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(54) **A PACKAGING APPARATUS FOR FORMING A PLURALITY OF SEALED PACKAGES FILLED WITH A POURABLE PRODUCT**

(57) A packaging machine (1) for forming a plurality of sealed packages (2) comprises: a conveying device (5), configured to advance a web (4) of packaging material; an isolation chamber (10); a tube forming device (13) configured to form a tube (3) from the advancing web (4) of packaging material; a sealing device; a filling device (15); a package forming unit (16) configured to form and transversally seal the packages (2) from the advancing tube (3); a tensioning device (32); a control unit (17) configured to control the conveying device (5) and/or the tensioning device (32) and/or the package forming unit (16) so to vary an advancement speed of the tube (3).

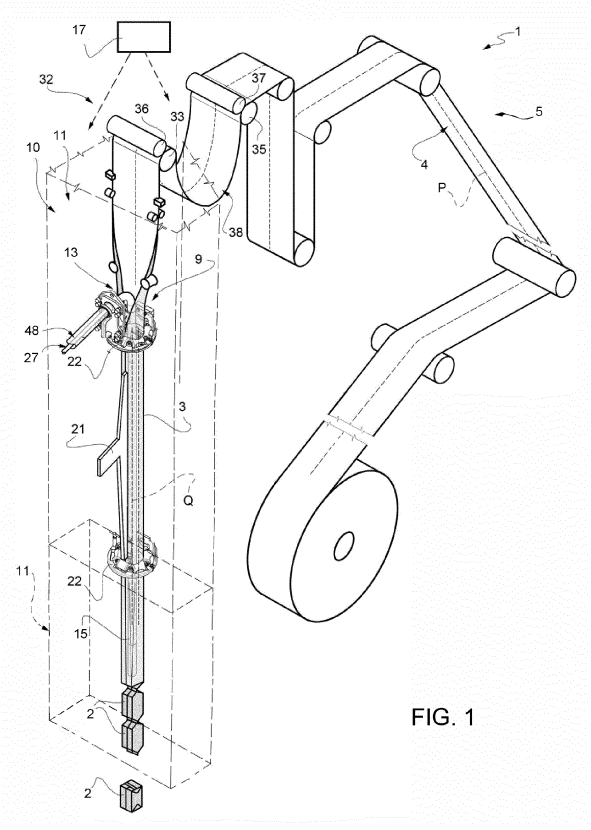

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present invention relates to a packaging machine for producing sealed packages of a pourable product, in particular a pourable food product.

[0002] The present invention also relates to a method for producing sealed packages of a pourable product, in particular a pourable food product.

BACKGROUND ART

[0003] Many liquid or pourable food products, such as fruit juice, UHT (ultra-high-temperature treated) milk, wine, tomato sauce, etc., are sold in packages made of sterilized packaging material.

[0004] A typical example is the parallelepiped-shaped package for liquid or pourable food products known as Tetra Brik Aseptic (registered trademark), which is made by sealing and folding laminated strip packaging material. The packaging material has a multilayer structure comprising a base layer, e.g. of paper, covered on both sides with layers of heat-seal plastic material, e.g. polyethylene. In the case of aseptic packages for long-storage products, such as UHT milk, the packaging material also comprises a layer of oxygen-barrier material (an oxygen-barrier layer), e.g. an aluminium foil, which is superimposed on a layer of heat-seal plastic material, and is in turn covered with another layer of heat-seal plastic material forming the inner face of the package eventually contacting the food product.

[0005] Packages of this sort are normally produced on fully automatic packaging machines, which advance a web of packaging material through a sterilization apparatus for sterilizing the web of packaging material at a sterilization station and an isolation chamber (a closed and sterile environment) in which the sterilized web of packaging material is maintained and advanced. During advancement of the web of packaging material through the isolation chamber, the web of packaging material is folded and sealed longitudinally at a tube forming station to form a tube having a longitudinal seam portion, the tube being further fed along a vertical advancing direction.

[0006] In order to complete the forming operations, the tube is filled with a sterilized or sterile-processed pourable product, in particular a pourable food product, and is transversally sealed and subsequently cut along equally spaced transversal cross sections within a package forming unit of the packaging machine during advancement along the vertical advancing direction.

[0007] Pillow packages are so obtained within the packaging machine, each pillow package having a longitudinal sealing band, a top transversal sealing band and a bottom transversal sealing band.

[0008] A typical packaging machine comprises a conveying device for advancing the web of packaging material along a web advancement path and a tube formed from the web of packaging material along a tube advancement path, the sterilization apparatus for sterilizing the web of packaging material prior to its formation into the tube, a tube forming and sealing device at least partially arranged within an isolation chamber and being configured to form the tube from the advancing web of packaging material and to longitudinally seal the tube, a filling device for filling the tube with the pourable product and a package forming unit adapted to form, transversally seal and cut the single packages from the tube of packaging material.

[0009] A typical packaging machine also comprises a tensioning device configured to control the tension of the tube, i.e. of the packaging material forming the tube. In particular, it is known to arrange the tensioning device between the sterilization station and the tube forming station for controlling the tension of the tube. Examples of a packaging machine comprising a tensioning device are disclosed in patent documents EP3725692B1 and EP3725689B1 in the name of the Applicant.

[0010] In order to correctly form the single packages, it is required that the hydrostatic pressure provided by the pourable product within the tube is sufficiently high as otherwise irregularly shaped packages would be obtained. Typically, the pourable product column present in the tube for providing for the required hydrostatic pressure extends at least 500 mm upwards from the hit position (i.e. the position at which the respective forming, sealing and cutting assemblies start to contact the advancing tube). As an alternative, patent document EP3456638B1 in the name of the Applicant proposes to provide a pressurizing device configured to direct, in use, a flow of sterile gas into the tube for obtaining a gas pressure within the tube providing a correct forming pressure. In such a way, the required hydrostatic pressure provided by product column is reduced.

[0011] Known packaging machines operate according to a "constant time" principle. Namely, when the packaging machine is started, packaging material and/or tube is accelerated from an initial speed (e.g. 0 m/s) to a target speed in a predefined time period (to reach a target capacity). Target-speed may depend on the format (i.e. the size and/or the shape) of the package to be formed, so that a packaging machine may be operated at a first target speed or at a second target speed, different from the first target speed, depending on the format of the package. However, in known machines, irrespective of the value of the target speed to reach the target capacity, the time period that the machine takes for accelerating from the initial speed to the target speed is the same. Consequently, the acceleration values to reach the target speed vary according to the values of the target speed. This behaviour leads to variable accelerations and so variable stresses to which components are subject during transition phases (in particular, the acceleration is variable depending on the package format).

[0012] A need is felt to improve this machine behav-

iour. In particular, a need is felt to increase lifetime of components.

DISCLOSURE OF INVENTION

[0013] It is therefore an aim of the present invention to provide a packaging machine which overcomes at least one of the a forementioned drawbacks. It is also aim of the present invention to provide a method for producing sealed packages which overcomes at least one of the a forementioned drawbacks.

[0014] These aims are fully achieved by the packaging machine and the method for producing sealed packages according to one or more of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Two non-limiting embodiments of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a packaging machine according to the present invention, with parts removed for clarity;

Figure 2 is an enlarged view of a detail of the packaging apparatus of Figure 1, with parts removed for clarity;

Figure 3 schematically shows the behaviour of a machine according to the state of the art, during transient phases; in particular, the vertical axis represents advancement speed of the web and/or tube of packaging material, the horizontal axis represents time;

Figure 4 schematically shows the behaviour of the machine according to the present invention, during transient phases; in particular, the vertical axis represents advancement speed of the web and/or tube of packaging material, the horizontal axis represents time.

BEST MODES FOR CARRYING OUT THE INVENTION

[0016] Number 1 indicates as a whole a packaging machine for producing sealed packages 2 of a pourable food product, such as pasteurized milk or fruit juice, from a tube 3 of a web 4 of packaging material. In particular, in use, tube 3 extends along a longitudinal axis, in particular having a vertical orientation.

