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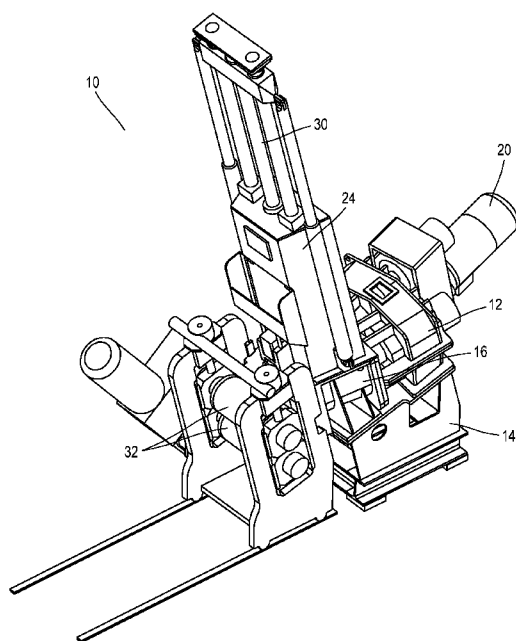


FIG. 1

(57) Abstract: Mixing and extrusion machine (10) for the manufacture of rubber mixtures, having a mixer with a converging conical twin screw (12) with a fixed frame (14) that supports sleeves (16). Two screws (18), being mounted at an angle, are mounted in the mixer (12) so as to move in translational movement between an opening (22) arranged upstream and an outlet (25) arranged downstream of the sleeves, so that the thread tips of each screw contact tangentially the surfaces of the opposite screw so that the screws remain substantially in contact with each other when the screws rotate at an angle and at a center distance that facilitates self-cleaning. The screw threads maintain tangential contact with the inner surfaces of the sleeves, thus preventing the retention of mixing material on these surfaces.

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**MIXING AND EXTRUSION MACHINE WITH
SELF-CLEANING TWIN SCREW AND METHOD OF USE**

TECHNICAL FIELD

The invention concerns mixers used in the field of rubber mixing. In particular, the invention concerns mixing and extrusion machines that make it possible to produce a variety of rubber mixtures, including sticky and de-cohesive mixtures, without reducing industrial productivity.

BACKGROUND

In the field of producing rubber mixtures, twin-screw extruders already exist, each having a chassis with common assembled parts. The assembled parts may include, without limitation, a sheath screw assembly (with or without its optional heating and cooling accessories), a drive unit (gearbox and coupling), a main motor, devices for supplying material (for example, dosers or hoppers) or for its treatment (for example, degassing devices), a cutting or shaping device for the extruded material, if applicable, a control cabinet that connects the motor drives, start and safety devices, and control, command, display and measurement devices. There are examples of twin-screw extruders described in the publication "Extrusion – Twin-Screw Extrusion Processes" by Bruno Vergnes and Marc Chapet, published on January 10, 2001 by *Techniques de l'Ingénieur, traité Plastiques et Composites* ("the Vergnes/Chapet reference").

The chassis often includes a manual or assisted sleeve opening device, allowing easy access to the screws for cleaning, inspection and/or maintenance. The most commonly used opening system consists of a slide that slides the sleeve relative to the screws (for example, of the type offered commercially by Colmec and Pomini TDE). There are also "portfolio" opening systems, where the sheath is articulated around a lateral hinge (typically known as the Farrel continuous mixer, or "FCM"). The sleeve screw assembly is the active part and ensures the treatment of the material. The sheath is the outer envelope. The sleeve is temperature regulated by the combination of a heating system, generally electric, controlled by temperature control probes, with a cooling system, usually with water circulation. Inside the sleeve, the two rotating screws consume the material and move it forward.

The mixing and screw extrusion machines that are usually used are made up of rotors (that is, the screw(s)) and stators (i. e., the sleeves)). Such a machine is described by the publication WO2005039847 that represents an example of a converging conical twin-screw machine with a movable door that closes the outlet.

5 This type of mixer allows the combination of a mixing phase of the raw materials and an evacuation phase of the mixture thanks to a movable door at the outlet (this movable door being arranged at the end of the screw). The movable door is closed and locked during the mixing cycle, preventing the mixture from exiting the machine. When the mixing cycle is complete, the movable door is unlocked and
10 opens. The rotating screws can then bring forward the product (also called "rubber" or "mixture") contained inside the machine.

This type of mixer mixes and discharges using screws such as Archimedes screws, which are not self-cleaning. When the mixtures become extremely sticky, a lot of product remains adhered on the screw walls. In this case, the product also
15 remains adhered to the sleeves and/or in the introduction hopper, so mixing and evacuation are only partially completed. A lot of product remains adhered on the metal walls of the screws, sleeves or introduction hopper. Even if adjustments of speed, temperature and pressure allow an improvement, they do not facilitate a good repeatability of the mixing or total evacuation of the mixer.

20 Self-cleaning screws are often used on known twin-screw mixers (for example, of the type shown by the publication JPH0550425). These self-cleaning twin-screw mixers are also known as "continuous mixers". They allow sticky mixtures to be made, but for rubber mixtures, their size and flow rates remain limited. Examples of self-cleaning screws are disclosed by patents EP0160124B1,
25 EP0002131B1, US 4,300,839, US 4,131,371, and US 6,022,133 and by publication WO2016/107527.

The use of mobile sleeves on mixing and extrusion machines is also known. In the past, mobile sleeves have been designed to vary in real time the internal clearances and volumes inside the mixing and extrusion machines having screws
30 and sleeves (see the examples disclosed in publications WO2009057753 and JPH0550425). The product to be extruded or mixed passes through the spaces left by the difference in volume between the screw and the sleeves. These spaces, and more particularly the clearance left between the thread tips of the screw and thread tips of the sleeve (if the sleeve has no threads, the smallest inside diameter is

considered), are important for working the product, for its forward speed and for managing any pressure inside the machine. The quality of mixing or extrusion is related to these internal clearances.

The product that is subjected to a very high pressure at the end of the screw
5 will seek to move to areas where the pressure is lower. When the product moves through the machine, it will undergo significant shearing, which will promote the work and homogenization of the product. The use of mobile sleeves allows, from the beginning of the mixing cycle, to have a large air gap and therefore a low pressure drop despite high viscosity. The product can thus be put into cycle from
10 the beginning.

In addition, mobile pressers (or "rams") allow to exert pressure on the mixture during the manufacturing process and thus improve the work of the rubber. Rams are widely used with internal batch mixers such as those of the type Banbury. The patent US1,370,398, for example, describes an internal mixer with a
15 ram, and the patent US7,404,664 explains an evolution in the shape of a ram to improve mixing. The rams also prevent any retention in the area above the rotors. However, these rams do not allow the complete evacuation of extremely sticky mixtures, which is usually done from below the mixer.

In addition, in a known way, the manufacture of rubber profiles involves
20 the use of extrusion equipment whose function is to produce rubber sheets according to a specific profile. These devices include a body and a screw rotating in the body so that rotating the screw has the effect of extruding the mixture and providing mechanical work to the mixture. On the one hand, the viscosity of the mixture is reduced, and on the other hand, the mixture is propelled towards an
25 extrusion die in order to give a determined profile to the extruded product. The extrusion die is generally formed by a fixed profiled blade and a rotating roller or two rotating rollers rotating in opposite directions (i.e., "a roller nose system"). Examples of roller nose systems are disclosed by patents FR1563077, FR2282993 and FR3001654. An example of a roller nose system used at the outlet of a
30 converging conical twin screw extrusion machine is disclosed by patents JP4294005 and US8,517,714.

The disclosed invention combines the benefits of converging conical twin-screw mixers with the benefits of self-cleaning screws. The disclosed invention also anticipates ways of achieving these benefits by combining them with the

benefits of a variety of tools, including rams, roller nose systems and mobile sleeves. By combining these solutions in variable combinations, improved mixing and total evacuation are achieved reliably and in reduced cycle times, even with particularly sticky and/or de-cohesive mixtures.

5

SUMMARY

The invention concerns a mixing and extrusion machine for the production of rubber mixtures. The machine includes a converging conical twin-screw mixer with a fixed frame that supports sleeves in which two screws are mounted at an angle between an opening arranged upstream of the sleeves, where an introduction hopper of the machine feeds the screws, and an outlet arranged downstream of the sleeves, where the mixer brings the mixture out at the end of a mixing cycle. The machine also includes one or more motors that rotate the two screws in the sleeves during the mixing cycle, and one or more movable doors provided at the outlet that allow, during the mixing cycle, the evacuation and shaping of a rubber mixture. The two screws are mounted in the mixer so that the thread tips of each screw remain in tangential contact with the surfaces of the opposite screw so that the screws remain substantially in contact with each other when rotating the screws at an angle and at a center distance that facilitates self-cleaning. The contour of an inner surface of the sleeves is predefined to allow a predetermined distance to be determined between each thread and the inner surface of a corresponding sleeve, with the thread tips of the screws remaining in tangential contact with the inner surfaces of the sleeves and preventing the retention of the mixture on these surfaces.

In some embodiments of the machine, the machine also includes a ram having an inner surface with a shape that is complementary to an outer contour of the two screws, the ram moving along the inside of the introduction hopper between a raised position, where the two screws remain accessible for introducing the mixture, and a lowered position, where the inner surface of the ram forms an upper part of the mixer.

In some embodiments, the machine also includes a roller nose system with two counter-rotating rollers arranged just downstream of the outlet to form a sheet of the mixture exiting the mixer.

In some embodiments of the machine, the machine also includes one or

more mobile sleeves that are arranged top-down towards the outlet, each mobile sleeve with a support surface with a predetermined surface area according to an elasticity of the mixture. The mobile sleeves include mobile elements that move in a linear movement relative to the outlet in order to adjust a predetermined space
5 between the sleeves and screws. The linear movement is defined between a closed position of the mobile sleeves to facilitate mixing, and an open position of the mobile sleeves to facilitate the flow of the mixture inside the mixer.

In some embodiments of the machine, the screws are selected from interpenetrated and conjugated profiles, including interpenetrated co-rotative
10 profiles with conjugated profiles.

In some embodiments of the machine, the mixer includes an interpenetrated contra-rotating twin-screw mixer, with screws mounted in the sleeves with a movable door at the end that follows the shape of the screws. There are embodiments of the machine in which the screws are symmetrical. There are other
15 embodiments of the machine in which the screws are asymmetrical.

In some embodiments of the machine, the sleeves include cooling channels that manage the temperature of the mixture during the mixing cycle.

In some embodiments of the machine, the movable door includes one or more sliding shutters installed relative to the outlet so that the sliding shutters
20 move linearly between a closed position, in which the sliding shutters prevent the mixer from discharging the mixture, and an open position, in which the sliding shutters are used to prevent the mixture from escaping through the sides of the counter-rotating rollers thereby forcing the mixture to pass between the rollers.

