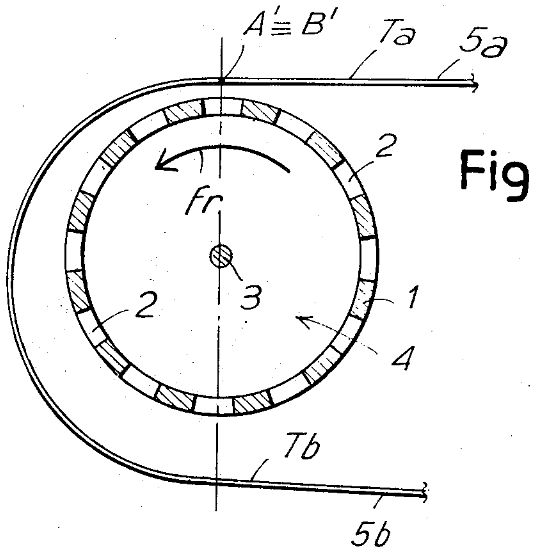


Fig. 2

Fig. 3

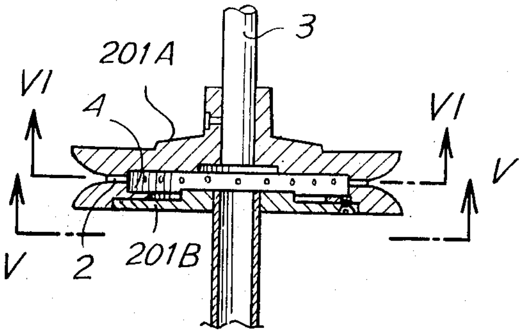


Fig. 5

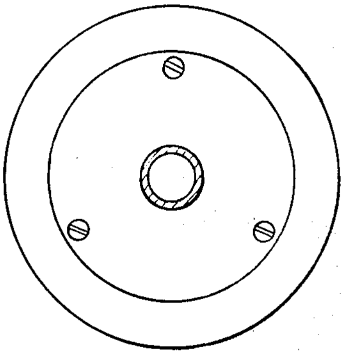


Fig. 4

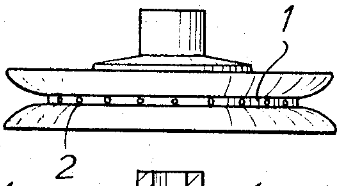
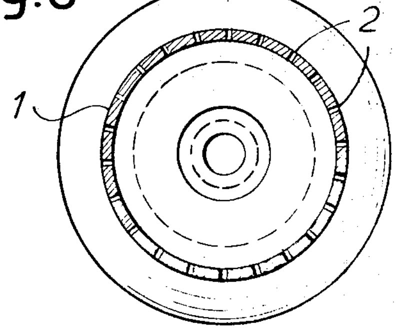