[0017] Web 4 of packaging material has a multilayer structure, and comprises a layer of fibrous material, normally paper, covered on both sides with respective layers of heat-seal plastic material, e.g. polyethylene.

[0018] Preferably, web 4 also comprises a layer of gas- and light-barrier material, e.g. aluminium foil or ethylene vinyl alcohol (EVOH) film, and at least a first and a second layer of heat-seal plastic material. The layer of gas- and light-barrier material is superimposed on the first layer of heat-seal plastic material, and is in turn covered with the second layer of heat-seal plastic material. The second layer of heat-seal plastic material forms the inner face of package 2 eventually contacting the food product.

[0019] A typical package 2 obtained by packaging apparatus 1 comprises a sealed longitudinal seam portion and a pair of transversal seal portions 66, in particular a pair of top and bottom transversal seal portions 66 (i.e. one seal portion 66 at an upper portion of package 2 and another seal portion 66 at a lower portion of package 2).

[0020] With particular reference to Figure 1, packaging machine 1 comprises a conveying device 5 for advancing in a known manner web 4 along a web advancement path P from a delivery station to a forming station 9, at which, in use, web 4 is formed into tube 3. Conveying device 5 is also configured to advancing tube 3 along a tube advancement path Q.

[0021] Packaging machine 1 comprises an isolation chamber 10 having an inner environment 11, in particular an inner sterile environment 11, containing a sterile gas, in particular sterile air, and being separated from an outer environment 12.

[0022] Packaging machine 1 comprises a tube forming device 13 extending along a longitudinal axis, in particular having a vertical orientation, and being arranged, in particular at forming station 9, at least partially, preferably fully, within isolation chamber 10 and being adapted to form tube 3 from the, in use, advancing web 4.

[0023] Packaging machine 1 comprises a sealing device at least partially arranged within isolation chamber 10 and being adapted to longitudinally seal tube 3 formed by tube forming device 13.

[0024] Preferentially, tube forming device 13 is adapted to gradually fold web 4 into tube 3, in particular by overlapping first and second edges with one another for forming a longitudinal seam portion of tube 3, in particular the longitudinal seam portion being, in use, sealed by activation of sealing device.

[0025] Preferentially, conveying device 5 is adapted to advance tube 3 and any intermediate of tube 3 along a tube advancement path Q, in particular from forming station 9 to a package forming unit 16. In particular, with the wording intermediates of tube 3 any configuration of web 4 is meant prior to obtaining the tube structure and after folding of web 4 by tube forming device 13 has started. In other words, the intermediates of tube 3 are a result of the gradual folding of web 4 so as to obtain tube 3, in particular by overlapping with one another a first edge of web 4 and a second edge of web 4, opposite to first edge.

[0026] Preferentially, tube forming device 13 comprises at least two forming ring assemblies 22, in particular arranged within isolation chamber 10 (in particular, within inner environment 11), being adapted to gradually fold in cooperation with one another web 4 into tube 3, in particular by overlapping edges with one another for forming longitudinal seam portion. In the specific case shown, a first forming ring assembly 22 is arranged downstream of a second forming ring assembly 22 along path Q. In particular, first and second forming ring assemblies

22 are spaced apart from and parallel to one another. Furthermore, first and second forming ring assemblies 22 are arranged coaxial to one another and define longitudinal axis of tube forming device 13.

[0027] Preferentially, sealing device comprises a sealing head 21 adapted to interact with tube 3, for longitudinally sealing tube 3, in particular for sealing longitudinal seam portion. In particular, sealing head 21 is adapted to heat tube 3, in particular along seam portion. Sealing head 21 can be of the kind operating by means of induction heating or by a stream of heat or by means of ultrasound or other means.

[0028] Preferentially, sealing device comprises a pressuring assembly adapted to exert a mechanical force on tube 3, in particular on the substantially overlapping edges of tube 3 so as to ensure sealing of tube 3 along seam portion. In particular, the pressuring assembly comprises an interaction roller and a counter-interaction roller adapted to exert a mechanical force onto seam portion from opposite sides thereof. In use, seam portion is interposed between interaction roller and the counter-interaction roller. Preferentially, interaction roller is supported by forming ring assembly 22.

[0029] Packaging machine 1 comprises a filling device 15 for continuously filling tube 3 with the pourable product.

[0030] With particular reference to Figures 1 and 2, filling device 15 comprise a filling pipe 27 being in fluid connection with a pourable product storage tank, which is adapted to store/provide for the pourable product to be packaged.

[0031] In particular, filling pipe 27 is adapted to direct, in use, the pourable product into tube 3. Preferentially, filling pipe 27 is, in use, at least partially placed within tube 3 for continuously feeding the pourable product into tube 3. In particular, filling pipe 27 includes a linear main pipe portion 28 extending within tube 3.

[0032] Even more particular, main pipe portion 28 comprises an upper section 29 and a lower section 30 coupled to one another (preferably, removably). In further detail, lower section 30 comprises an outlet opening from which the pourable product is fed, in use, into tube 3.

[0033] Packaging machine 1 comprises package forming unit 16 which is adapted to shape, to transversally seal and to transversally cut the, in use, advancing tube 3 for forming packages 2. In particular, package forming unit 16 is arranged downstream of isolation chamber 10 and tube forming device 13 and sealing device along path Q.

[0034] With reference to Figure 2, package forming unit 16 comprises:

- a plurality of operative assemblies 61 (only one shown) and a plurality of counter-operative assemblies 62 (only one shown); and
- a track (not shown) adapted to advance the operative assemblies 61 and the counter-operative assemblies 62 along respective conveying paths. In particular, each of the operative assembly 61 and counter-operative assembly 62 advances cyclically along the respective conveying path. In even more particular, each of the operative assembly 61 and counter-operative assembly 62 is movable along said track independently from one another.

[0035] In more detail, each operative assembly 61 is adapted to cooperate, in use, with one respective counter-operative assembly 62 for forming a respective package 2 from tube 3. In particular, each operative assembly 61 and the respective counter-operative assembly 62 are adapted to shape, to transversally seal and, preferably also to transversally cut, tube 3 for forming packages 2.

[0036] In further detail, each operative assembly 61 and the respective counter-operative assembly 62 are adapted to cooperate with one another for forming a respective package 2 from tube 3 when advancing along a respective operative portion of the respective conveying path. In particular, during advancement along the respective conveying path each operative assembly 61 and the respective counter-operative assembly 62 advance parallel to and in the same direction as tube 3.

[0037] In more detail, each operative assembly 61 and the respective counter-operative assembly 62 are configured to contact tube 3 when advancing along the respective operative portion of the respective conveying path. In particular, each operative assembly 61 and the respective counter-operative assembly 62 are configured to start to contact tube 3 at a (fixed) hit position.

[0038] Furthermore, each operative assembly 61 and counter-operative assembly 62 comprises:

- a half-shell 63 adapted to contact tube 3 and to at least partially define the shape of packages 2;
- one of a sealing element 64 or a counter-sealing element 65, adapted to transversally seal tube 3 between adjacent packages 2 for obtaining transversal seal portions 66; and
- one of a cutting element (not shown and known as such) or a counter-cutting element (not shown and known as such) for transversally cutting tube 3 between adjacent packages 2, in particular between the respective seal portions 66.

[0039] In particular, each half-shell 63 is adapted to be controlled between a working position and a rest position by means of a driving assembly. In particular, each half-shell 63 is adapted to be controlled into the working position with the respective operative assembly 61 or the respective counter-operative assembly 62, in use, advancing along the respective operative portion.

[0040] It is noted that sealing element 64 and counter-sealing element 65 can be of the kind operating by means of induction heating or by a stream of heat or by means of ultrasound or other means.

[0041] According to a preferred non-limiting embodiment, package forming unit 16 is of the type described

in any of patent documents EP3254980A1, EP3476751A1 in the name of the present Applicant. It is expressly understood that all the functional and structural features of the forming assembly of patent documents EP3254980A1, EP3476751A1 can be applied to package forming unit 16 described herein.