The invention also concerns a mixing process of the type including a step
25 of mixing and extruding a rubber mixture from the disclosed machine. The process includes the following steps:

- a step of rotating the screws forward with the movable doors closed;
- a step of introducing the mixture into the machine, during which the screws continue to rotate and the movable doors remain closed;
- 30 - a step of reversing the screws with the movable doors closed, during which the screws rotate in a direction opposite to the direction of rotation during the step of turning the screws forward; and
- a step of emptying the machine, during which the movable doors open to discharge the mixture from the machine outlet toward a downstream process and in

which the screws continue to rotate until the mixer is empty.

In some embodiments of the process, the step of introducing the mixture into the machine includes the introduction of raw materials to form the mixture.

In some embodiments of the process, the step of introducing the mixture to
5 the machine includes the introduction of one or more masterbatches.

In some embodiments of the process, the movable door is open at the end of the mixing cycle, and the mobile sleeves are in the closed position at the end of the mixing cycle.

Other aspects of the invention will become evident through the following
10 detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The nature and various advantages of the invention will become more obvious when reading the following detailed description, in conjunction with the
15 attached drawings, in which the same reference numbers refer everywhere to identical elements, and in which:

Figure 1 shows a perspective view of a mixing and extrusion machine of the invention.

Figure 2 shows a lateral view, in partial section, of an embodiment of the
20 machine of Figure 1 with a converging conical twin-screw mixer.

Figure 3 shows a partial cross-sectional lateral view of a screw from the mixer of Figure 2 mounted in mixer sleeves.

Figure 4 shows a top view of the screws of Figure 3 mounted in the mixer with a closed movable door, and Figure 5 shows a corresponding view with the
25 movable door open.

Figure 6 shows a front view of a ram of an embodiment of the machine of the invention.

Figure 7 shows a partial cross-sectional lateral view of the ram of Figure 6 in a lowered position relative to the mixer.

Figure 8 represents a lateral view, in partial section, of an embodiment of
30 the machine of the invention having the ram of Figures 6 and 7 and at least one of a roller nose type system and one or more mobile sleeves arranged towards an outlet of the mixer.

Figure 9 shows a lateral view, in partial section, of a screw of the mixer of

Figure 8, including mobile sleeves.

Figure 10 shows a top view of an embodiment of the mixer with self-cleaning, interpenetrating counter-rotating twin screws, the screws being symmetrical.

5 Figure 11 shows an expanded schematic view of the clearances between the threads of the screws of Figure 10.

Figure 12 shows a top view of an embodiment of the mixer with self-cleaning, interpenetrating counter-rotating twin screws, the screws being asymmetric.

10 Figure 13 shows a lateral view, in partial section, of an embodiment of the machine using the symmetrical screws in Figure 10 together with rollers and mobile sleeves.

Figures 14 to 16 represent steps in an exemplary cycle of a mixing process of the invention.

15

DETAILED DESCRIPTION

Referring now to the figures, in which the same numbers identify identical elements, Figure 1 represents an embodiment of a mixing and screw extrusion machine (or "machine") 10 of the invention. The machine 10 includes a
20 converging conical twin-screw mixer (or "mixer") 12 suitable for rubber materials. The mixer 12 includes a fixed frame 14 that supports fixed sleeves (or "sleeves") 16 in which the two screws 18 are mounted. One or more motors 20 rotate the two screws in the sleeves 16 during a mixing cycle. An upper surface of the fixed frame 14 includes guides (not shown) on which the sleeves 16 (without the screws
25 18) are able to move in translational movement. The mixer 12 is chosen from commercially available mixers, including those of the type disclosed by US Patent 7,556,419 and proposed by Colmec S.p.A.

Referring further to Figure 1 and also to Figures 2 to 5 (which represent an embodiment of the machine of Figure 1), the screws 18 are mounted in the sleeves
30 16 at an angle between an opening 22 arranged upstream of the sleeves (where an introduction hopper 24 of the machine 10 feeds the screws 18), and an outlet 25 arranged downstream of the sleeves (where the mixer 12 discharges the mixture at the end of the mixing cycle). The sleeves 16 can include known cooling channels for managing the temperature of the mixture. A mode of realization of the cooling

channels is represented in Figures 4 and 5 by the channels 17, but it is understood that equivalent configurations can be substituted therefor.

The machine 10 can include an optional conveyor known to the skilled person (for example, the belt 26 shown in Figure 2) for use in introducing
5 components through the introduction hopper 24. These components can be all types of components necessary for the manufacture of rubber products.

Referring further to Figures 1 to 5, at least one movable door 28 is provided at the outlet 25 of sleeves 16 that closes the outlet during the mixing cycle (see Figures 3 and 4). The movable door 28 is opened at the end of the mixing cycle
10 (see Figure 5) in order to allow the rubber mixture to be evacuated and shaped. As used here, the terms "movable door" and "movable doors" are interchangeable.

In an embodiment of the machine 10 shown in Figures 3 to 5, the two screws 18 are mounted in the mixer 12 so that the thread tips of each screw contact tangentially the surfaces of the opposite screw. In other words, the screws are in
15 substantial contact with each other at an angle and at a center distance that facilitates self-cleaning. The screws are said to be "substantially in contact" when the screws can be cleaned by friction, or when the two screws face each other with such a small gap between them that an extruded material cannot remain attached to the surfaces of the screws. The screws are said to rub against each other, or to be
20 "self-cleaning", when the materials transported in the channel of one of the screws cannot remain in that channel for more than one revolution of the screw. As a result, the material undergoes much more movement in the downstream direction, parallel to the screw axis, than in a lateral direction, perpendicular to the axis.

The two screws 18 are assembled in the mixer 12 with the axes of the two
25 screws in the same plane and with the tops of the threads inscribed in a predefined cone in which an acute angle σ is predefined. The axes are separated by an acute angle α that will leave very little clearance between the surfaces of the screws 18 and between the thread tips of the screws and the sleeves 16 of the machine 10. The clearance will depend on the size of the machine 10 but will not exceed a few
30 millimeters. During the rotation of the screws 18, the thread tips of each screw, being substantially in contact during the duration of the mixing cycle, remain in tangential contact with the surfaces of the flanks of the opposite screw. Thus, no product can remain stuck on a screw surface without being pushed by a rotating screw thread.

In this embodiment of the screws 18, the screws are chosen from interpenetrated and conjugated profiles, and particularly from interpenetrating co-rotating profiles with conjugated profiles (which are known for their self-cleaning nature). Different screw profiles are known to be self-cleaning when the screws are
5 used in twin-screw mixers. With respect to the direction of rotation, the screws are said to be co-rotating if they rotate in the same direction and counter-rotating if they rotate in opposite directions from one another. With respect to interpenetration, the screws are said to be interpenetrated when the thread of one screw penetrates more or less deeply into the channel of the neighboring screw (the
10 screw being either partially or fully interpenetrated). Otherwise, the screws are said to be non-interpenetrated or tangent. It is understood that the flow conditions are implicated by conjugated or non-conjugated profiles, parallel or conical screws, single-threaded or multi-threaded profiles, and modular or non-modular screws.

The contour of an inner surface 16a of the sleeves 16 is predefined, which
15 allows the determination of a distance between each thread and the inner surface of a corresponding sheath, and thus the shear rate on the inner surface of the sleeves. Similarly, the thread tips of the screws contact tangentially the inner surfaces of the sleeves, preventing any retention of mixing material on these surfaces.

Referring further to Figures 6 and 7, another embodiment of the machine
20 10 includes the two screws 18 and a ram 30 that moves inside the introduction hopper 24. The ram 30 is similar to the rams used in mixing processes performed by Banbury type internal mixers.

As with internal mixers, the ram 30 presses the mixture and thus allows the transmission of more energy and shear to the mixture (see, for example, US Patent
25 7,404,664 cited above). An inner surface 30a of the ram 30 has a shape that is complementary to an outer contour of the two screws 18. Guidance of the ram 30 is effected between a raised position (shown in Figure 2), where the two screws 18 remain accessible to introduce the mixture, and a lowered position (see Figure 7), where the inner surface 30a of the ram 30 forms an upper part of the mixer 12. The
30 guidance of the ram 30 is done by sliding systems as known on Banbury rams (animated, for example, by cylinders that can be pneumatic, hydraulic or their equivalents). Thus, in its lowered position, the ram 30 leaves only a very small clearance between the thread tips of the screws 18 and its inner surface 30a. In this position, there are no more internal surfaces that are not "cleaned" by the

movements of the screws. In addition, there are no more dead zones in the machine 10. When the movable door 28 opens to discharge the mixture, no product retention is possible, and the entire mixture will be evacuated by the movement of the screws 18.

5 Referring again to Figure 7 (the two screws being shown in schematic form), the ram 30 presses the mixture, allowing the transmission of more energy and shear to the mixture. The ram 30 also serves to clean the surfaces of the hopper 24 during its downward movement, removing the pieces of rubber that could stick to it. At the same time, the ram 30 also serves to improve the ingestion of the
10 mixture when it arrives as a "masterbatch" from an upstream machine (the qualities of a "masterbatch" are described below). The ram 30 forces the mixture to pass quickly between the screws 18 and thus prevent it from remaining in block form above the screws.

Referring further to Figure 8 (wherein the same numerals identify the same
15 elements), an embodiment of the machine 10 may include a roller nose system. A roller nose type system includes two counter-rotating rollers 32 disposed just downstream of the outlet 25 to form a sheet of the mixture discharged from the mixer 12 (the rollers 32 are also shown in Figure 1). The roller nose type system may also include optional control means (not shown) for controlling the feed rate
20 of the mixture to the rollers. The rotation of the rollers 32 is controlled by the amount of the mixture discharged by the mixer 12 (detected, for example, by a proximity sensor, by a pressure sensor or by an equivalent device).

Referring to the embodiments of the machine shown heretofore, the screws 18 are selected from interpenetrated and conjugate profiles, and particularly from
25 interpenetrating co-rotative profiles with conjugate profiles (which are known for their self-cleaning nature). It is understood that there are several embodiments of the screws 18, including without limitation, of type one, two or three threads, or double-threaded conjugate type. The screws can be selected from screws with one thread or from screws with two, three or four threads. The interpenetrating contra-
30 rotative profiles are also known for their assembly and their use in the mixer 12. The invention applies these types of screws and their equivalents to the mixer 12 of the machine 10 according to the chosen rubber mixture recipe and its desired properties.