Fig. 6



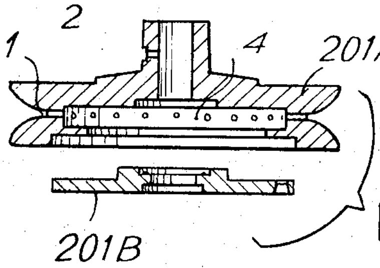


Fig. 7

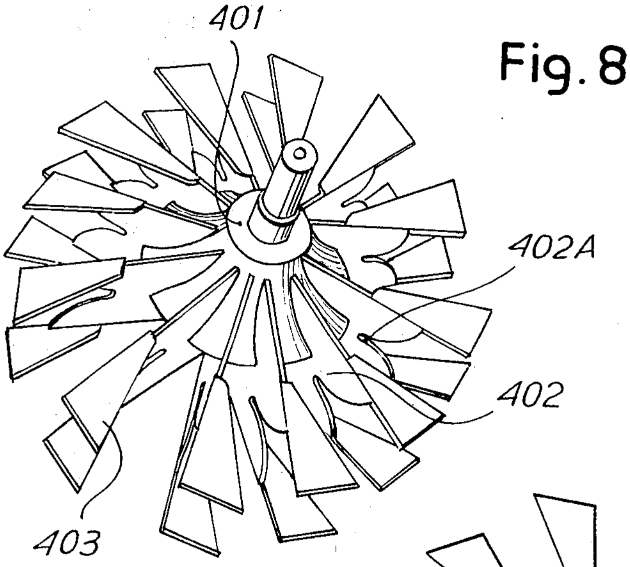


Fig. 8

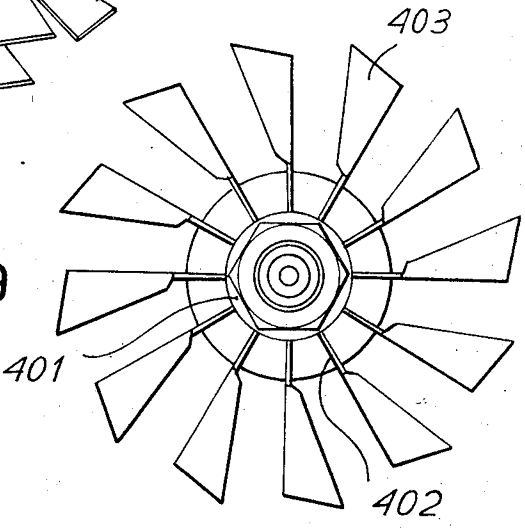


Fig. 9

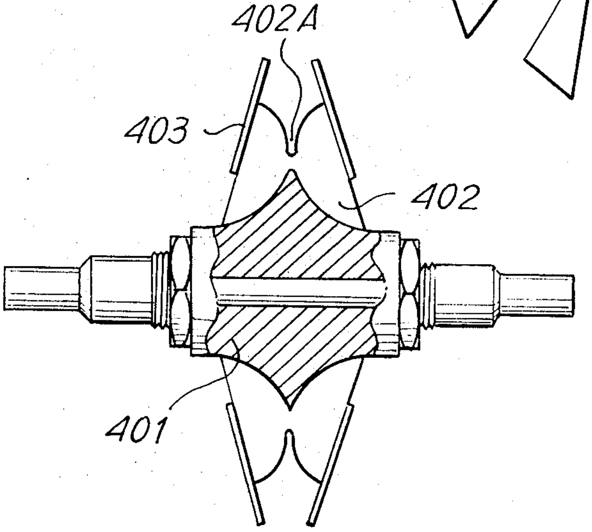


Fig. 10

Fig.11

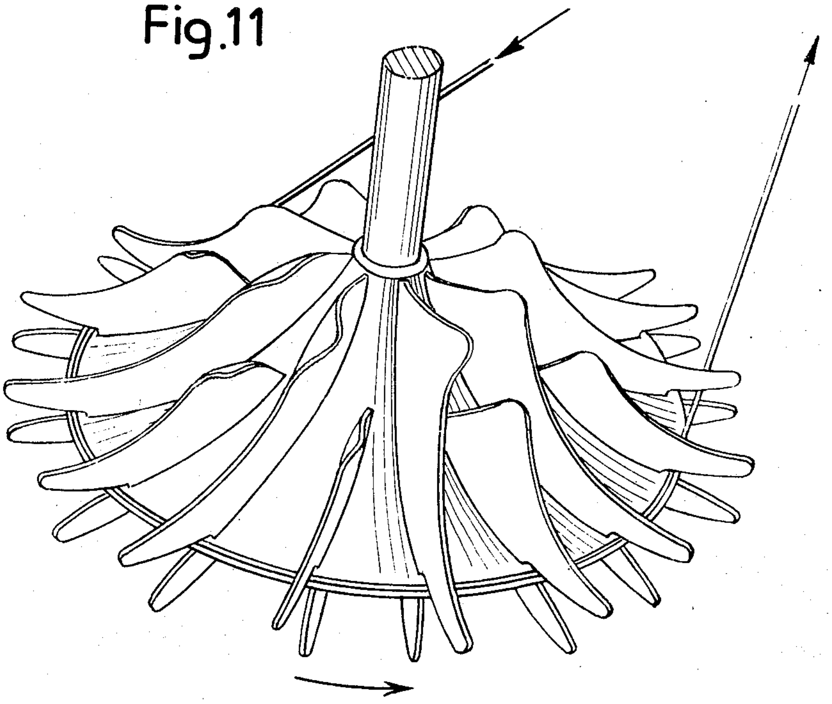


Fig.12

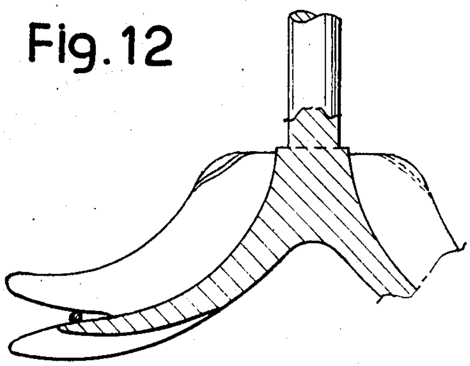


Fig.13

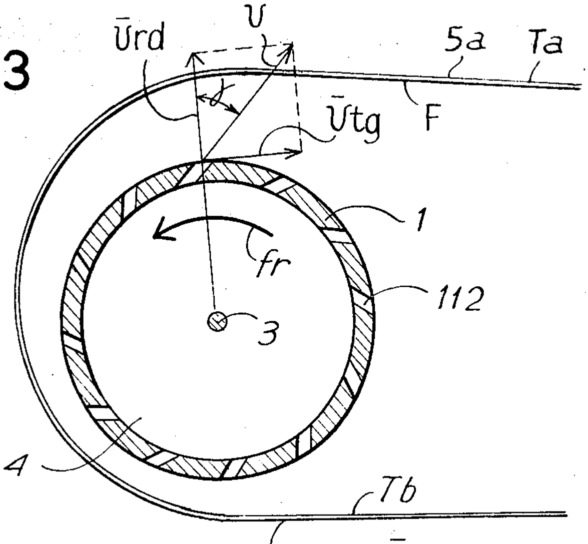


Fig.14

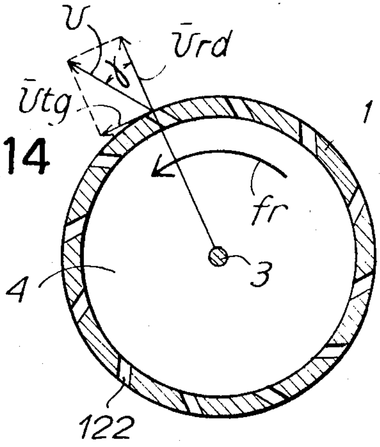


Fig.15

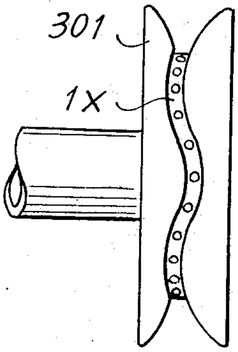
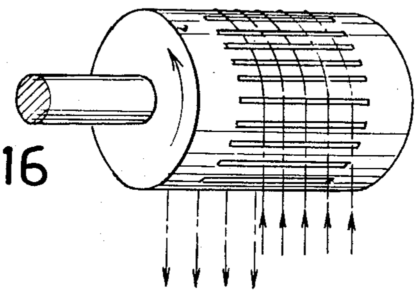


Fig.16



YARN FEEDING DEVICE

BACKGROUND OF THE INVENTION

The problem of the positive feed of yarn to textile machines becomes important when textured yarns or the like are desired to be used. The same problem is then present in all the yarn processing stages, such as in winding on coilers or reels; or in feeding yarn to textile machines, coilers or other yarn processing machinery. There has also long been a problem in the positive and uniform feeding of yarn to multifeed circular knitting machines in that it is important to have the yarn fed uniformly to all feeds. Some textured yarns have large and especially irregular length variations (and thus linear density), even under minimum tension variations or in the untensioned state. These inherent properties of textured yarns complicate the independently existing problem of feeding even a relatively stable yarn under uniform tension and at a given rate. The problem manifests itself in the surface appearance of the finished products, such as knitted fabrics or the like, or bobbins or windings. The more constant the surface density (mass/area) and the volumetric density (mass/volume) of a given length of yarn or adjacent portions of the finished fabric, the better the surface appearance of the product. Therefore, to achieve the best results the yarn which is being processed must have both a constant linear density, and a constant tension. Moreover, when several yarns operate in parallel, all the feeds must have the same features.

A constant linear density is the first condition required to assure the constant homogeneity of the product. Since all tensions of all yarns are substantially equalized in the finished product, it is apparent that a constancy of tension be applied to all yarns. Otherwise, the yarns fed into the finished product at a lower tension are relaxed with a consequent reduction of the density and viceversa. It is apparent then that, in general, the tension constancy and the linear density constancy are strictly bound to each other.