[0042] With particular reference to Figures 1 and 2, isolation chamber 10 comprises a housing 14 (only schematically shown) delimiting the inner environment 11 (i.e. housing 14 separates inner environment 11 from outer environment 12). In particular, inner environment 11 comprises (i.e. contains) sterile gas, in particular the sterile air, at a given pressure. Preferentially, the given pressure is slightly above ambient pressure for reducing the risk of any contaminants entering inner environment 11. In particular, the given pressure is about 100 Pa to 500 Pa (0,001 bar to 0,005 bar) above ambient pressure.

[0043] Preferentially, packaging apparatus 1 comprises means (not shown and known as such) for feeding the sterile gas, in particular the sterile air, into isolation chamber 10, in particular inner environment 11.

[0044] According to one or more embodiments of the present invention and with particular reference to Figure 2, packaging apparatus 1 also comprises:

- a delimiting element 40 placed, in use, within tube 3 and designed to divide tube 3, in use, into a first space 41 and a second space 42; and
- a pressurizing device 43 adapted to direct, in particular to continuously direct, in use, a flow of sterile gas into second space 42 for obtaining a gas pressure within second space 42 that is higher than the gas pressure within first space 41.

[0045] In more detail, first space 41 is delimited by tube 3, in particular the walls of tube 3, and delimiting element 40. Furthermore, first space 41 opens up into inner environment 11. Even more particular, delimiting element 40 delimits first space 41 at a downstream portion, in particular a bottom portion, of first space 41 itself.

[0046] In more detail, second space 42 is delimited, in use, by tube 3, in particular the walls of tube 3, delimiting element 40 and transversal seal portion 66.

[0047] In further detail, first space 41 is arranged upstream of second space 42 along tube advancement path Q. Even more particular, first space 41 is arranged upstream of delimiting element 40 along path Q. In the specific example shown, second space 42 is placed below first space 41.

[0048] In particular, as will become clear from the following description, second space 42 defines a high-pressure zone within tube 3 and first space 41 defines a low-pressure zone within tube 3.

[0049] In the context of the present application, high-pressure zone (i.e. second space 42) is to be understood such that the internal pressure lies in a range of about 5kPa to 40kPa (0,05 bar to 0,4 bar), in particular of about 10kPa to 30 kPa (0,10 bar to 0,30 bar) above ambient pressure. In other words, second space 42 is overpressurized.

[0050] Low-pressure zone (i.e. first space 41) is to be understood such that the pressure is slightly higher than the ambient pressure. In particular, slightly higher than the ambient pressure means that the pressure lies in a range between 100 Pa to 500 Pa (0,001 bar to 0,005 bar) above ambient pressure.

[0051] In further detail, first space 41 is in (direct) fluidic connection with inner environment 11. Thus, sterile gas present in first space 41 can flow to inner environment 11.

[0052] In particular, tube 3 (and its intermediates) lie at least partially within isolation chamber 10 (in particular, within inner environment 11).

[0053] Preferentially, the pressure inside first space 41 (substantially) equals the given pressure present in isolation chamber 10, in particular in inner environment 11. Preferentially, the pressure inside first space 41 ranges between 100 Pa to 500 Pa (0,001 bar to 0,005 bar) above ambient pressure.

[0054] Filling device 15, in particular filling pipe 27, is adapted to direct the pourable product into second space 42. Thus, in use, second space 42 contains the pourable product and the pressurized sterile gas. The pressurized sterile gas provides for the required hydrostatic force needed for a correct forming of packages 2 (i.e. in other words, the sterile gas replaces the effect of the pourable product column within tube 3).

[0055] Advantageously, delimiting element 40 is designed to provide, in use, for at least one fluidic channel 44, in particular having an annular shape, for fluidically connecting second space 42 with first space 41 allowing for, in use, a leakage flow of sterile gas from second space 42 into first space 41. In particular, in use, the sterile gas leaks from second space 42 (the high-pressure zone) to first space 41 (the low-pressure zone) through fluidic channel 44. By providing for fluidic channel 44 it is possible to control the gas pressure within second space 42 with an increased accuracy. Preferentially delimiting element 40 is designed such that, in use, fluidic channel 44 is provided by a gap between the inner surface of tube 3 and delimiting element 40, in particular a peripheral portion 45 of delimiting element 40.

[0056] In particular, pressurizing means 43 are configured to provide for a variable flow of sterile gas of about 10 to 200 Nm3/h, in particular of 20 to 180 Nm3/h, even more particular of about 25 to 150 Nm3/h.

[0057] Preferentially, pressurizing means 43 are adapted to vary the flow of sterile gas in dependence of the sterile gas flowing from second space 42 to first space 41, in particular through at least fluidic channel 44.

[0058] Preferentially, pressurizing device 43 is adapted to control the gas pressure within second space 42 to range between 5 kPa to 40 kPa (0,05 bar to 0,40 bar), in particular between 10 kPa to 30 kPa (0,1 bar to 0,3 bar), above ambient pressure.

[0059] Advantageously, pressurizing device 43 is designed such to provide for a closed sterile gas circuit from

inner environment 11 into second space 42 and back into inner environment 11. In more detail, pressurizing device 43 is adapted to withdraw sterile gas from inner environment 11, to pressurize (to compress) the sterile gas and to direct the pressurized (compressed) sterile gas into second space 42.

[0060] Preferentially, pressurizing device 43 comprises a pumping device 46 adapted to withdraw sterile gas from inner environment 11, to pressurize (to compress) the sterile gas and to direct the pressurized sterile gas into second space 42. Preferentially, pumping device 46 is a rotary machine, even more particular a compressor.

[0061] Packaging machine 1 also comprises a control unit 17 for controlling operation of packaging machine 1.

[0062] Preferably, control unit 17 is adapted to control the operating parameters of pumping device 46, in particular the compressor. As explained further below, control unit 17 is configured to control the operating parameters of pumping device 46 as a function of at least one of the advancement speed of web 4 or the advancement speed of tube 3 (both advancement speeds are equal) or the format or the shape of packages 2 to be formed or the volume of packages 2 to be formed.

[0063] Preferably, the rotary machine, in particular the compressor is configured to operate at rotation speeds ranging between 10000 to 100000 rpm, in particular 20000 to 80000 rpm, even more particular 30000 to 60000 rpm.

[0064] In the specific example disclosed, control unit 17 is adapted to control the rotation speed of the rotary machine, in particular of the compressor as a function of at least one of the advancement speed of web 4 or the advancement speed of tube 3 or the format of packages 2 to be formed or the volume of packages 2 to be formed.

[0065] Preferably, the rotary machine, in particular the compressor is configured such that the pressure provided increases with increasing rotation speed.

[0066] Preferably, the rotary machine, in particular the compressor is configured to allow for a variable flow of sterile gas by maintaining a substantially constant gas pressure within second space 42, in particular as a function of the flow of gas from second space 42 to first space 41 (through fluidic channel 44).

[0067] Preferably, pressurizing device 43 comprises a gas feeding pipe 48 being at least indirectly fluidically connected with inner environment 11 and second space 42 for directing the sterile gas from inner environment 11 into second space 42. In particular, gas feeding pipe 48 is directly fluidically connected with second space 42. Preferentially, gas feeding pipe 48 is at least indirectly connected with pumping device 46, in particular the compressor.

[0068] In more detail, gas feeding pipe 48 comprises at least a main portion 49, which, in use, extends within tube 3. In particular, main portion 49 extends parallel to main pipe portion 28. Even more particular, at least main portion 49 and main pipe portion 28 are coaxial to one another.

[0069] In the specific example shown, filling pipe 27 extends at least partially within gas feeding pipe 48. Alternatively, gas feeding pipe 48 could at least partially extend within filling pipe 27.

[0070] In more detail, at least main pipe portion 28 of filling pipe extends at least partially within main portion 49 of gas feeding pipe.

[0071] In particular, the cross-sectional diameter of main pipe portion 28 of filling pipe is smaller than the cross-section diameter of main portion 49 of gas feeding pipe.