Referring again to Figures 1 to 8, and also to Figure 9, another embodiment

of the machine 10 associates the benefits of the screws 18, the ram 30 and the counter-rotating rollers 32 with one or more mobile sleeves such as the mobile sleeves 34 shown in Figures 8 and 9. The mobile sleeves 34 are arranged top-down towards the outlet 25. It is understood that other embodiments of the mobile sleeves can be used (for example, left-right and angled modes). The mobile sleeves 34 include mobile elements for adjusting a predetermined space between the sleeves 16 and the screws 18. Each mobile sleeve has a support surface 34a with a predetermined surface area according to an elasticity of the mixture. It is understood that the mobile sleeves having support surfaces with different surface may be interchangeable to ensure the use of the machine without having to replace it.

The embodiment shown has two mobile sleeves 34, but it is understood that only one mobile sleeve (or another equivalent element) or several mobile sleeves (or other equivalent elements) can be integrated (for example, into top-bottom mode, left-right mode, or angled mode). The mobile sleeves 34 adjust the space between the sleeves and the screws to promote the flow of the mixture inside the mixer 12, thus adjusting the duration and degree of mixing of the mixture.

Referring again to Figures 8 and 9, the two screws 18 circulate the mixture from an upstream side (next to the introduction hopper 24) to a downstream side where the mobile sleeves 34 of the machine 10 are installed. The mobile sleeves 34 are installed relative to the outlet 25 of the mixer 12 so that, in an open position, they allow the flow of the mixture to the rollers 32 of the roller nose type system. The mobile sleeves can move alternately or randomly to reduce the space between the screws and the bearing surface in a random manner, thus creating downstream-upstream flow of the mixture and preferably above or below). For example, in one way of using the machine 10, the mobile sleeves 34 are mostly in the open position at the beginning of the mixing cycle when the mixture has a high viscosity (to promote the flow of mixture), and they are mostly in the closed position at the end of the mixing cycle when the mixture has a lower viscosity (to promote mixing). Guidance of the mobile sleeves 34 is effected by known systems (animated, for example, by cylinders that can be pneumatic, hydraulic or their equivalents). The linear movement of the moving sleeves 34 is controlled by the amount of the mixture discharged by the mixer 12 (detected, for example, by a proximity sensor, by a pressure sensor or by an equivalent device).

Referring further to Figures 10 to 13, these figures show embodiments of the mixer 12, these being self-cleaning contra-rotating twin-screw embodiments. For each embodiment, the screws are mounted in the sleeves 16' with a movable outlet door 28' that follows the shape of the screws. In Figures 10 and 11, the two screws 18' are symmetrical in order to remove the dead zones in the machine 10 during the mixing cycle. Figure 11 particularly shows the minimal gaps left between the threads of the screws 18', which remain substantially in contact. In Figure 12, the two screws 18'' are asymmetrical in order to liberate larger spaces that will promote the flow of mixture. For each embodiment, the sleeves 16' may include known cooling channels (represented by the channels 17') for managing the temperature of the mixture.

It is understood that these embodiments of the screws are likely to be incorporated into different embodiments of the machine 10. For example, Figure 13 shows an embodiment of the machine 10 in which the symmetrical screws 18' are used together with the rollers 32 and the mobile sleeves 34 (the mobile sleeves being in a partially closed state with a mobile sleeve 34_f remaining in a closed position and the other mobile sleeve 34_o taking an open position). It is understood that the asymmetrical screws 18'' may be substituted by the symmetrical screws 18' depending on the recipe of the selected mixture without changing the operation of the machine 10.

In this embodiment of the machine 10, the movable doors can be sliding shutters 40 as shown in Figure 14. The sliding shutters 40 are interposed between the rollers 32 and a front face of the mobile sleeves 34 of the machine 10. The sliding shutters 40 include movable elements for regulating the flow of the mixture exiting the mixer 12. The sliding shutters 40 are installed relative to the outlet 25 of the mixer 12 so that, in a closed position (not shown), they prevent the discharge of the mixture from the mixer 12 (for example, to promote mixing when the mixture has a lower viscosity). In an open position (shown in Figure 14), the sliding shutters serve as "ears" to the rollers 32 that prevent the mixture from escaping through the sides of the rollers 32. Thus, the mixture is forced to pass between the two rollers and will be calendered in the form of a thin sheet of a predefined width by the opening of the sliding shutters.

Referring again to Figures 14 to 16, a detailed description is given by way of example of a cycle of a mixing process of the invention. It is understood that the

process can easily be adapted for all embodiments of the machine 10.

In launching a cycle of the mixing process of the invention, the mixing process includes a step of rotating the screws 18 in the forward direction (see arrow A of Figure 15) with the movable doors 28 closed. During this step, the
5 rotating screws cause the product to move downstream of the mixer as soon as the mixture (or raw materials) is introduced into the machine 10. In all embodiments of the machine 10, the speed of rotation can be variable during the cycle. When the screws 18 are interpenetrated, the speed of rotation of the two screws is synchronized.

10 The mixing process includes a step of introducing a mixture M into the machine 10 (shown by the arrow B of FIG. 15 as being conveyed by the belt 26). During this step, the screws 18 continue to rotate and the movable doors 28 remain closed. In the embodiments of the machine 10 having a ram 30, the ram remains in its raised position during this step. In the embodiments of the machine 10 also
15 having the rollers 32, the rollers remain on standby during this step. In the embodiments of the machine 10 further having the mobile sleeves 34, the mobile sleeves remain in their open position (i.e., with maximum space between the sleeves and the screws) during this step.

During the step of introducing the mixture into the machine 10, the cycle of
20 the mixing process can be started by introducing, into the empty machine, the different raw materials necessary for producing the product, including, without limitation, a material elastomer (for example, a natural rubber, a synthetic elastomer and combinations and equivalents thereof) and one or more ingredients, such as one or more processing agents, protecting agents and reinforcing fillers.
25 The raw materials may also include one or more other ingredients such as carbon black, silica, oils, resins, and crosslinking or vulcanizing agents. All ingredients are introduced in varying amounts depending on the desired performance of the products obtained from the mixing processes (for example, tires).

The mixing cycle can also be done by starting the cycle with a product
30 already mixed but not containing all the ingredients of the recipe (called "masterbatch"). For example, resins and vulcanizing agents are not present in the masterbatch. These ingredients, which make mixing difficult (especially for stickiness or decohesion problems), can be added to the mixer 12 to complete the mixing. In this case, either the masterbatch is recovered hot from an upstream

mixer (such as an internal mixer or an external mixer), or the masterbatch is cold because it was manufactured and conditioned several hours or several days beforehand.

During the step of introducing the mixture into the machine 10, the belt 26 (or other equivalent means) serves to successively introduce the raw materials and other necessary ingredients according to a predetermined recipe. In one embodiment, elastomeric material is introduced into the machine 10, followed by the introduction of reinforcing fillers such as carbon black or silica, oils, resins and vulcanizing agents.

In the embodiments of the machine 10 having a ram 30, the mixing process includes a step of lowering the ram that is carried out after the step of introducing the mixture M into the machine 10 (see arrow C of FIG. 15). The screws 18 continue to rotate during this step. In the embodiments of the machine 10 also having the rollers 32, the rollers remain on standby during this step.

In the embodiments of the machine 10 further having the mobile sleeves 34, the mixing process includes a step of partially closing the mobile sleeves 34 (either the two mobile elements simultaneously or the two mobile elements alternately) (see the arrows D of Figure 15). The partial closing of the mobile sleeves may refer to their reciprocating movement (see the example shown in Figure 13) or to their simultaneous movement. During this step, the screws continue to turn, and the ram stays lowered.

In the embodiments of the machine 10 having the ram 30, the mixing process includes a step of raising the ram (see arrow E of Figure 16). In the embodiments of the machine 10 having the rollers 32, the two rollers remain on standby during this step. In embodiments of the machine 10 further having the mobile sleeves 34, the mobile sleeves are in a partially closed position during this step. For each embodiment of the machine 10, the screws continue to rotate during this step.

The mixing process includes a step of reversing the rotation of the screws 18 (see arrow F of Figure 16) with the movable doors 28 closed. During this step, the screws rotate in the opposite direction with respect to the step of rotating the screws in the forward direction. The entire mixture located in the machine 10 has a downstream-upstream movement that will cause additional distribution of raw materials. In the embodiments of the machine 10 having the ram, the ram remains

raised during this step. In the embodiments of the machine 10 having the rollers 32, the two rollers remain on standby during this step. In the embodiments of the machine 10 further having the mobile sleeves 34, the mobile sleeves remain partially closed during this step.

5 The mixing process further includes a step of rotating the screws forward (as represented by the arrow A of Figure 15) with the movable doors 28 closed. During this step, the screws turn in the opposite direction with respect to the step of rotating the screws in reverse. In the embodiments of the machine 10 having the ram 30, the ram remains raised during this step. In the embodiments of the machine 10 having the rollers 32, the two rollers remain on standby during this step. In the embodiments of the machine 10 further having the mobile sleeves 34, the mobile sleeves remain partially closed during this step.

 In the embodiments of the machine 10 having a ram 30, the mixing process includes a step of lowering the ram (as represented by the arrow C of Figure 15) carried out after the preceding step of rotating the screws 18 forward. The screws continue to rotate during this step. In the embodiments of the machine 10 also having the rollers 32, the rollers remain on standby during this step. In the embodiments of the machine 10 further having the mobile sleeves 34, the mobile sleeves remain partially closed during this step.

20 In the embodiments of the machine 10 further having the mobile sleeves 34, the mixing process includes a step of completely closing the sleeves, thus eliminating the space between the sleeves 16 and the screws 18 (see the arrows G of the Figure 17). This step includes either the simultaneous closing or the alternating closing of the two mobile elements. During this step, the ram 30 is again raised (as represented by the arrow E of Figure 16). During this step, the screws 18 continue to rotate and the rollers 32 remain on standby.

 The mixing process includes a final step of emptying the machine 10. During this step, the movable doors 28 open to discharge the mixture from the machine outlet 25 toward a downstream process (see Figure 5 that shows the mixer 12 with the movable door 28 open). In the embodiments of the machine 10 where the movable doors include two or more movable elements, this step includes either the simultaneous opening or the alternative opening of the movable elements. In the embodiments of the machine 10 having the ram 30, the ram is lowered during this step. In the embodiments of the machine 10 also having the rollers 32, this step

further includes the step of rotating the rollers (see arrows H of Figure 17) to allow the mixture to be discharged in the form of sheets. In the embodiments of the machine 10 further including the mobile sleeves 34, the mobile sleeves remain completely closed, but they can be adjusted according to a volume of the mixture exiting the mixer. In each embodiment of the machine 10, the screws 18 continue to rotate during this step in order to completely empty the machine 10.