Constancy of tension by the use of positive feeders capable of feeding the yarn at the speed required by the machine has been achieved in various ways by synchronizing mechanically or electrically the speed of the feeders to that of the machine. These types of feeders, although able to induce the linear speed of the yarn required by the machine which they supply, cannot entirely correct the variations in the incoming yarn received by the feeder.

The object of the present invention is to provide a positive feeder capable of supplying a yarn having a constant linear density and a constant tension, and moreover capable of supplying the same yarn at all possible speeds required by the machine, from zero to the maximum speed, with practically no effect as a result of inertia.

SUMMARY OF THE INVENTION

The feeder device according to the present invention includes a rotary element rotating in the feed direction around which the yarn to be fed is partly wound. The rotary element is provided with means designed to generate airstreams having a centrifugal component which acts in such a manner as to urge the yarn outwardly from the surface of the rotary element and assume a winding arc variable with the tension conditions upstream and variations in the incoming yarn. There is thus achieved downstream a tension and linear density that are constant and independent of the upstream tension, and, within certain limits, upon the upstream linear density with any yarn delivery condition.

The rotary element rotates with a continuous and also constant motion, subject only to the condition that its peripheral speed is greater than the maximum yarn feed speed. When the yarn processing machine downstream from the feeder, such as a multifeed knitting machine, does not require yarn (null feed condition), the yarn is detached from the rotary element by outwardly directed air currents which have radial components.

According to one embodiment, the rotary element may take the form of a race pulley, along the inner periphery of which are provided holes or slots through which the air exits. According to another embodiment, the rotary element takes the form of a fan having recesses on the peripheral edge or rim of its vanes designed to receive and guide the yarn with the vanes arranged to generate an outward flow of air in a generally radial direction. According to other embodiments, the rotary element takes the form of a cage or a cylinder provided with appropriate air slits.

In most embodiments the yarn is laid on the rotary element, along the periphery of a transmission disc defining a path perpendicular to the rotational axis of the rotary element, however it is not absolutely necessary that this path be perpendicular to said axis (FIG. 15).