[0072] Preferentially, gas feeding pipe 48 and filling pipe 27 define/delimit an annular conduit 50 for the sterile gas to be fed into second space 42. In particular, annular conduit 50 is delimited by the inner surface of gas feeding pipe 48 and the outer surface of filling pipe 27.

[0073] In other words, in use, the sterile gas is directed into second space 42 through annular conduit 50.

[0074] Pressurizing means 43 also comprise:

- a first gas conduit 51 being in direct fluidic connection with pumping device 46, in particular the rotary machine, even more particular the compressor and the gas feeding pipe 48; and
- a second gas conduit 52 being in direct fluidic connection with inner environment 11 and pumping device 46, in particular the rotary machine, even more particular the compressor.

[0075] Thus, in use, sterile gas is withdrawn from inner environment 11 through gas conduit 52, is then pressurized (compressed) by pumping device 46, and is then directed into second space 42 through gas conduit 51 and gas feeding pipe 48.

[0076] Preferentially, delimiting element 40 is removably connected to at least a portion of filling pipe 27 and/or gas feeding pipe 48. In particular, delimiting element 40 is connected to at least a portion of filling pipe 27 and/or gas feeding pipe 48 in a floating manner (i.e. with play). In particular, in a floating manner means that delimiting element 40 is adapted to(slightly) move parallel to tube advancement path Q. In other words, delimiting element 40 is adapted to (slightly) move parallel to the, in use, advancing tube 3.

[0077] With particular reference to Figure 1, packaging machine 1 also comprises a tensioning device 32 configured to control the tension of tube 3. In particular the tension of tube 3 may be controlled in dependence of cyclic advancement speed of web 4 and/or tube 3 and/or in dependence of the operation of package forming unit 11.

[0078] In particular, tensioning device 32 is arranged upstream of tube forming device 13 along web advancement path P and is configured to control the tension of tube 3, and in particular of the portion of web 4 extending between tensioning device 32 and tube forming device 13. Even more particular, tensioning device 32 is arranged upstream of tube forming device 13 and down-

stream of the sterilization station and/or the sterilization device.

[0079] Advantageously, control unit 17 is configured to control operation of tensioning device 32.

[0080] With particular reference to Figures 1, tensioning device 32 comprises:

- a main drive roller 33 rotatable around a main rotation axis; and
- a main drive motor, in particular a servo motor, connected to main drive roller 33 and configured to actuate rotation of main drive roller 33 around main rotation axis.

[0081] According to a preferred non-limiting embodiment, tensioning device 32 further comprises:

- an auxiliary drive roller 35 rotatable around an auxiliary rotation axis; and
- an auxiliary drive motor, in particular an auxiliary servo motor, connected to auxiliary drive roller 35 and configured to actuate and/or control rotation of auxiliary drive roller 35 around auxiliary rotation axis.

[0082] According to a preferred non-limiting embodiment, auxiliary drive roller 35 and main drive roller 33 are spaced apart along web advancement path P, in particular with auxiliary drive roller 35 being arranged upstream of main drive roller 33.

[0083] According to a preferred non-limiting embodiment, tensioning device 32 further comprises:

- a main counter-roller 36 rotatable around a central axis and being arranged adjacent, in particular peripherally adjacent, even more particular tangential, to main driver roller 33; and
- an auxiliary counter-roller 37 rotatable around a central axis and being arranged adjacent, in particular peripherally adjacent, even more particular tangential, to auxiliary drive roller 35.

[0084] According to a preferred non-limiting embodiment, and according to the relative arrangement of auxiliary drive roller 35 and main drive roller 33, auxiliary counter-roller 37 is arranged upstream of main counter-roller 36 along web advancement path P.

[0085] In particular, in use, web 4 is interposed and/or advances between main counter-roller 36 and main drive roller 33, and in particular between auxiliary counter-roller 37 and auxiliary drive roller 35.

[0086] Advantageously, control unit 17 is configured to control main drive motor such that an angular speed of main drive roller 33 is cyclically varied such to control the tension of tube 3, and in particular also of the portion of web 4 extending between main drive roller 33 and tube forming device 13.

[0087] In particular, in the context of the present description, the term "cyclically varied" indicates that the angular speed and/or the angular acceleration of main drive roller 33 follows respectively a time-dependent speed profile and/or time-dependent acceleration profile, which repeat(s) according to a defined and/or determined and/or given frequency.

[0088] In other words, control unit 17 is configured to control main drive motor such that the angular speed and/or the angular acceleration of main drive roller 33 is cyclically varied according to respectively a time-dependent speed profile and/or acceleration profile, which repeats according to a defined operation frequency. In particular, the time-dependent speed profile is defined according to a cycle of the production of a package 2 and/or the operation of package forming unit 16.

[0089] In particular, controlling the angular speed and/or the angular acceleration of main drive roller 33 around the respective rotation axis (and the respective main drive motor) according to respectively a cyclic speed profile and/or acceleration profile is advantageous as the forces acting on tube 3 during the formation of packages 2 are cyclic.

[0090] According to a preferred non-limiting embodiment, control unit 17 is configured to control main drive motor such that the angular speed and/or the angular acceleration of main drive roller 33 is varied and/or controlled as a function of the operation of package forming unit 11 and/or as a function of the package forming cycle and/or the forces acting on tube 3 and/or the operation of filling device 15 and the filling of tube 3.

[0091] In particular, the package forming cycle is substantially determined by the interaction of operative assemblies 61 and counter-operative assemblies 62, in particular of the respective half-shells 63, sealing elements 64 and counter-sealing elements 65, with tube 3.

[0092] It should be noted that operation of package forming unit 16 (and the interaction of operative assemblies 61 and counter-operative assemblies 62 with tube 3) determines a cyclic advancement speed of web 4 (in particular of the portion of web 4 downstream of tensioning device 32) and/or tube 3. In particular, the cyclic advancement speed profile is a repetition (according to a defined frequency) of the advancement speed of web 4 and/or tube 3 during the formation of one single package 2.

[0093] According to a preferred non-limiting embodiment, control unit 17 is also configured to control the auxiliary drive motor and main drive motor such that a free loop 38 of web 4 expands and/or advances, in use, between auxiliary drive roller 35 and main drive roller 33.

[0094] With respect to the present invention, the term free loop 38 indicates that the portion of web 4 expanding and/or advancing between auxiliary drive roller 35 and main drive roller 33 is not subjected to any tension and defines and/or forms free loop 38; i.e. the portion of web 4 defining and/or forming free loop 38 is exposed to no tensional forces and/or is free of any tensional forces. In other words, free loop 38 is a tension-free portion of web 4.

[0095] Preferentially but not necessarily, control unit 17 is configured to control the auxiliary drive motor such that an angular speed of auxiliary drive roller 35 is such to maintain and/or control, in particular the extension of, free loop 38 expanding and/or advancing between auxiliary drive roller 35 and main drive roller 33.

[0096] In particular, while, in use, the angular speed of auxiliary drive roller 35 substantially controls the extension of the respective free loop 38, the angular speed of main drive roller 33 substantially controls the tension of tube 3.

[0097] According to a preferred non-limiting embodiment, packaging machine 1 further comprises a sterilization apparatus for sterilizing at least a portion of web 4, preferentially at least a first face, even more preferentially the first face and a second face, in particular at a sterilization station. Preferentially, the sterilization station is arranged upstream of tube forming station along web advancement path P. Preferentially, the sterilization station is in fluid connection with the isolation chamber 10.

[0098] In particular, irradiation device comprises at least a first irradiation emitter, in particular a first electron beam emitter, configured to direct the sterilizing irradiation, in particular the electromagnetic irradiation, even more particular the electron beam irradiation on the first face of web 4 of packaging material. Preferentially irradiation device also comprises a second irradiation emitter, in particular a second electron beam emitter, configured to direct the sterilizing irradiation, in particular the electromagnetic irradiation, even more particular the electron beam irradiation, in use, on the second face of web 4 of packaging material.