At the end of the mixing cycle, the product is finished mixing and can be used in a downstream process (which may be, for example, a palletizing process, a shaping process, and/or another mixing process and/or extrusion process). After the end of the step of emptying the machine 10, the cycle of the mixing process can restart. It is understood that certain stages of the cycle, as well as the cycle itself, can be performed in an iterative manner depending on the chosen mixing recipe. Owing to the self-cleaning performed by the screws 18, all types of mixtures, including sticky mixtures and cohesive mixtures, are thus completely removed from the machine.

It is contemplated that the machine 10 may perform one or more processes relating to the plasticization of natural elastomers.

A cycle of the mixing process of the invention may be realized by PLC control and may include pre-programming of the control information. For example, a process control may be associated with the mixture that is provided to the mixer 12, including the properties of the screws 18, the properties of the mixture entering the hopper 24, and the properties of the mixture discharged from the mixer.

For all embodiments, a monitoring system may be put in place. At least a portion of the monitoring system may be provided in a portable device such as a mobile network device (for example, a mobile phone, a laptop, a portable device or devices connected to the network, including "augmented reality" and/or "virtual reality" devices, portable clothing connected to the network and/or any combination and/or all equivalents thereof).

In some embodiments of the invention, the machine 10 (and/or a system that incorporates the machine 10) may receive voice commands or other audio data representing, for example, a start or stop of rotation of the screws 18. The request may include a request for the current state of a mixing process cycle. A generated response can be represented in an audible, visual, tactile (for example, using a haptic interface) and/or virtual or augmented manner.

In an embodiment, the process can include a step of training the machine 10 (or a system that incorporates the machine 10) to recognize values representative of the mixture exiting the mixer 12 (for example, temperature and viscosity values) and to make a comparison with target values. This step can include the step of
5 training the machine to recognize non-equivalence between the compared values. Each step of the training can include a classification generated by self-learning means. This classification may include, without limitation, the parameters of the raw materials and masterbatches of the chosen mixing recipe, the configurations of the self-cleaning screws, the duration of the mixing cycles and the values expected
10 at the end of a mixing cycle in progress (for example, the value of the space between the sleeves and the screws during the current mixing cycle when the sleeves are partially closed, etc.).

The machine 10 is suitable for processing a variety of rubber mixtures, including sticky mixtures and de-cohesive blends, without decreasing industrial
15 productivity.

The term "de-cohesive" refers to a mixture that, in an industrial use of a shaping process, has a raw strength that is less than the forces of forced elongations. This has the consequence of tearing the material and generating industrial difficulties (for example, loss of material, lower mixing efficiency, and
20 irregular supply of the machines following sheet tearing). Factors that influence the de-cohesion level include, without limitation, the characteristic of the polymer (for example, chemistry (SBR, IR, BR, NR), functionalization, macrostructure and microstructure), the characteristic of the mixture (for example, the volume fraction of filler and plasticizer and the rate of implementing agents), and the existence of a
25 balance between the adhesion of the mixture to the tools of implementation and their energy of internal cohesion.

The term "sticky" defines a property of a rubber blend that varies according to the formulations of the mixtures. Below are described the formulation parameters influencing the stickiness of mixtures on industrial processes.

30

EXAMPLE

In considering the level of stickiness of the mixtures in the manufacturing plants, the properties of a composition of the mixtures influence this level, in particular:

- The ratio of the reinforcing filler content and the plasticizer ratio, this ratio indicating a stickier mixture as a function of lowering the ratio.

- The ratio of resin in the mixture, this ratio indicating a stickier mixture as a function of ratio increase.

- 5 • The volume fraction of elastomer that indicates a stickier mixture as a function of lowering volume fraction.

The characteristic of the elastomer that can be included in the stickiness component of the mixtures is also considered. In this example, a Mooney ML1 + 4 100°C of dry elastomer < 50 points, or the presence of isoprene is considered. Mooney, also known as viscosity or plasticity, characterizes, in a known manner, solid substances. An oscillatory consistometer as described in ASTM standard D1646 (1999) is used. This measurement of plasticity is carried out according to the following principle: the sample analyzed in the raw state (i.e., before curing) is 15 molded (formed) in a cylindrical chamber heated to a given temperature (for example 35°C or 100° C). After one minute of preheating, the rotor rotates within the specimen at 2 rpm and the torque needed to maintain this movement is measured for 4 minutes of rotation. The Mooney viscosity (ML 1 + 4) is expressed in "Mooney unit" (with 1UM = 0.83 Nm) and corresponds to the value obtained at 20 the end of the 4 minutes

A very sticky mixture is not necessarily an "extreme" mixture on one of the criteria, but it is the combination of all the criteria that gives its stickiness and therefore its difficulty of realization. By multiplying these criteria, a "stickiness index" is thus found and represented by the table below:

25

1 – Ratio Carbon black/Plastifier											
Carbon black/Plastifier index	150.38	140.30	130.23	120.15	110.08	100.00	89.92	79.85	69.77	59.70	49.62
Severity value	1	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
2 – Resin Presence											
Tackifying resin index	0.00	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00
Severity value	1	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
3 – Mixture cohesion											
Volume fraction of elastomer index	143	134	126	117	109	100	91	83	74	66	57
Severity value	1	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00

TABLE 1

In an empirical way and according to various criteria of industrial feasibility, a balance is made of the industrial feasibility of several mixtures. The feasibility limit is established for stickiness indexes above 3.5 and 4.5 points.

Examples of mixtures :

5

	Sticky KM	Sticky KM blend	Non-sticky KM
1 – Ratio Carbon black/Plastifier			
Carbon black/Plastifier index	94.7	75.2	117.3
Severity value	1.55	1.75	1.33
2 – Resin presence			
Tackifying resin index	132.0	112.0	20.0
Severity value	1.66	1.56	1.10
3 – Mixture cohesion			
Volume fraction of elastomer index	67.2	85.4	99.4
Severity value	1.88	1.67	1.50
Stickiness index	4.9	4.5	2.2

TABLE 2

The two "Sticky KM" and "Sticky KM blend" mixtures, with respective indices 4.9 and 4.5, are not considered to have satisfactory industrial feasibility. However, the machine of the invention allows these mixtures to be produced industrially with a higher productivity compared to conventional machines of the internal mixer or external mixer type.

In order to obtain the mixtures with the desired properties in shorter cycles, the invention preserves all the advantages of a convergent conical two-screw mixer. At the same time, the invention combines the solutions of self-cleaning screws, rams and roller nose systems. In addition, the invention combines these solutions with mobile sleeve solutions. Thus, only one machine is provided that can process a variety of mixtures, including sticky and de-cohesive mixtures, without changing equipment in a mixing plant.

The terms "at least one" and "one or more" are used interchangeably. The ranges that are presented as "between a and b" include the values "a" and "b".

Although particular embodiments of the disclosed apparatus have been illustrated and described, it will be appreciated that various changes, additions and modifications can be made without departing from the spirit and scope of this disclosure. Therefore, no limitation should be imposed on the scope of the

5 invention described except those set forth in the appended claim

CLAIMS

1. A mixing and extruding machine (10) for the manufacture of rubber mixtures, the machine (10) comprising a convergent conical twin-screw mixer (12) with a fixed frame (14) that supports sleeves (16, 16') in which two screws (18) are inclinedly mounted between an opening (22) disposed upstream of the sleeves, where an introduction hopper (24) of the machine 10 feeds the screws, and an outlet (25) disposed downstream of the sleeves, where the mixer (12) discharges the mixture at the end of a mixing cycle, one or more motors (20) rotating the two screws in the sleeves during the mixing cycle, and one or more movable doors (28, 28') provided at the outlet (25) that allow, during the mixing cycle, the evacuation and shaping of a rubber mixture, characterized in that:

the two screws (18) are mounted in the mixer (12) such that the thread tips of each screw tangentially contact surfaces of the opposite screw in order that the screws remain substantially in contact with each other when rotating the screws with an angle and a center distance that facilitates self-cleaning; and

the outline of an inner surface (16a, 16a') of the sleeves (16, 16') is predefined in order to determine a predetermined distance between each thread and the inner surface of a corresponding sleeve, the thread tips of the screws remaining in tangential contact with the inner surfaces of the sleeves and preventing the retention of mixture on these surfaces.

2. The machine (10) of claim 1, further comprising a ram (30) having an inner surface (30a) with a shape that is complementary to an outer contour of the two screws (18), the ram moving along the inside of the introduction hopper (24) between a raised position, where the two screws remain accessible to introduce the mixture, and a lowered position, where the inner surface (30a) of the ram forms an upper part of the mixer (12).

3. The machine (10) of claim 1 or claim 2, further comprising a roller nose type system comprising two counter-rotating rollers (32) disposed just downstream of the outlet (25) to form a sheet of the mixture exiting the mixer (12).

4. The machine (10) of claim 2 or claim 3, further comprising one or more mobile sleeves (34) that are arranged top-down toward the outlet (25), each mobile sleeve with a support surface (34a) having a predetermined surface area as a function of elasticity of the mixture, and the mobile sleeves (34) comprising
5 mobile elements that move in a linear movement relative to the outlet (25) in order to adjust a predetermined space between the sleeves and the screws, and the linear movement being defined between a closed position of the mobile sleeves to promote mixing, and an open position of the mobile sleeves so as to promote the flow of the mixture inside the mixer.

10

5. The machine (10) of any one of claims 1 to 4, wherein the screws (18) are selected from interpenetrated and conjugate profiles, including interpenetrated co-rotative profiles with conjugate profiles.

15

6. The machine (10) of claim 5, wherein the mixer (12) comprises an interpenetrating contra-rotating twin-screw type mixer, with screws (18) mounted in the sleeves (16) with a movable door (28') at the end that comes to marry the shape of the screws.

20

7. The machine (10) of claim 6, wherein the screws (18) are symmetrical.

8. The machine (10) of claim 6, wherein the screws (18) are asymmetrical.

25

9. The machine (10) of any one of claims 1 to 8, wherein the sleeves (16) comprise cooling channels for controlling the temperature of the mixture during the mixing cycle.

30

10. The machine (10) of any one of claims 3 to 9, wherein the movable door comprises one or more sliding shutters (40) installed relative to the outlet (25) so that the sliding shutters move linearly between a closed position, in which the sliding shutters prevent the mixer (12) from discharging the mixture, and an open position, in which the sliding shutters serve to prevent the mixture from escaping

from the sides of the counter-rotating rollers (32) in order to force the mixture to pass between the rollers.

11. A mixing process of the type comprising a step of mixing and
5 extruding a rubber mixture from the machine (10) of any one of claims 1 to 10, the method comprising the steps of:

a step of rotating the screws (18) forward with the movable doors (28, 28') closed;

a step of introducing the mixture to the machine (10), during which the
10 screws (18) continue to rotate and the movable doors (28, 28') remain closed; and

a step of emptying the machine (10), during which the movable doors open to discharge the mixture from the outlet (25) of the machine toward a downstream process and in which the screws continue to rotate until the mixer is empty.