The feeder according to the invention includes the following features: (1) it consists of means capable of supplying yarn from zero speed to the maximum speed required by the textile machine without varying the speed of its rotary positions; (2) it is provided with means sensitive to the machine requirements; (3) it is capable of receiving yarn varying in tension and linear density from an upstream source and delivering the yarn to a downstream machine under conditions of relatively constant tension and linear density.

With the feeder according to the invention one obtains particular effects. When the linear density of the yarn length being fed from the feeder outlet to the textile machine increases, the yarn supply in terms of length decreases with a sensitivity on the order of thousandths of a second and viceversa, while in the length of yarn between the feeder and the use, the yarn is settled and recovers the excess of linear density in length. When the downstream requirement is increased, the yarn supply is increased with a sensitivity of the order of thousandths of a second, and viceversa. The sensitivity to the above variations may be increased or decreased by varying the surface shape on which the yarn lies, or by varying the shape, number and/or direction of the air inlets, air pressure, the rotational speed, and in general any of the other elements which comprise the device, as it will be later described. When the textile machine does not require yarn, the feeder does not supply it, even though its rotational speed is not changed. Under these conditions the yarn is lifted from the surface of the rotary element by means of an air pad or cushion which also prevents altering the characteristics of the same yarn. In the above respect, the air with its cooling action, eliminates any danger of heating the yarn.

The yarn tension downstream from the feeder, when the textile machine does not require it, that is the residual tension, is generally slightly lower than that of the yarn in the supplying stage; however, it is possible to manufacture feeders for which the downstream tension is independent of the machine requirement, apart, of course, the instant of the start.

The upstream tension may vary significantly without affecting significantly the downstream tension. Also the influence which the upstream tension variations may have on the downstream tension depends upon the structural features of the feeder device; in particular, it is possible, by varying the inclination of the holes and the air pressure, to design not only feeders in which an upstream tension increase corresponds to a minimum increase of the downstream tension, but also feeders wherein an upstream tension increase even corresponds with a downstream tension decrease, except of course, during the start.

In any case, it is possible to make feeders for which the upstream tension varies from the minimum value required to assure the regularity of the operation (for instance, 0.05 g/den) to the tearing tension, without the downstream tension undergoing sensitive variations.

The accompanying drawing illustrates by diagrammatical embodiments and some practical embodiments, both the operational mode and several possible embodiments of the invention; the examples being demonstrative only and not restrictive of the invention's scope. In the drawings:

FIG. **1** illustrates a diagrammatical schematic embodiment of the rotary element of the feeder and yarn thereon in its relative position under the delivery conditions;

FIG. **2** is similar to FIG. **1**, except illustrating the relative position of the yarn and feeder when there is no downstream feed requirement;

FIGS. **3, 4, 5, 6,** and **7** illustrate a first embodiment of a pulley type rotary element and is shown successively in a diametrical section, in elevation, in sections taken along the lines V—V and VI—VI of FIG. **3** and in an exploded view;

FIGS. **8, 9** and **10** illustrate respectively a perspective view, an axial view and a cross-section of an embodiment of a fan-type rotary element;

FIGS. **11** and **12** illustrate a perspective view and an axial partial section of a variation of a fan of vane-type rotary element;

FIGS. **13** and **14** schematically illustrate a rotary element similar to that of FIG. **1**, except showing variations in the direction of the air streams;

FIG. **15** shows yet another embodiment of a pulley-type rotary element similar to that illustrated in FIG. **4**; and

FIG. **16** illustrates an example of a drum-type rotary element.

In the following specification reference is made to several portions shown and referred to in the drawings during explanation of the associated operation. The main structural components are hereby immediately explained: **1** denotes a rotary element having an outer surface designed to carry the yarn F to be fed, whose length ***5a*** comes from the reel or other tank through clutches, and whose length ***5b*** is forwarded to the user machine or to an interposed braking unit; the surface of rotary element **1** has a radius r and is provided with a set of slits or openings. In the embodiment of FIGS. **1** and **2** there are provided radial openings **2**, while **3** denotes the rotational axis of the rotary element; in FIGS. **13** and **14** instead of the radial slits **2**, there are provided radial slits **112** and **122** respectively, inclined in a reversed direction and respectively coincident to the direction of the tangential speed of the rotary element, which rotates in the direction of the arrow *fr*.

In one practical embodiment shown in FIGS. **3** to **7**, the active portion of the rotary element **1** for the forwarding of the yarn with holes **2** is formed by the bottom of the race of a pulley body formed by the elements **201A** and **201B**, which, when coupled, also form a cavity **4** through which is fed compressed air to create through the holes or slits **2** airstreams directed toward the outside of the winding and forwarding surface.

In the variation of FIG. **15**, a pulley body **301** has an undulated bank annular race providing an active surface **1X** which operationally corresponds to the active surface of rotary element **1**, but which tends to deviate in the yarn which is forwarded therefrom in a lateral direction in such a manner as to compel it to rest on the walls and thus to increase the entraining effect. The variation of FIG. **15** is particularly suitable for nontexturized yarns or those with a low friction coefficient.