[0099] Preferably, the irradiation device is of the type described in patent documents EP3549878A1 and EP3549613A1, in the name of the present Applicant. It is expressly understood that all the functional and structural features of the apparatus of patent documents EP3549878A1 and EP3549613A1 can be applied to the irradiation device of the machine described herein.

[0100] According to a preferred non-limiting embodiment, packaging machine 1 further comprises a folding unit configured to receive the formed and sealed packages 2 from the package forming unit 16 and for producing folded packages.

[0101] It should be noted that each package 2 produced by the package forming unit 16 (so called "pillow package") comprises a main portion, and first and second end portions arranged on respective opposite sides of said main portion; said first end portion comprising a first fin and a pair of first flaps projecting laterally from said main portion. Second end portion comprising a second fin and a pair of second flaps projecting laterally from said main portion. In particular, first fin has a rectangular shape and projects from an (upper) transversal seam portion 66 and second fin has a rectangular shape and projects from another (lower) transversal seam portion 66. First end portion tapers from the main portion towards first fin, and second end portion tapers from main portion towards second fin. First flaps have a substantially triangular shape and project from opposite sides of first end portion, and second flaps have a substantially triangular shape and project from opposite sides of second end portion.

[0102] Folding unit substantially comprises:

- an endless conveyor for feeding packages 2 continuously along a folding path from a supply station to an output station;
- first folding means which cooperate cyclically with each package 2 to perform folding operations, in particular flatten first end portion, fold relative first fin onto first end portion, and bend first flaps onto main portion towards the second end portion;
- second folding means which cooperate cyclically with each package 2 to perform further folding operations, in particular for flattening second end portion, folding second fin onto second end portion and folding second flaps onto the second fin.

[0103] Preferably, folding unit further comprises a heating device, in particular configured acting on bent first and second flaps to melt the external layer of the packaging material and seal the flaps before they are pressed against main portion and second fin, respectively.

[0104] Preferably, folding unit further comprises a pressing device, in particular configured cooperating with each package 2 to hold flaps onto flattened fin as flaps cool. Heating device is, in particular, arranged between folding means and pressure device along folding path.

[0105] In particular, heating device comprises: an assembly air device; a pair of first nozzles connected to assembly air device and adapted to direct hot air onto first flaps of each package before each package 2 reaches pressing device; and a pair of second nozzles connected to assembly and adapted to direct hot air onto second flaps of each package 2.

[0106] Preferably, the folding unit is of the type described in patent document EP3549613A1, in the name of the present Applicant. It is expressly understood that all the functional and structural features of the apparatus of patent document EP3549613A1 can be applied to the folding unit described herein.

[0107] According to a preferred non-limiting embodiment, packaging machine 1 further comprises a strip applicator, configured to apply a sealing strip onto the web of a packaging material. The strip applicator comprises an advancement device configured to advance the sealing strip along a strip advancement path and towards and onto the web 4 of packaging material, before formation of tube 3. The strip applicator comprises a heat distribution device configured to direct a stream of the heated gas (in particular, air) onto the web of multilayer packaging material and/or onto the sealing strip. The strip applicator comprises an application device configured to apply the sealing strip onto the web of multilayer pack-

aging material.

[0108] Preferably, the strip applicator is of the type described in patent document EP4137295A1, in the name of the present Applicant. It is expressly understood that all the functional and structural features of the apparatus of patent document EP4137295A1 can be applied to the folding unit described herein.

[0109] According to one or more embodiments, the packaging machine 1 is configured to receive the pourable product from an upstream equipment and/or to transfer the formed and sealed (and folded) packages 2 to a downstream equipment.

[0110] According to an aspect of the present disclosure, the control unit 17 is configured to control the conveying device 5 and/or the tensioning device 32 and/or the package forming unit 16 so to vary and/or change an advancement speed of the tube 3 and a release speed of the formed and sealed packages 2.

[0111] Preferably, the control unit 17 is configured to control a first variation in the advancement speed and a second variation in the advancement speed. The first variation lasts a first time period. The second variation lasts a second time period. The first variation is from a first initial speed up to a first target speed. The first initial speed may be lower or higher than the first target speed. The second variation is from a second initial speed up to a second target speed. The second initial speed may be lower or higher than the second target speed. The first initial speed may be different from the second initial speed, and/or the first target speed may be different from the second target speed.

[0112] It is noted that first target speed and second target speed are meant as final speed values reached during first speed variation and second speed variation, respectively. In particular, first target speed and second target speed are representative of desired operational conditions of the machine.

[0113] Preferably, the first initial speed is different from the second initial speed and/or the first target speed is different from the second target speed. However, the present disclosure also discloses that the first initial speed may be equal to the second initial speed, when the first target speed is different from the second target speed; and, similarly, the first target speed may be equal to the second target speed, when the first initial speed is different from the second initial speed.

[0114] According to a non-limiting embodiment, the first initial speed and the second initial speed are zero and the first target speed and the second target speed are different from zero and from one another (i.e. the first variation of speed and the second variation of speed are accelerations from zero). According to another non-limiting embodiment, the first initial speed and the second initial speed are different from zero and from one another, and the first target speed and the second target speed are zero (i.e. the first variation of speed and the second variation of speed are decelerations up to zero). According to another non-limiting embodiment, the first initial speed and the second initial and the first target speed and the second target speed are different from zero (in this case the first variation of speed and the second variation of speed may be accelerations or decelerations).

[0115] It is here noted that expressions first target speed and second target speed indicate two desired values of speeds to be reached. A speed change from initial speed to a different desired, or target, speed may be required during startup as well as during operation. In particular, during startup the machine may be accelerated from zero (i.e. first initial speed) to a first target speed; then during operation it may be necessary to slow down the tube in order to meet issues of the line (for example, temporary stops of the downstream equipment that require slowing down of the release speed of formed packages); once said issues are resolved, the tube is accelerated again from a second initial speed (being greater than zero) to a second target speed (that may be equal or different with respect to first target speed).

[0116] In this light, advantageously control unit 17 is configured to control conveying device 5 and/or tensioning device 32 and/or the package forming unit 16 so that:

- once the first target speed has been reached, the advancement speed remains equal to the first target speed for a first target time period, and/or
- once the first target speed has been reached, the advancement speed remains equal to the first target speed for a second target time period.

[0117] Hence, once the first target speed has been reached, and/or once the second target speed has been reached, the acceleration of the tube 3 is brought to zero (and kept equal to zero for a certain amount of time).

[0118] It is further noted that the present disclosure also provides a case wherein the first target speed is greater than the first initial speed and the second target speed is greater than the second initial speed, and the tube 3 does not undergo a stop between the first time period and the second time period. Similarly, the present disclosure provides an alternative case wherein the first target speed is lower than the first initial speed and the second target speed is lower than the second initial speed, and the tube 3 does not undergo a stop between the first time period and the second time period.

[0119] In particular, it may be required to vary the advancement speed of the packaging machine due to a change in the format (i.e. the size and/or the shape) of the packages to be released, and/or due to the need to adapt the packaging machine to the speed of an upstream equipment (providing the pourable product) and/or a downstream equipment (receiving the formed packages).

[0120] According to an example, the first initial speed is zero, the first target speed is the advancement speed necessary to release 15000 packages per hour of a first format of package, the second initial speed is zero and the second target speed is the advancement speed nec-

essary to release 15000 packages per hour of a second format of package, different from the first format.

[0121] According to a further example, the first initial speed is zero, the first target speed is the advancement speed necessary to release 15000 packages per hour of a first format of package, the second initial speed is zero and the second target speed is the advancement speed necessary to release 16000 packages per hour of said first format of package.

[0122] Preferably, the control unit 17 is configured to control the conveying device 5 and/or the tensioning device 32 and/or the package forming unit 16 so that an advancement acceleration of the tube 3 equals a predefined acceleration value during the first variation and during the second variation. In other words, the advancement acceleration of the tube 3 is constant and/or unchanged during the first variation and the second variation. So, the advancement acceleration of the tube is constant and/or unchanged over the whole first time period and over the whole second time period. It is noted that said "predefined acceleration" may have a positive or negative value (in the latter case, it is a deceleration).