12. The process of claim 11, wherein the step of introducing the mixture
15 to the machine (10) comprises introducing raw materials to form the mixture.

13. The process of claim 11, wherein the step of introducing the mixture
20 to the machine (10) comprises introducing one or more masterbatches.

14. The process of any one of claims 11 to 13, further comprising a step
of rotating the screws in reverse with the movable doors closed, during which the screws rotate in an opposite direction with respect to the step of rotating the screws forward.

15. The process of any one of claims 11 to 14, wherein:
the movable door (28, 28') is open at the end of the mixing cycle; and
the mobile sleeves are in the closed position at the end of the mixing
cycle.

30

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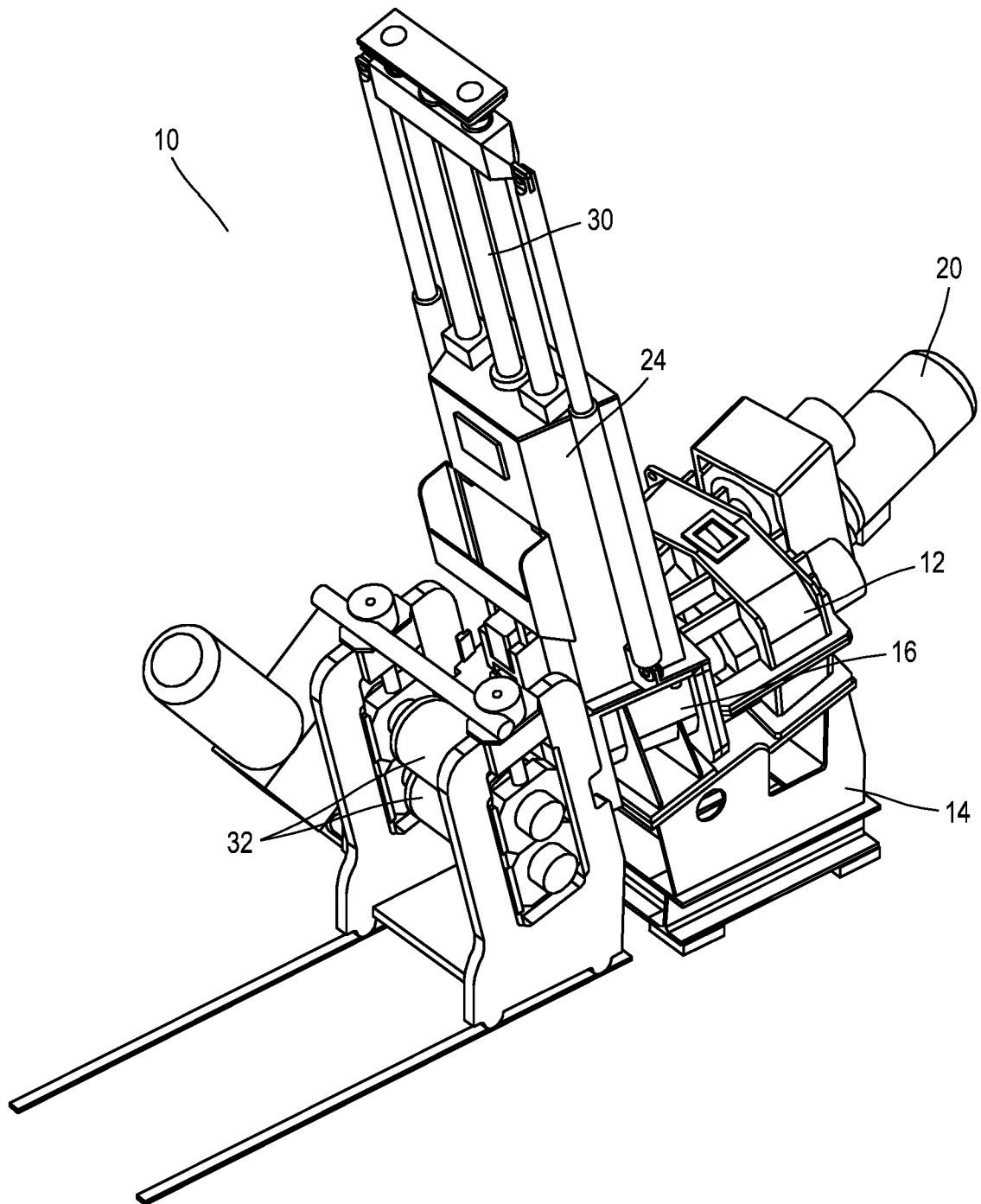


FIG. 1

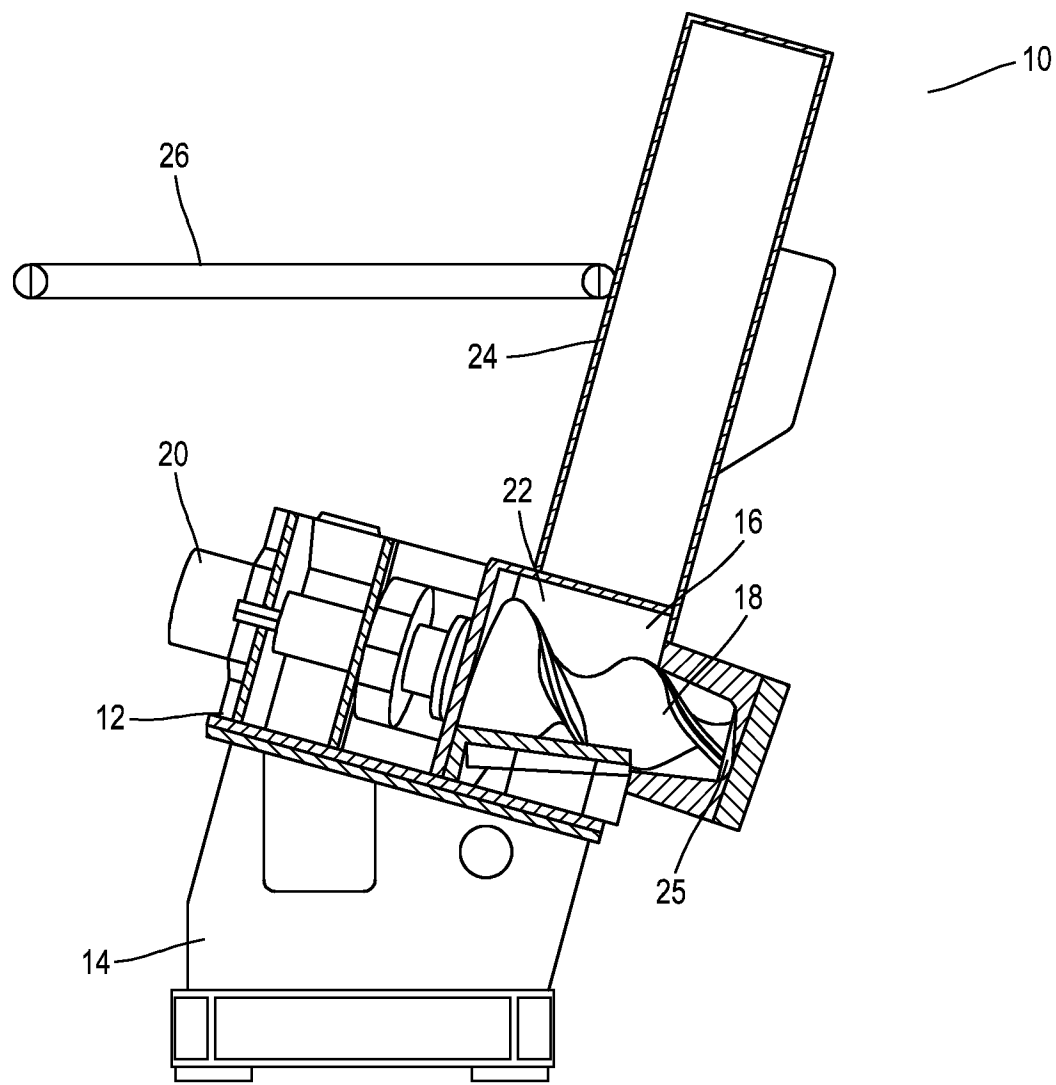


FIG. 2

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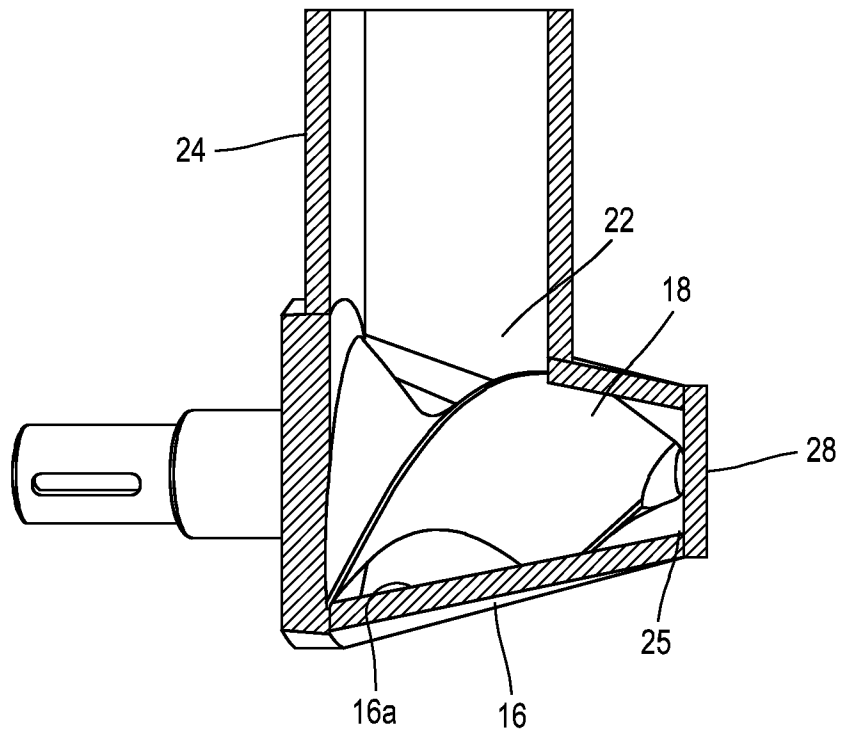