In FIGS. **8** to **10**, there is shown a rotary element which is formed like a fan, with a main body **401** shaped and provided with substantially radial vanes **402**. Rotation of body **401** forms air streams moving toward the outside and having at least a radial component. The vanes **402** are preferably provided with sides or wings **403** which tend to direct the air streams toward the symmetry plane of body **401** transverse to the rotational axis. The vanes **402** have on the outer periphery recesses **402A** which constitute contact points of the yarn on the rotary element. In the modified embodiment of FIGS. **11** and **12** the fan is asymmetric so that the yarn besides lying on the races may also lie on a lateral wall of the vanes. In all cases, the vanes of the fan may be radial or inclined rearwardly or forwardly as already stated for the holes **2**.

As above stated, the feeder substantially may be diagrammatically shown as illustrated in FIGS. **1** and **2**, and includes one or more rotary surfaces, such as wheels or cylinders, or pulleys or vanes as shown in FIGS. **3** to **16**.

In FIGS. **1** and **2** there are illustrated in section the essential elements of the invention and together the two extreme positions of the yarn. Around the support or rotary element, defined by a revolution surface, the yarn F is wound and forwarded. This support **1** is capable of rotating around its axis **3** in the direction shown by the arrow *fr*, and carries the yarn in the manner described hereinafter. The element **1** is simply illustrated in FIGS. **1** and **2** as an annular member bearing holes or slits **2**. In practice, this support may be a cylinder provided with perforations or slits (FIG. **16**); the race of a pulley provided with radial holes (FIGS. **3** to **7**), or radial slits, or a metal mesh cylindrical cage; or the bottoms of radial recesses made in a vaned wheel (FIGS. **8** to **12**) or the like.

The revolution surface of support **1** is not necessarily flat, but may have the contour of a regular polygon that is oblique and symmetric with respect to the plane of the drawing, except in the case of the revolution surface formed by an undulated profile or a broken contour profile, as illustrated in FIG. **15**.

The rotary element includes an inner space. If the rotary element is shaped as a pulley provided with radial holes, the active portion thereof will be the section corresponding to the race, and a cavity **4** is provided in the interior of the pulley body (FIG. 3). If the rotary element is in the form of a cylinder having slits around the periphery thereof or in the form of a cylindrical cage, the active portion thereof will be the peripheral section of the cylinder forming the cage and the inner chamber will be the space enclosed by the cylinder or cage. If the rotary element is a fan, the active portion is the bottoms of the recesses in the outer ends of the vanes, or in the case of the asymmetrical fan (FIGS. 11 and 12), the vanes and by a lateral conical surface, and the inner space is the region between the vanes adjacent the axis of the fan, the air outlet slits being the spaces between successive vane ends.

Making reference again to FIGS. 1 and 2 the element 1 rotates in the direction of the arrows *fr*, that is in a direction tending to carry the yarn toward the downstream machine, with a peripheral speed about **50%** higher than the maximum speed at which the yarn may be required. In cavity **4** air arrives slightly above atmospheric pressure. In the case of pulleys, cylinders, or cages or the like, this pressure is supplied by a small compressor (not shown); in the case of a vane wheel or a fan, this pressure can be generated by the motion of the wheel which draws air into the inner space at a point adjacent the axis of the fan, and pushes the air along the vanes. The the holes exits to the outside through theholes or slits **2** or between the vanes. In FIGS. 1 and 2, slits **2** are radial, however they may have a different direction; for example, in FIG. 13 slits **112** are shown through which the air exits in a direction inclined with respect to the radius and opposite the rotation; in FIG. 14 the slits **122** are oppositely inclined toward the direction of rotation. In the schematic illustration of FIG. 13, the motion of the rotary element is induced in reaction to the air which comes out through slits **112.** If one indicates the outcoming air speed as $\overline{v}$, the vector may be broken down into a radial component $\overline{v}_{rd}$ and in a tangential component $\overline{v}_{tg}$. In FIG. 13 the component $\overline{v}_{tg}$ has a direction opposite the peripheral speed of the rotary element, while in FIG. 14, the component $\overline{v}_{tg}$ has the same direction of the peripheral speed of the rotary element.

Yarn F, after passing through suitable upstream clutches, partially encircles the element 1 according to an arcuate or polygonal contour which starts in the point A and ends at the point B, the point B being variable, however included in the maximum arc *5c* which in FIG. 1 is 180°. It is apparent that maximum arc *5c* may vary as long as it remains less than 360°. At the point B, the yarn disengages the periphery of element 1 and is fed to the textile machine feed, wither directly or through suitable clutches. *5a* represents the length of yarn F between the reel and the feeder, *5ab* indicates the yarn length that engages rotary element 1 between point A and point B, and *5b* represents the length of yarn F between point B and the textile machine or to a succeeding clutch member. Moreover, T*a* represents the yarn tension in the portion *5a*, $T\phi$ the yarn tension at a prescribed point of the arc AB corresponding to the angle ϕ, and *Tb* the yarn tension in the portion *5b*. ϕ is the angle between the origin defined by the point A and a prescribed point on the arc AB. ϕ_b is the angle subtended by the arc A–B.