[0123] Preferably, the control unit 17 is configured to control the conveying device 5 and/or the tensioning device 32 and/or the package forming unit 16 so that the first time period is different from the second time period (i.e. they last a different amount of time).

[0124] In particular, if an absolute value of the first variation is greater than an absolute value of the second variation, the first time period is greater than the second time period. Conversely, if an absolute value of the first variation is lower than an absolute value of the second variation, the first time period is lower than the second time period. In case the target speed is greater than the initial speed, the "absolute value" of the variation is defined as a difference between the target speed and the respective initial speed; conversely, in case the target speed is lower than the initial speed, the "absolute value" of the variation is defined as a difference between the initial speed and the target speed.

[0125] So, in case the first target speed is greater than the first initial speed, the absolute value of the first variation is the difference between the first target speed and the first initial speed. Analogously, in case the second target speed is greater than the second initial speed, the absolute value of the second variation is the difference between the second target speed and the second initial speed.

[0126] In case the first target speed is lower than the first initial speed, the absolute value of the first variation is the difference between the first initial speed and the first target speed. Analogously, in case the second target speed is lower than the second initial speed, the absolute value of the second variation is the difference between the second initial speed and the second target speed.

[0127] Generally speaking, the control unit 17 is configured to control a plurality of variations in the advancement speed so that the advancement acceleration is equal to said predefined acceleration value during all of said plurality of variations in the advancement speed; however, said plurality of variations may last different time periods. Said plurality of variations include said first variation and said second variation.

[0128] Hence, as explained above, machines of the state of the art are configured to operate according to a "constant time" approach during advancement speed variations.

[0129] Conversely the packaging machine according to the present invention is configured to operate according to a "constant acceleration" or "constant deceleration" approach, during advancement speed variations. In particular, the machine according to the invention is configured to operate according to a "constant acceleration" or "constant deceleration" approach, irrespective of the target speed to be reached and/or irrespective of the format of the package to be formed. However, it should be noted that, preferably, the packaging material structure (i.e. multilayer composition) is the same in all the package formats processed by the machine.

[0130] Figure 1 illustrate an example of operation of a machine of the state of the art. In particular, three advancement speed variations are illustrated: a first variation, illustrated by a first speed line, is from zero speed to first target speed Si; a second variation, illustrated by a second speed line, is defined from zero speed to a second target speed S_2; a third variation, illustrated by a third speed line, is defined from zero speed to a third target speed S_3. As evident from figure 1, first variation, second variation and third variation last a predefined time period to. However, during each one of said first variation, second variation and third variation, the advancement acceleration of the web 4 and/or tube 3 (represented by the inclination of the respective speed line) is different.

[0131] Figure 2 illustrate an example of operation of the packaging machine according to the invention. In particular, three advancement speed variations are illustrated: a first variation, illustrated by a first speed line, is from zero speed to first target speed Si; a second variation, illustrated by a second speed line, is defined from zero speed to a second target speed S_2; a third variation, illustrated by a third speed line, is defined from zero speed to a third target speed S_3. As evident from figure 1, first variation lasts a first time period ti, second variation lasts a second time period t_2 and third variation lasts a third time period t_3. First time period ti, time period t_2 and third time period t_3 are different from each other. However, the advancement acceleration of the web 4 and/or tube 3 (represented by inclination α of the speed lines) is the same in the first variation, second variation and third variation.

[0132] The advantages of operating the machine according to said "constant acceleration" and/or "constant deceleration" approach reside in lower stress to which the machine components are subject and the uniform machine behavior at transient phases, with particular regard to sealing device, sealing elements and/or irradia-

tion device and/or other components. In fact, as the machine is accelerated and/or decelerated according to a predefined acceleration and/or deceleration, quick changes in the power delivered by said components (sealing device, sealing elements and/or irradiation device and/or others) are not needed anymore.

[0133] According to one or more embodiments, control unit 17 is configured to control the sealing device (in particular, sealing head 21) so as to change a sealing power delivered by the sealing device (in particular, sealing head 21), as a function of said variation of the advancement speed. In particular, control unit 17 is configured to control an increase in the sealing power delivered by the sealing device (in particular, sealing head 21), responsive to an increase in said advancement speed. Conversely, control unit 17 is configured to control a decrease in the sealing power delivered by the sealing device (in particular, sealing head 21), responsive to a decrease in said advancement speed. Hence, having a predefined acceleration during said increase in advancement speed, and/or having a predefined deceleration during said decrease in the advancement speed, leads to a predefined speed of increase and/or decrease of the sealing power delivered by sealing device. Said predefined speed of increase and/or decrease of the sealing power is less stressful for the sealing head 21, compared to a variable increase and/or decrease of the sealing power.

[0134] The control unit 17 is configured to control the sealing device such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the sealing power delivered by the sealing device and the advancement speed is constant (i.e. unchanged).

[0135] Preferably, the control unit 17 is configured to control transversal sealing assembly, (i.e. the sealing element 64 of each operative assembly 61) so as to change a sealing power delivered by the sealing element 64, as a function of said variation of the advancement speed.

[0136] In particular, control unit 17 is configured to control an increase in the sealing power delivered by sealing element 64, responsive to an increase in said advancement speed. Conversely, control unit 17 is configured to control a decrease in the sealing power delivered by sealing element 64, responsive to a decrease in said advancement speed. Hence, having a predefined acceleration during said increase in advancement speed, and/or having a predefined deceleration during said decrease in the advancement speed, leads to a predefined speed of increase and/or decrease of the sealing power delivered by sealing element 64. Said predefined speed of increase and/or decrease of the sealing power is less stressful for the sealing element 64, compared to a variable increase and/or decrease of the sealing power.

[0137] In particular, control unit 17 is configured to control the sealing element 64 of each operative assembly 61 such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the sealing power delivered by the sealing element 64 and the advancement speed is constant (i.e. unchanged).

[0138] Preferably, control unit 17 is configured to control the sterilization apparatus so to change an irradiation power delivered by said sterilization apparatus, as a function of said variation of the advancement speed. In the context of the present disclosure, "irradiation power" means a quantity of radiation (in particular, a quantity of electrons) emitted per unit of time.

[0139] In particular, control unit 17 is configured to control an increase in the irradiation power delivered by said sterilization apparatus, responsive to an increase in said advancement speed. Conversely, control unit 17 is configured to control a decrease in the irradiation power delivered by said sterilization apparatus, responsive to a decrease in said advancement speed. Hence, having a predefined acceleration during said increase in advancement speed, and/or having a predefined deceleration during said decrease in the advancement speed, leads to a predefined speed of increase and/or decrease of the irradiation power delivered by said sterilization apparatus. Said predefined speed of increase and/or decrease of the irradiation power is less stressful for the sterilization apparatus, compared to a variable increase and/or decrease of the irradiation power.

[0140] In particular, control unit 17 is configured to control the sterilization apparatus such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the irradiation power delivered by the sterilization apparatus and the advancement speed is constant (i.e. unchanged).

[0141] Also, control unit 17 may be configured to control the heat distribution device of the strip applicator so to vary the heating power delivered onto the strip and/or the web 4 of packaging material, before formation of tube 3. In particular, the control unit 17 is configured to increase the heating power of the strip applicator, when increasing said advancement speed of the tube 3 and/or release speed of the packages 2.

[0142] In particular, control unit 17 may be configured to control an increase in the heating power delivered by strip applicator, responsive to an increase in said advancement speed. Conversely, control unit 17 is configured to control a decrease in the heating power delivered by strip applicator, responsive to a decrease in said advancement speed. Hence, having a predefined acceleration during said increase in advancement speed, and/or having a predefined deceleration during said decrease in the advancement speed, leads to a predefined speed of increase and/or decrease of the heating power delivered by strip applicator. Said predefined speed of increase and/or decrease of the irradiation power is less stressful for the strip applicator, compared to a variable increase and/or decrease of the heating device of the folding unit.