FIG. 3

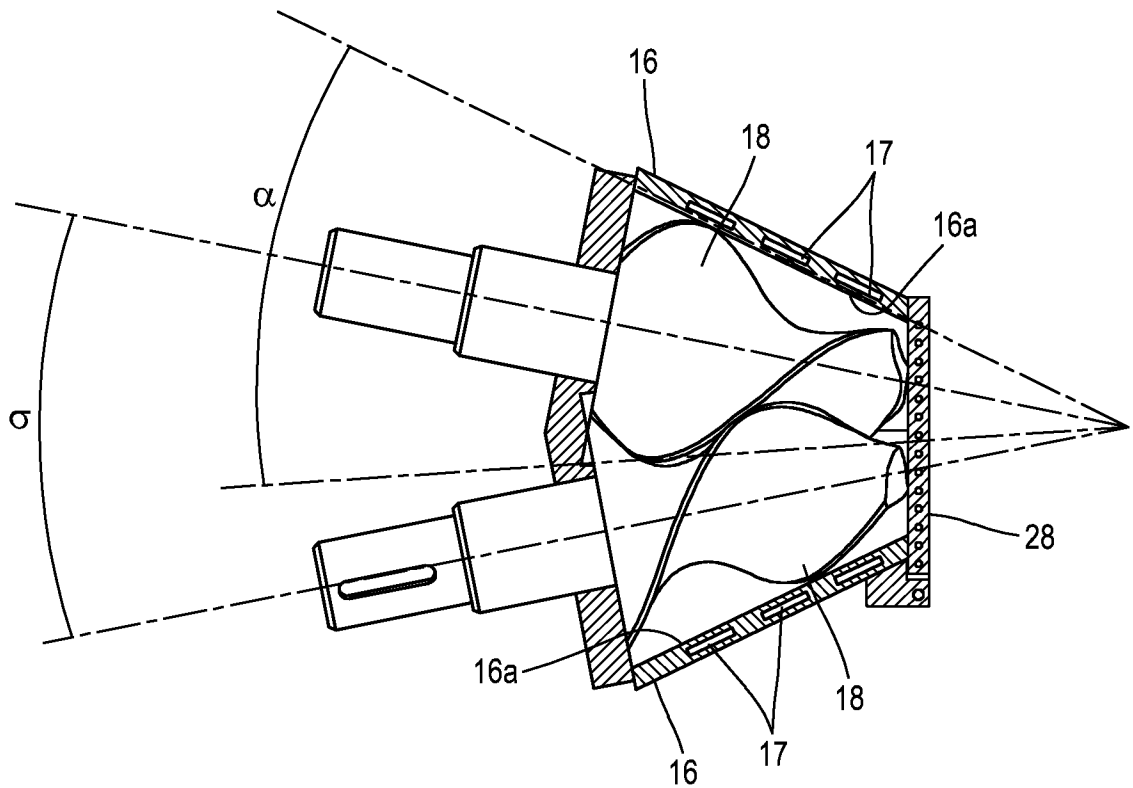


FIG. 4

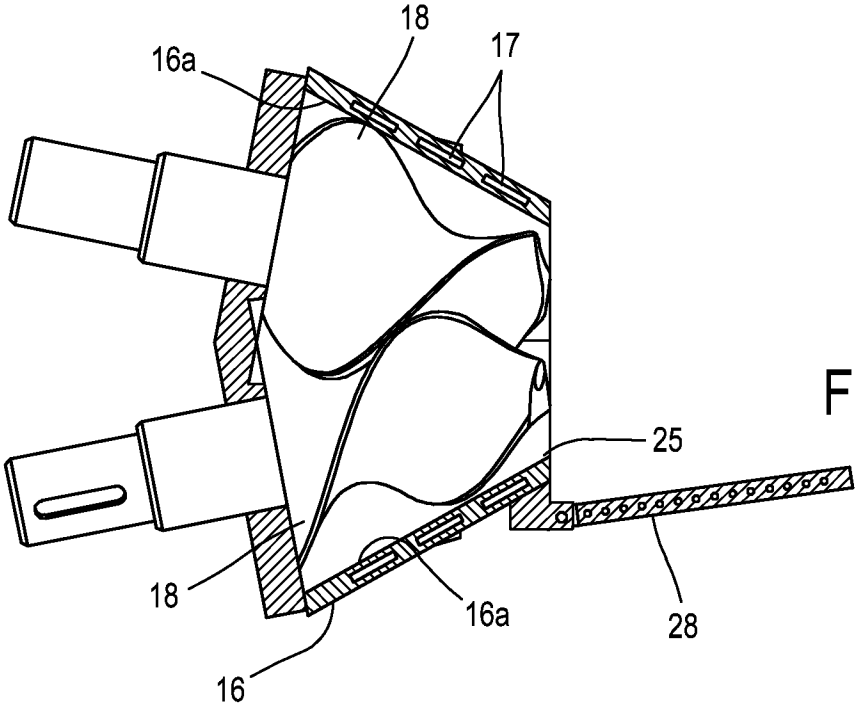
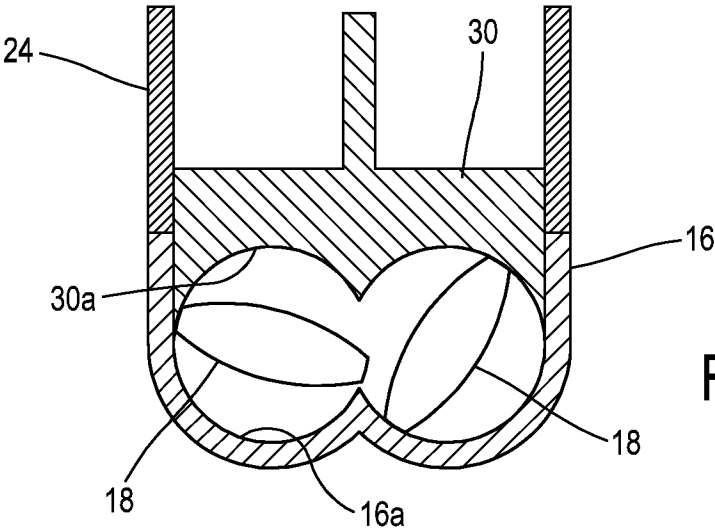
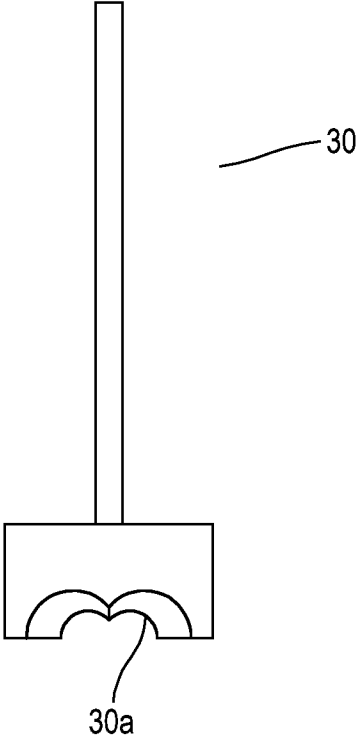


FIG. 6



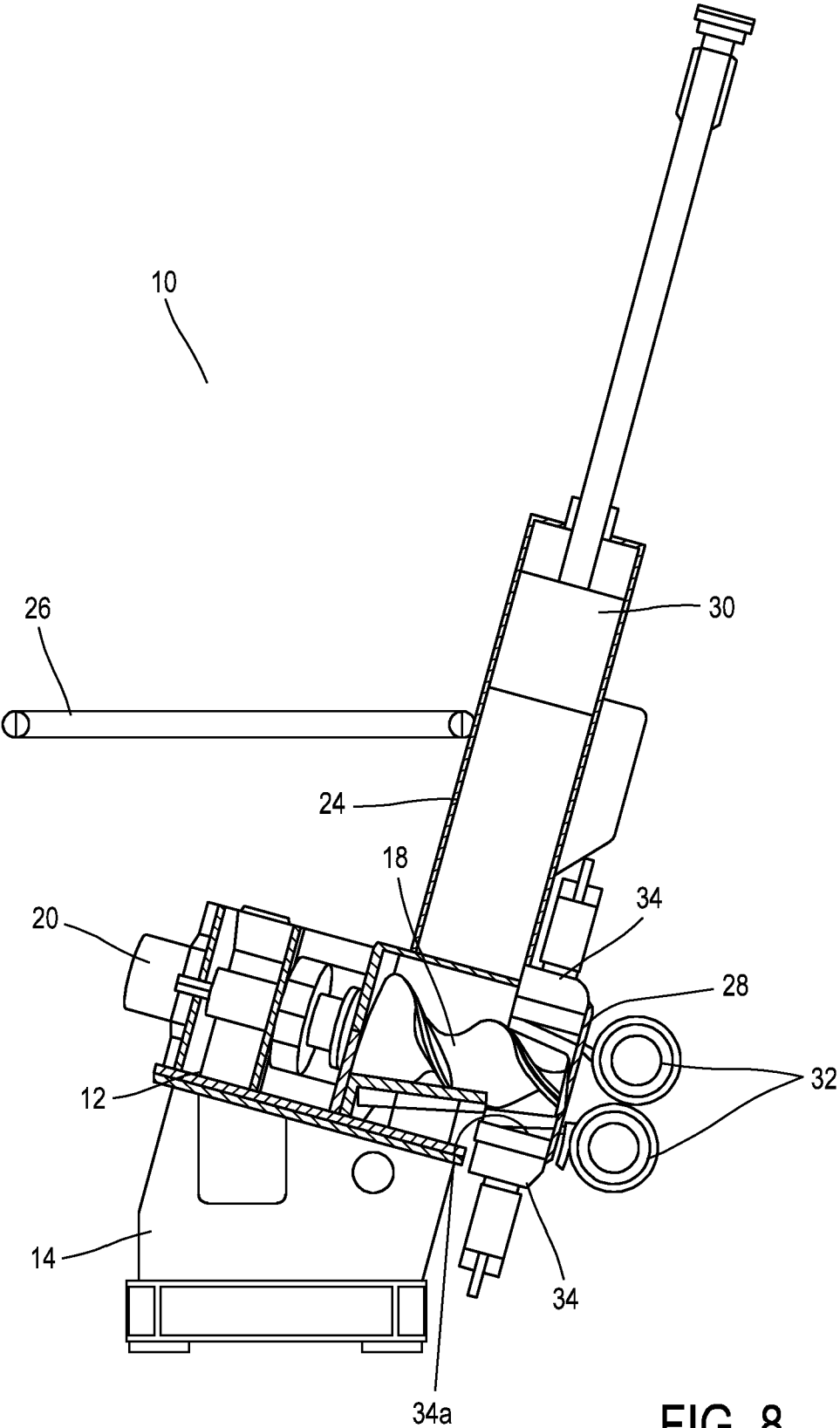


FIG. 8

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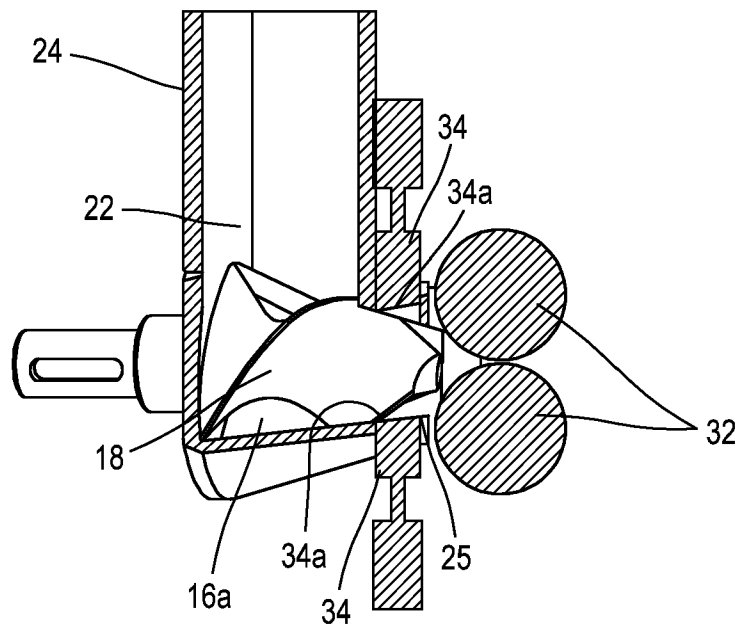