As above stated, the feeder rotates at a constant speed, independently upon the fact that the machine requires or does not require yarn, the peripheral speed of the element 1 being higher than the maximum speed at which the yarn F is used by the machine.

It is convenient to separately examine these conditions:

a. the null delivery stage wherein the machine does not require any yarn in which case a stationary stage is obtained;

b. a temporary or changing stage wherein the downstream feed requirements of the yarn being fed increases or decreases; for example during start-up or when the downstream requirements change;

c. the operating stage wherein the downstream machine requires the yarn at a constant speed; and in this case, one obtains a second "stationary" stage.

CASE a. At times when the machine does not require any yarn, the air stream exiting from the holes or slits 2 is sufficient to disengage the yarn from the active surface element 1 and the point B is brought into B' coinciding with A' (FIG. 2). The frictional engagement between the yarn and element 1 is null and there is no feed of yarn, and therefore the yarn remains stationary and supported by an air pad. This stage may last indefinitely without any damage either to the yarn or the rotary element. This stage is shown in FIG. 2, although the spacing of the yarn from the active surface is exaggerated in the figure for the purpose of clarity. In FIG. 13 is shown the position which the yarn assumes during this null delivery stage in case of rearwardly inclined holes, which emphasizes the air transporting effect.

CASE b. In these situations the feeder must suddenly supply yarn at the speed requested by the machine either because of initial start-up or because the downstream speed requirement is changed.

The yarn F is initially balanced by the double effect of the air thrust and the residue tension (FIG. 2). The request of yarn by the textile machine is converted into a small increase in the tension T_b. The balance is broken and the yarn moves into engagement with the surface of the rotary element **1.** At the point where the yarn initially touches said surface, it receives, upon contact, a thrust or carrying effect in the feed direction. As a result of this thrust, the yarn tension upstream the contact point increases and all the yarn upstream the contact point adheres substantially instantaneously to the surface of the element **1.** The yarn quickly assumes the position defined by the arc *5ab* along which the yarn lies on the rotary element, the arc *5ab* being developed to the point B so that the contact arc is sufficient to deliver a carrying force equal to $T_a - T_b$. It should be recognized that because of braking means on the branch *5a* of the yarn, T_a is greater than T_b. (This last condition however is not absolutely necessary; in fact in the case of rearwardly inclined holes (FIG. 11) T_a may also be smaller than T_b).

More exactly, along the arc AB, progressing from B to A, the tension increases according to the known exponential law $T\phi = T_b\, e^{K(\varphi \quad - \varphi)}$ which is appropriately corrected to take account of the lift and drag due to the air thrust; the extreme variability of the friction coefficient *k*, which depends upon the creeping speed; the chemical-physical conditions of the yarn; the turn affected by the friction phenomena due to the aforesaid creeping, the action of the air; and the like; to reach the value T_a, the tension at which the yarn arrives at the rotary element.

The aforesaid phenomena on the whole occur in a minimum time which is difficult to measure due to the complexity of the phenomena in question, and their extreme variability. Calculations however show that its order of magnitude is in thousandths of a second (photographic controls confirm these values).

CASE c. In situations where the machine requires yarn to be fed at constant speeds and thus the feeder is under running conditions, the following observations are made. Assuming that T_o is the optimum tension of the yarn at the inlet of the textile machine, if there is interposed a friction device between the feeder and the machine having a force T_f, it should be apparent that $T_b + T_f = T_o$; if the yarn goes directly from the feeder to the machine, it should be $T_b = T_o$. The tension T_b thus should be constant and not greater than T_o. In the modern machines for knitting stockings and other textile machines, T_o in general is included between 0.015 and 0.05 grams/denier.

As such values are well within the possibilities of the feeder herein described, the condition $T_b \leq T_o$ may be considered as always complied with.

Now the feeder of the present invention will be examined in order to see how the necessary constancy of T_b is assured even in the case of large variations of T_a.

The yarn arrives at the rotary element at point A and is entrained on the active surface thereof throughout contact arc AB, subject to the double action of the friction and the air thrust through openings **2.** At point B the yarn becomes disengaged from the element **1,** and downstream from point B the friction effect is annulled and the air thrust quickly decreases. The position of point B is determined by the relationship between the tension of the yarn laid onto the element **1** and the air thrust which tends to move it away from the surface of rotary element **1.** Strictly speaking, one should take account also of the centrifugal force, but this is negligible due to the smallness of the yarn linear density.