[0143] In particular, control unit 17 may be configured to control the strip applicator such that during the first

variation of the advancement speed and during the second variation of the advancement speed, a ratio between the heating power delivered by the strip applicator and the advancement speed is constant (i.e. unchanged).

[0144] Preferably, the control unit 17 is configured to control the pressurizing device 43 (in particular the pumping device 46, even more in particular the compressor) so to vary and/or change the second gas pressure. Preferably the control unit 17 controls the pressurizing device 43 such that a variation (namely, an extent of variation) of said second gas pressure is dependent on a variation (namely, an extent of variation) of said advancement speed and/or release speed, and/or controls the conveying device 5 and the tensioning device 32 and the package forming unit 16 so that a variation (namely, an extent of variation) of said advancement speed and/or release speed is dependent on a variation (namely, an extent of variation) of said second gas pressure. Preferably, the variation in said advancement speed and/or release speed is simultaneous with the variation in said second gas pressure.

[0145] In particular, the control unit 17 is configured to control the conveying device 5 and the tensioning device 32 and the package forming unit 16 so to actuate a variation and/or a change in the advancement speed of the tube and in the release speed of the formed and sealed packages and, accordingly, actuate a variation and/or a change in the second gas pressure. Preferably, at each variation in the advancement speed of the tube 3 the control unit 17 also controls a corresponding variation in the second gas pressure.

[0146] So, in order to keep the tension of the tube and the tension of the packages approximately constant, the control unit 17 when controlling a change in the advancement speed, also controls a change in the second gas pressure. In such a way, the change in the second gas pressure (and in the pourable product) always compensates for the change in the advancement speed of the tube 3.

[0147] As a result, the quality of the packages 2 obtained is good at any advancement speed of the tube and even in the transient phases when the advancement speed is varied from one value to one another. As "quality of the packages" it is here meant that the values of a number of parameters of the packages, such as the weight the dimensions, the surface appearance (namely, the number and entity of wrinkles on the external surface of the package), remain into predefined acceptable values so that the packages are not discarded.

[0148] It is here underlined that the possibility to not discard the packages in the transient phases when the advancement speed is varied from one value to one another improves sustainability of the machine, as the production waste is reduced.

[0149] It is noted that the possibility to operate the machine according to said "constant acceleration" and/or "constant deceleration" approach is particularly advantageous in a context wherein the speed of the machine may be dynamically varied and a number of parameters of the packages, such as the weight, need to be kept into predefined acceptable values even during speed variations. In fact, as the packages produced during speed variations are good packages that meet the quality requirements and so do not need to be discarded, the time period for changing the advancement speed from one initial value to one target value may be shorter or longer, with substantially no consequences on a productivity of the machine and/or on a discard rate. Hence, operating the machine according to said "constant acceleration" and/or "constant deceleration" approach leads to less stress on components without affecting the productivity of the machine and/or on the discard rate.

[0150] Preferably, the control unit 17 has access to a database including a plurality of values of the advancement speed and/or release speed and a corresponding plurality of values of the second gas pressure. In said database, to each value of the advancement speed a corresponding value of the second gas pressure is associated. The control unit 17 is then configured to dynamically control the conveying device 5 and/or the tensioning device 32 and/or the package forming unit 16 and the pressurizing device 43 as a function of the values contained in the database. In particular, when the control unit 17 controls a change in the advancement speed from an initial value of advancement speed to a target value of advancement speed, it consults the database to extract the value of the second gas pressure corresponding the target value of advancement speed, and controls the pressurizing device 43 such that in the second space 42 said value of the second gas pressure corresponding the target value of advancement speed is reached.

[0151] As mentioned above, the package forming unit 16 is configured to operate cyclically leading to a cyclic profile of the advancement speed of the tube 3 (and of the release speed of the packages 2). Consequently, the control unit 17 is configured to control the main drive motor of the tensioning device 32, such that an angular speed of the main drive roller 33 is cyclically varied, and an advancement speed of the web 4 repeats according to a defined frequency.

[0152] The control unit 17 is configured to control the conveying device 5 and/or the tensioning device 32 and/or the package forming unit 16 so to modify said cyclic profile of the advancement speed of the tube 3 (and of the release speed of the packages 2. In particular, control unit 17 is configured to modify the cyclic profile and/or said frequency of the angular speed of the main drive roller 33 in order to modify the cyclic profile of the advancement speed of the tube 3.

[0153] The modification of the cyclic profile of the advancement speed may include a variation in the frequency of the cycle and/or a modification of the values. In particular, in the context of the present disclosure, when "a variation in the advancement speed" is mentioned, a variation within the cyclic profile and/or a modification of the cyclic profile of the are meant.

[0154] According to one or more aspects of the present disclosure, the control unit 17 is configured to control the pressurizing device 43 to vary the second gas pressure according to a modification of the cyclic profile of the advancement speed of the tube 3. In particular, the control unit 17 is configured to control the pressurizing device 43 so to vary the second gas pressure during the first variation of the advancement speed and during the second variation of the advancement speed.

[0155] Preferably, control unit 17 is further configured to control the filling device 15 so as to change an output rate of the pourable product, as a function of said variation in said advancement speed and/or release speed. In particular, control unit 17 is configured to increase the output rate of the pourable product when increasing the advancement speed and/or release speed.

[0156] Preferably, control unit 17 is configured to control a speed of the endless conveyor of the folding unit as a function of the advancement speed and/or release speed. Preferably, control unit 17 is configured to control the heating device of the folding unit so as to change the delivered heating power as a function of the advancement speed and/or release speed.

[0157] In particular, control unit 17 may be configured to control an increase in the heating power delivered by said heating device of the folding unit, responsive to an increase in said advancement speed. Conversely, control unit 17 is configured to control a decrease in the heating power delivered by said heating device of the folding unit, responsive to a decrease in said advancement speed. Hence, having a predefined acceleration during said increase in advancement speed, and/or having a predefined deceleration during said decrease in the advancement speed, leads to a predefined speed of increase and/or decrease of the heating power delivered by said heating device of the folding unit. Said predefined speed of increase and/or decrease of the heating power is less stressful for the heating device of the folding unit, compared to a variable increase and/or decrease of the heating device of the folding unit.

[0158] In particular, control unit 17 is configured to control the heating device of the folding unit such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the heating power delivered by the heating device and the advancement speed is constant (i.e. unchanged).

[0159] The present disclosure also provides a method for forming a plurality of sealed packages 2 filled with a pourable product. Preferably, the method is carried out by the machine which is object of the present disclosure.

[0160] The method includes a step of advancing a web 4 of packaging material along a web advancement path P, through a conveying device 5.

[0161] The method includes a step of forming a tube 3 from the advancing web 4 of packaging material, through a tube forming device 13 extending along a longitudinal axis and being at least partially arranged within an inner environment 11 of an isolation chamber 10 containing a sterile gas.

[0162] The method includes a step of advancing the tube 3 along a tube advancement path Q, according to an advancement speed. A delimiting element 40 is arranged within the tube and divides the tube in a first space 41 being in fluidic connection with the inner environment 11 and a second space 42 being arranged downstream of the first space 41 along the tube advancement path Q.

[0163] The method includes a step of directing a variable flow of sterile gas into the second space 42, through a pressurizing device, for obtaining a second gas pressure within the second space 42, said second gas pressure being higher than a first gas pressure within the first space 41.

[0164] The method includes a step of longitudinally sealing the tube formed by the tube forming device 13, through a sealing device being at least partially arranged within the inner environment 11 of the isolation chamber 10.

[0165] The method includes a step of continuously filling the tube 3 with a pourable product, through a filling device 15.

[0166] The method includes a step of forming and transversally sealing (and cutting) the packages 2 from the advancing tube 3, through a package forming unit 16.

[0167] The method includes a step of controlling the tension of the web 4 of packaging material and/or of the tube 3, through a tensioning device 32.

[0168] The method includes a step of varying the advancement speed of the tube and/or a release speed of the formed and sealed packages.