FIG. 9

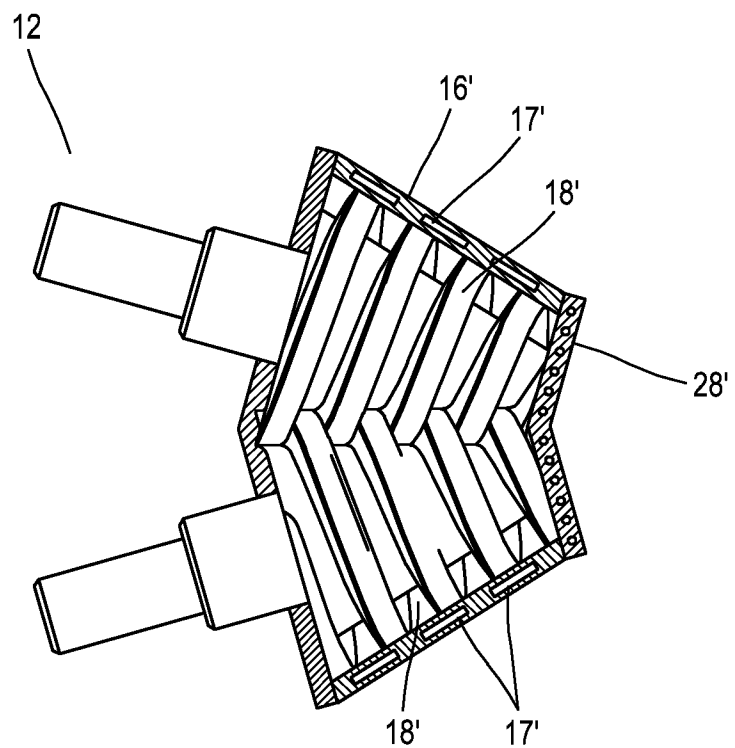


FIG. 10

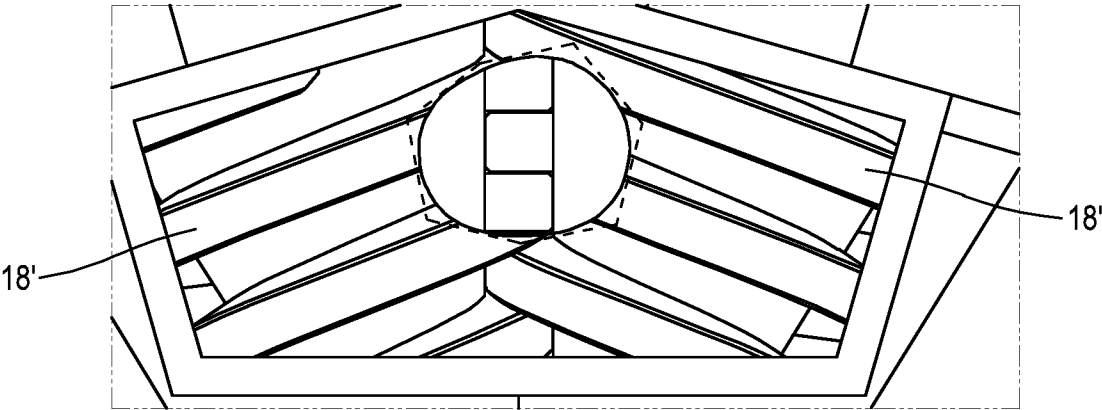


FIG. 11

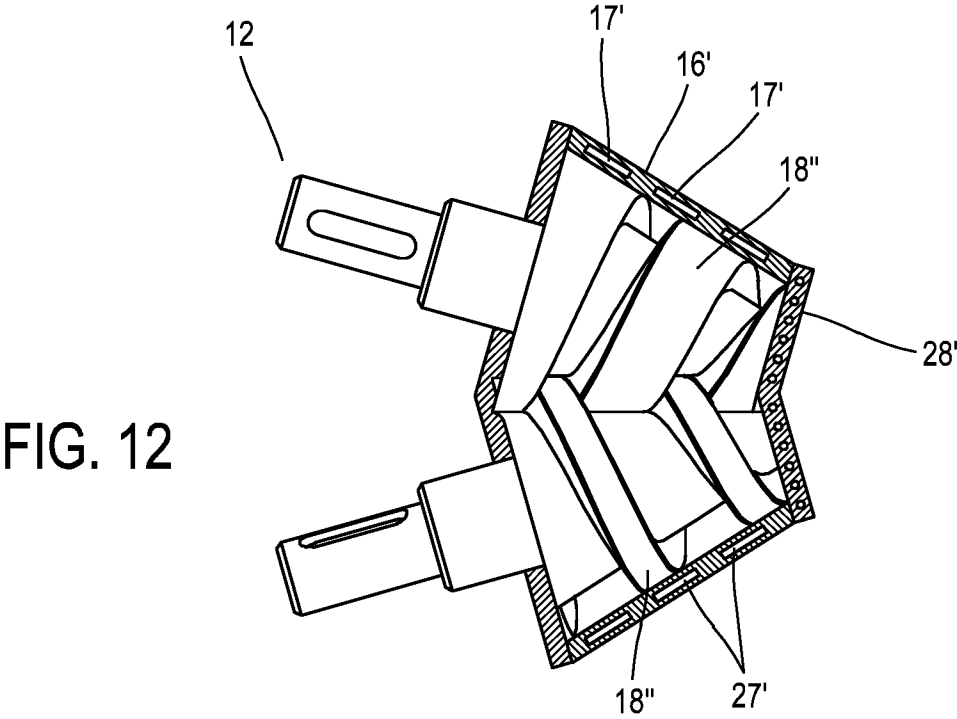


FIG. 12

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FIG. 13

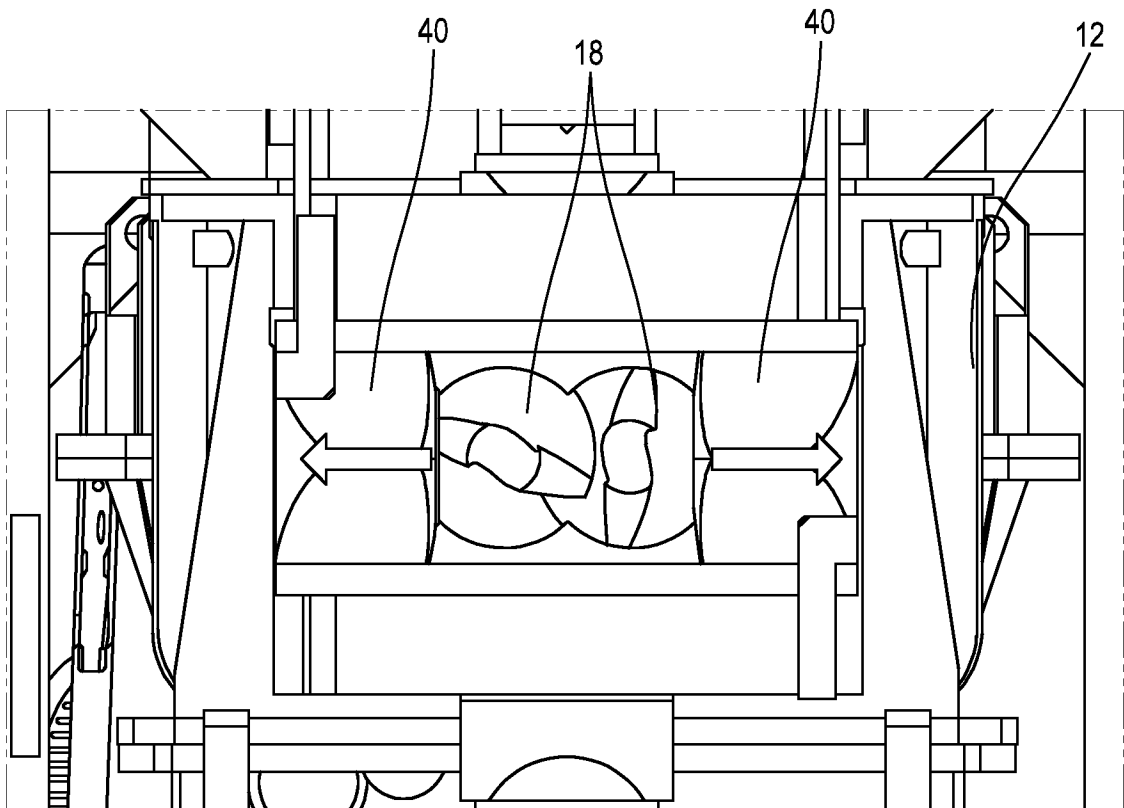
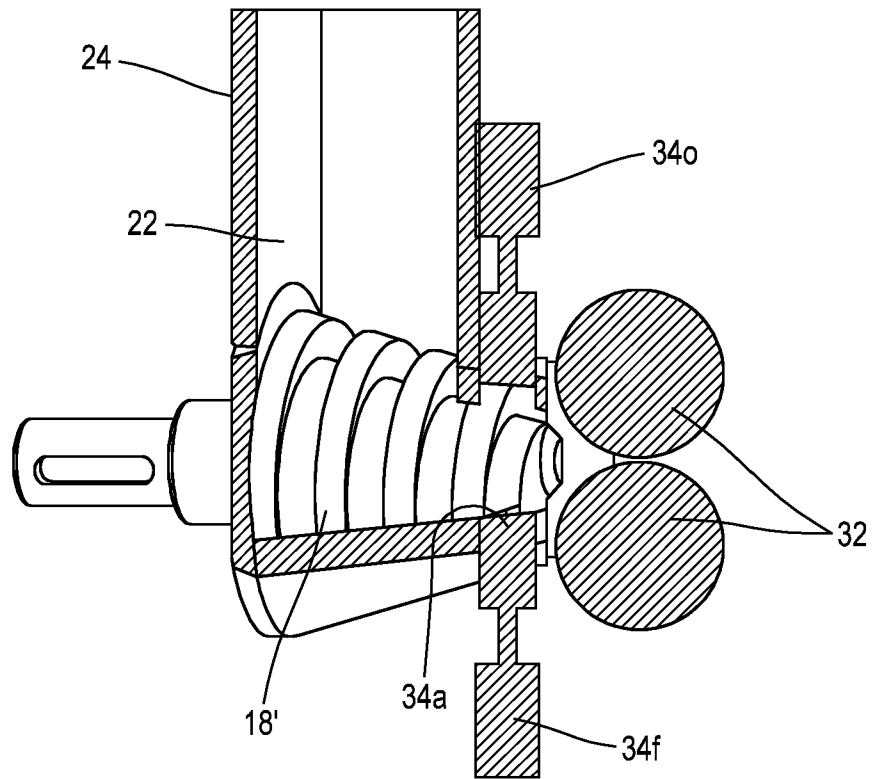