By referring to $F_{air/d}$ as the radial component of the air thrust exerted on the unit length of the yarn, and $T\phi$, as already stated, as the yarn tension at a prescribed point, a given length of yarn Δe will be subject to the two radial forces, having opposite sign $F_{air/d} \cdot \Delta e$ and $T\phi/r \cdot \Delta e$, r being the radius of the rotary element **1.**

As long as $(T\phi \cdot \Delta e)/r > F_{air/rd} \cdot \Delta e$, that is as long as $T\phi/r > F_{air/rd}$, the yarn lies on the surface of rotary element **1** with a force equal to:

$$(T\phi/r) - F_{aird/rd} \tag{1}$$

The tension $T\phi$ which in A is equal to T_a decreases as one moves away from A, that is as ϕ increases. When at point B, $T\phi$ assumes the value of T_b such that T_b/r is equal to $F_{air/rd}$, the yarn is detached from rotary element **1** and the carrying force that the element **1** exerts as a result of friction on the yarn is annulled.

It is obvious that with the variation of T_a the length of the contact arc AB will vary. Due to the minimum value of the yarn linear density with respect to the forces in question, the response time, that is the delay of the movement of B with respect to the variation of T_a, can be considered as negligible for all effects.

Neglecting the effect of the tangential component $F_{air/tg}$, of the air force on the yarn, from (1) that one may write for the position B:

$$T_b = r F_{air/rd}. \tag{1'}$$

Immediately one deducts the constancy of T_b when $F_{air/rd}$ is constant, and the possibility of adjusting the value of T_b, within certain limits, by adjusting $F_{air/rd}$.

In the feeder, as schematically illustrated in FIGS. **1** to **7, 11, 12, 14,** the adjustment of $F_{air/rd}$ is obtained by changing the air pressure in the cavity **4.** In other embodiments based on the same principle, such as fans and the like, the adjustment of $F_{air/rd}$ is obtained in another manner. In any case, $F_{air/rd}$, once established, is strictly constant and consequently also T_b is strictly constant.

With the detachment and the subsequent separation of the yarn from rotary element **1,** $F_{air/rd}$ decreases to be null; for example, downstream from the point B, the yarn is not subjected to tangential forces, ($F_{air/tg}$ being neglected), its tension remains constant and substantially equal to T_b. Referring to R as the bending radius of the yarn in one of its points P downstream B from the equation:

$$R \cdot F_{air/rd} = T_b = \text{const.}$$

one deducts that, upon decreasing the value of $F_{air/rd}$ to zero, the value of R will increase to infinity. The yarn, which in the arc from A to B has a constant radius r, downstream from the point of detachment B assumes a curved line which subsequently approaches a straight line (R = infinity).

As the point B is moved on the periphery of the rotary element **1** to compensate for the variations of T_a and the chemical-physical variations of the yarn, the curve defined by the downstream yarn continuously varies. This could cause stationary waves in the yarn length between the feeder and the machine, but the minimum linear density of the yarn and the relatively high friction due to the air stream dampen these oscillations, and they are practically cancelled.

For simplicity of explanation, previously $F_{air/rd}$ has been considered without taking into account the fact that such value depends, not only upon the speed and the inclination with which the air exits the slit, but also upon the yarn linear density.

As $F_{air/rd}$ increases responsive to the increase of the yarn linear density, it follows that, in lengths of greater linear density, T_b will increase.

As a greater linear density is caused by irregular winding of the filaments in multi-filaments yarns, or by irregular twist in the single-filament yarns, it follows that the feeder of the present invention tends to supply a yarn having a practically constant linear density and tension. In fact, in both cases, between the feeder and the downstream use, the yarn settles and the major tension is converted into a decrease of linear density. It is appropriate to add that for values of r sufficiently high with respect to the speed of yarn requirement, for instance $r > 2 \div 3$ cm, $v < 200 \div 300$ metres/min, the settling has already taken place in the portion AB of FIG. **1.**

The effects of the aforementioned variations in the friction coefficient k, which may be high, are compensated automatically and practically instantaneously. Looking at the equation:

$$T_a = T_b \cdot e^{\kappa\varphi_b} \tag{2}$$

where T_b is constant for equation (1) and (1'), and T_a changes from reel to reel and from point to point of the same reel, (more in general, from the whole previous history of the yarn,) which gives rise to the need of a feeder in the first place. Constant k changes with the chemical-physical conditions of the yarn and also with the surface heating at the level of few uni-molar layers due to the yarn friction on the element **1**.

For obvious considerations, it is preferable to work with a sufficiently high T_a, for instance, from 0.05 to 0.5 gr/den, to assure the maximum possible homogeneity of the yarn at the input of the feeder. Increasing T_a is easily accomplished by employing upstream braking means. From (2) one immediately obtains:

$$\phi_b = (1/k) \log (T_a/T_b). \tag{3}$$

The point A is fixed, ϕ_b depends therefore only upon the point B wherein the yarn is detached from the element **1**, that is from the point wherein $T\phi$ assumes the predetermined constant value T_b. Variation in the conditions upstream will cause the point B to move around the periphery of the element **1**, subject only to the fact that the relations (1') and (2) are in each instant complied with, said relations assuring the required constancy of the tension T_b, at which the yarn is supplied to the feeder. For this purpose it is sufficient that in each instant equation (3) is satisfied. In order that equation (3) may be satisfied, it is always necessary for arc **5***c* of FIG. **1** to be large enough to contain all possible angles ϕ_b. Arc **5***c*, if required, may be greatly increased by employing two or more elements **1** in series; it is however simpler to use a different configuration of contact surface (as in FIG. **15**) which increases the friction on the yarn by the rotary element **1** and thus decreases the maximum value of ϕ_b. This different configuration is achieved, for instance, by reducing the race section of a pulley contoured element **1**, or by creating the contact surface under the form of a broken line on an arcuate surface (FIG. **15**), or in other similar manners. With such a contact surface configuration, the arc **5***c* may fall between 180° and 270° and the safety margin (the difference between the arc **5***c* and the maximum possible value of ϕ_b) may be increased to the point of assuring the constancy of T_b to the maximum value of the tension T_a which corresponds obviously to the value at which the yarn is torn. It is important to observe that the feeder of the present invention, though theoretically independent upon the yarn features, is particularly efficient and sensitive for texturized yarns.

From the formula (3) one may note that the variations of the ratio T_a/T_b affect the arc **5***ab* (arc A–B) only logarithmically. Therefore even large variations of T_a/T_b cause relatively small variations of the contact arc A–B.

Hereinabove there has been considered only the radial component $F_{air/rd}$ of the force which the air coming out of the holes **2** exerts on the yarn. Now, from a qualitative viewpoint only, other effects of the air on the yarn will be examined, leaving out of consideration the heretofore discussed effect of self-adjustment due to the $F_{air/rd}$.

The first and most fundamental effect is the cooling of the yarn or more accurately the very thin surface layer of the filaments that compose the yarn. This effect is fundamental because, in absence thereof, the yarn might become fused with the rotary element.

Another important effect, relating to the performance of the feeder, is the following: if $\bar{v}$ is the air speed and γ is the angle which its direction forms with the radius, the force which the air exerts on the yarn, will be, firstly and necessarily approximately, proportional to v^2, and for a same yarn, increasing with the linear density of the yarn element on which the air acts. The vector $\bar{v}$ can be decomposed in its tangential and radial components:

$$v_{tg} = v \cdot \sin\gamma \text{ and } v_{rd} = v \cdot \cos\gamma$$

It can be immediately recognized that the total force F_{air} that the air exerts on the yarn in the case of rearwardly inclined slits, will have the effect of decreasing the lift, that is the entraining effect of the feeder, at least when the resulting speed of the algebric sum of v_{tg} and of the peripheral speed of the rotary element becomes smaller than the yarn speed.

As far as the downstream portion of B is concerned, the effect of $F_{air/tg}$ is a counter-lift which, as already stated, causes no appreciable effect.

As a result of what happens on the arc A–B, however, $F_{air/tg}$ has the effect of increasing the tension of the yarn which arrives into the textile machine with the double result: (1) of increasing the tension T_b, with the same air pressure in the chamber **4**; (2) of increasing the accuracy of the yarn detachment from the rotary element **1**, still with the same pressure in the chamber **4**.

In the case of radial holes, this second result may be obtained, with a reasonable margin of safety, by merely varying the pressure of the air in chamber **4**. The inclination of the holes achieves the same safety margin with remarkable smaller pressure and thus with remarkably smaller air consumptions and costs.

What is claimed is:

1. Yarn feeding device comprising a rotary element having means associated therewith for rotating said rotary element in a feed direction, said rotary element including a winding surface rotatable with said rotary element and around which the yarn being fed is at least partially wound, said rotary element also including means for limiting lateral movement of said yarn relative to said winding surface, said yarn feeding device also including means for generating air currents directed across the winding surface and having at least a radial component, said air currents being of a magnitude to normally urge said yarn away from said winding surface when the yarn is traversing the said device at a predetermined yarn tension, and said air currents being overcome by yarn tension in excess of said predetermined yarn tension to bring the yarn into variable engagement with the winding surface and achieve a winding arc variable with the upstream tension conditions and yarn features and responsive to downstream feed requirements, whereby a constant tension is obtained downstream which is independent upon the upstream tension during any delivery condition of the yarn.

2. Device according to claim **1**, wherein said rotary element continuously rotates at a constant speed, said speed of rotation being greater than the maximum downstream feed speed.

3. Device according to claim 1, wherein said yarn is disengaged from the surface of the rotary element by effect of the centrifugal air thrust even during periods of no downstream feed requirements.

4. Device according to claim 1 wherein said rotary element comprises a pulley race, the bottom of said race including holes or slits through which pressurized air exits.

5. Device according to claim 1, wherein said rotary element comprises a fan-shaped member, having vanes, recesses formed on the peripheral edges of said vanes for receiving and guiding the yarn, the vanes of said fan so arranged as to generate radial air currents during operation thereof.

6. Device according to claim 1, wherein said winding surface further includes means associated therewith for urging said yarn into a non-circumferential path, said urging means including wall portions adjacent said winding surface extending into said yarn path and engaging said yarn at prescribed points.

7. Device according to claim 1, wherein said air currents are inclined with respect to the relevant radial direction, to present a tangential component either along or opposite to the yarn feed direction.

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