FIG. 14

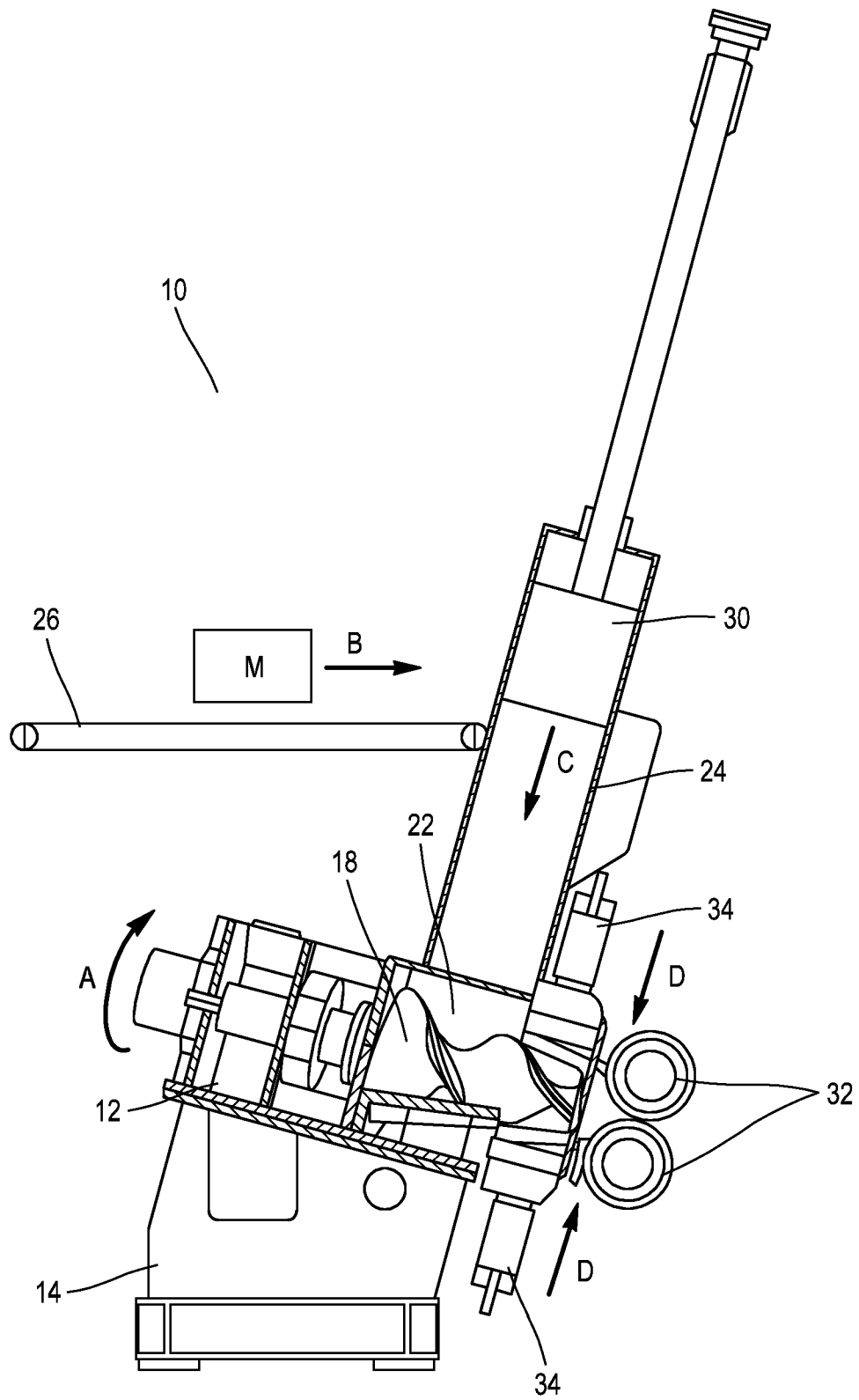
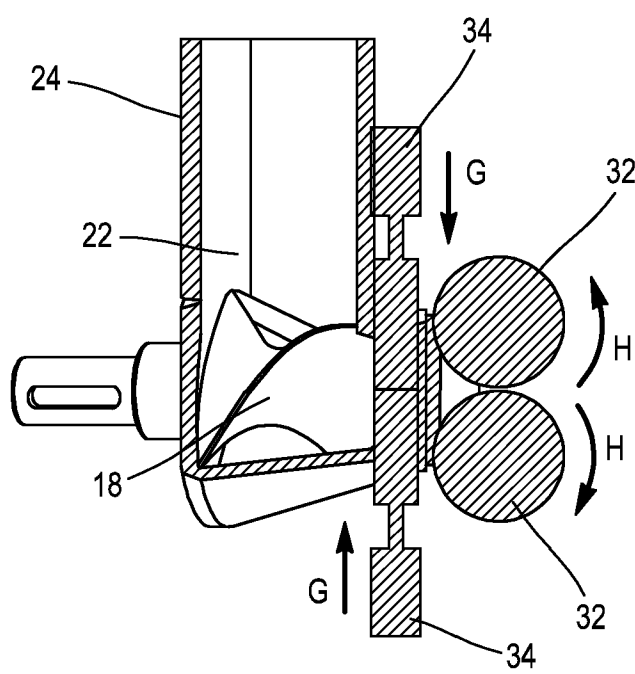
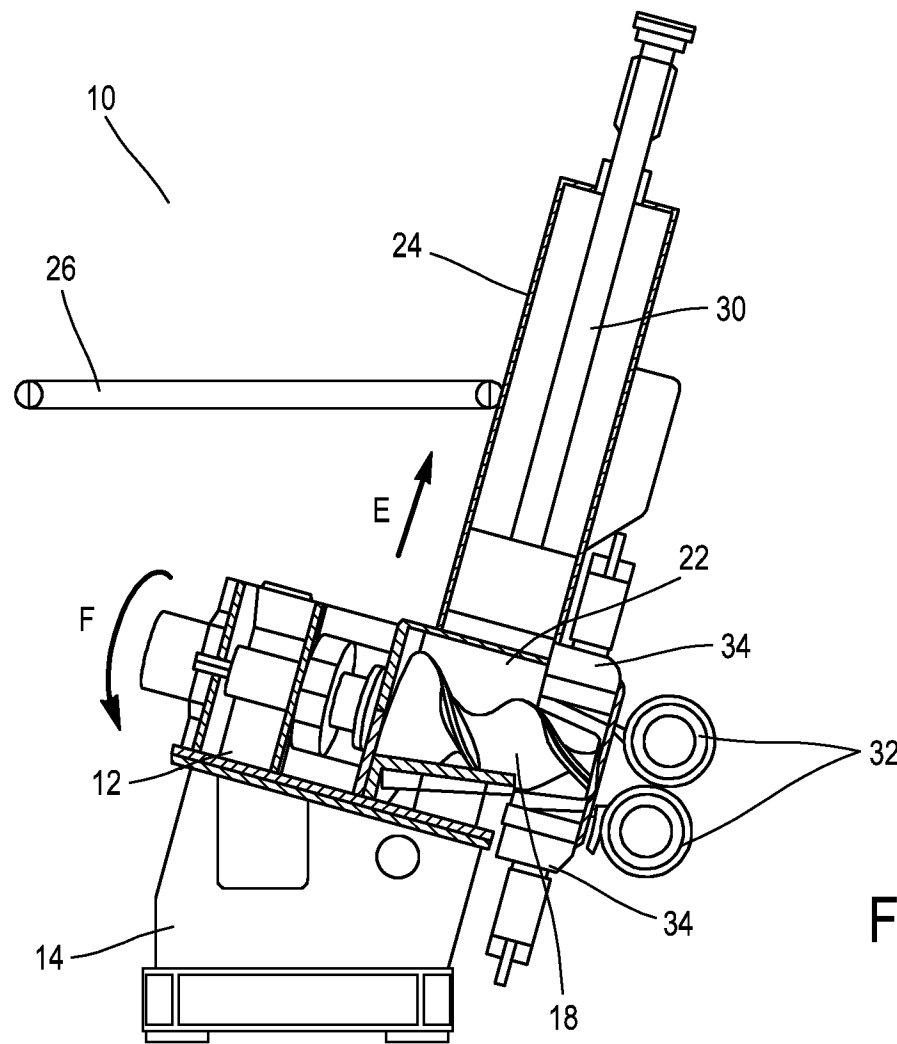


FIG. 15

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2020/054850

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29B7/20 B29B7/80 B29B7/26 B29B7/74 B29C48/395
 B29C48/40 B29C48/525
 ADD. B29B7/18 B29B7/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B29B B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 2019/162803 A1 (COLMEC S.P.A. [IT]) 29 August 2019 (2019-08-29) page 1, lines 5-9 page 1, line 20 - page 3, line 8 page 3, line 30 - page 4, line 31 page 5, line 19 - page 9, line 8 abstract; claims 1-9; figures 1-5 -----	1-15
X	EP 1 543 930 A2 (THYSSENKRUPP ELASTOMERTECHNIK [DE]) 22 June 2005 (2005-06-22) paragraphs [0001] - [0003], [0006] - [0010], [0013], [0020] - [0028] abstract; claims 1-17; figures 1-5 ----- -/-	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

3 April 2020

Date of mailing of the international search report

17/04/2020

Name and mailing address of the ISA/

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 Fax: (+31-70) 340-3016

Authorized officer

Brunold, Axel

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/054850

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Information on patent family members

International application No

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