[0169] In particular, the method includes varying an advancement speed of the tube 3 according to a first variation, and varying the advancement speed of the tube 3 according to a second variation. An acceleration of the tube 3 equals a predefined acceleration value during both the first variation and the second variation. Hence, the acceleration of the tube 3 is constant during both the first variation and the second variation.

[0170] The first variation lasts a first time period and the second variation lasts a second time period, the first time period being different from the second time period.

[0171] Preferably, the method further includes a step of varying the second gas pressure, wherein a variation in said second gas pressure is dependent on a variation in said advancement speed and/or release speed and/or vice versa.

[0172] Preferably, the method further includes a step of controlling the sealing device so as to change a sealing power delivered by the sealing device, as a function of said variation in said advancement seed and/or release speed.

[0173] Preferably, the method further includes a step of sterilizing at least a first face of the web 4 of packaging material through a sterilization apparatus comprising an irradiation device configured to direct a sterilizing irradiation onto at least the first face while, in use, advancing

along a sterilization portion of the web advancement path. Preferably, the method further includes a step of controlling the sterilization apparatus so to change an irradiation power delivered by said sterilization apparatus, as a function of said variation in said advancement speed and/or release speed.

Claims

1. A packaging machine (1) for forming a plurality of sealed packages (2) filled with a pourable product, comprising:

    - a conveying device (5), configured to advance a web (4) of packaging material along an advancement path (P);
    - an isolation chamber (10) separating an inner environment (11) containing a sterile gas from an outer environment (12);
    - a tube forming device (13) extending along a longitudinal axis, being at least partially arranged within the isolation chamber (10) and being configured to form a tube (3) from the, in use, advancing web (4) of packaging material;
    - a sealing device, being at least partially arranged within the isolation chamber and being configured to longitudinally seal the tube formed by the tube forming device;
    - a filling device (15) configured to continuously fill the tube (3) with the pourable product;
    - a package forming unit (16) configured to form and transversally seal the packages (2) from the, in use, advancing tube (3);
    - a tensioning device (32) configured to control the tension of the web (4);
    - a control unit (17) configured to control operation of the packaging machine (1),

    wherein the control unit (17) is configured to control the conveying device (5) and/or the tensioning device (32) and/or the package forming unit (16) so to vary an advancement speed of the tube (3),

    wherein the control unit (17) is configured to control:

        - a first variation in the advancement speed, said first variation lasting a first time period;
        - a second variation in the advancement speed, said second variation lasting a second time period;

    wherein the first time period is different from the second time period;

    wherein the first variation is a speed variation from a first initial speed to a first target speed, and the second variation is a speed variation from a second initial speed to a second target speed, wherein the first initial speed is different from the second initial speed and/or the first target speed is different from the second target speed;

    wherein the control unit (17) is configured to control the conveying device (5) and/or the tensioning device (32) and/or the package forming unit (16) so that an advancement acceleration of the tube (3) equals a predefined acceleration value during both the first variation and the second variation.

2. The packaging machine (1) according to claim 1, wherein the control unit (17) is configured to control the conveying device (5) and/or the tensioning device (32) and/or the package forming unit (16) so that, once the first target speed has been reached, the advancement acceleration of the tube (3) is brought to zero, and, once the first target speed has been reached, the advancement acceleration of the tube (3) is brought to zero

3. The packaging machine (1) according to claim 1 or 2, wherein the control unit (17) is configured to control the conveying device (5) and/or the tensioning device (32) and/or the package forming unit (16) so that:

    - either the first target speed is greater than the first initial speed and the second target speed is greater than the second initial speed, or the first target speed is lower than the first initial speed and the second target speed is lower than the second initial speed; and
    - the tube (3) does not undergo a stop between the first time period and the second time period.

4. The packaging machine (1) according to any one of the preceding claims, wherein an absolute value of the first variation is greater than an absolute value of the second variation, and wherein the first time period is greater than the second time period.

5. The packaging machine (1) according to any one of the preceding claims, wherein the control unit (17) is configured to control the sealing device so as to change a sealing power delivered by the sealing device, as a function of said variation of the advancement speed,

    wherein the control unit (17) is configured to control an increase in the sealing power delivered by the sealing device, responsive to an increase in said advancement speed, and/or a decrease in the sealing power delivered by the sealing device, responsive to a decrease in said advancement speed.

6. The packaging machine (1) according to claim 5, wherein the control unit (17) is configured to control

the sealing device such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the sealing power delivered by the sealing device and the advancement speed is constant.

7. The packaging machine (1) according to any one of the previous claims, wherein the package forming unit (16) comprises: a plurality of operative assemblies (61), a plurality of counter-operative assemblies (62), a track adapted to advance the operative assemblies (61) and the counter-operative assemblies (62) along respective conveying paths,

wherein each operative assembly (61) and the respective counter-operative assembly (62) are configured to cooperate with one another to shape, transversally seal and transversally cut the tube (3) for forming the packages (2), and comprises:

- a half-shell (63) adapted to contact the tube (3) and to at least partially define the shape of the packages (2);
- one of a sealing element (64) or a counter-sealing element (65), adapted to transversally seal the tube (3) between adjacent packages (2) for obtaining transversal seal portions (66); and
- one of a cutting element or a counter-cutting element for transversally cutting the tube (3) between adjacent packages (2),

wherein the control unit (17) is configured to control the sealing element (64) of each operative assembly (61) so as to change a sealing power delivered by the sealing element (64), as a function of said variation of the advancement speed,
wherein the control unit (17) is configured to control an increase of the sealing power delivered by the sealing element (64) of each operative assembly (61), responsive to an increase of said advancement speed, and/or to control a decrease of the sealing power delivered by the sealing element (64) of each operative assembly (61), responsive to a decrease of said advancement speed.

8. The packaging machine (1) according to claim 7, wherein the control unit (17) is configured to control the sealing element (64) of each operative assembly (61) such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the sealing power delivered by the sealing element (64) and the advancement speed is constant.

9. The packaging machine (1) according to any one of the previous claims, comprising a sterilization apparatus including an irradiation device configured to sterilize at least a first face of the advancing web (4) of packaging material by directing a sterilizing irradiation onto at least the first face while, in use, advancing along a sterilization portion of the web advancement path,

wherein the control unit (17) is configured to control the sterilization apparatus so to change an irradiation power delivered by said sterilization apparatus, as a function of said variation of the advancement speed,
wherein the control unit (17) is configured to control an increase of the irradiation power delivered by the sterilization apparatus, responsive to an increase of said advancement speed, and/or to control a decrease of the irradiation power delivered by the sterilization apparatus, responsive to a decrease of said advancement speed.

10. The packaging machine (1) according to claim 9, wherein the control unit (17) is configured to control the sterilization apparatus such that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the irradiation power delivered by the sterilization apparatus and the advancement speed is constant.

11. The packaging machine (1) according to any one of the previous claims, comprising a folding unit configured to receive the packages (2) from the package forming unit (16) and for producing folded packages, wherein the folding unit comprises an endless conveyor for feeding the packages (2) continuously along a folding path from a supply station to an output station, first folding means which cooperate cyclically with each package (2) to perform folding operations, second folding means which cooperate cyclically with each package (2) to perform further folding operations, and a heating device,

wherein the control unit (17) is configured to control the folding unit so to change a heating power delivered by the heating device of the folding unit, as a function of said variation of the advancement speed,
wherein the control unit (17) is configured to control an increase of the heating power delivered by the heating device of the folding unit, responsive to an increase of said advancement speed, and/or to control a decrease of the heating power delivered by the heating device of the folding unit, responsive to a decrease of said advancement speed,
wherein the control unit (17) is configured to control the heating device of the folding unit such

that during the first variation of the advancement speed and during the second variation of the advancement speed, a ratio between the heating power delivered by the heating device of the folding unit and the advancement speed is constant.

12. The packaging machine (1) according to any one of the previous claims, comprising:

- a delimiting element (40) arranged, in use, within the tube (3) and designed to divide the tube (3) in a first space (41) being in fluidic connection with the inner environment (11) and a second space (42) being arranged downstream of the first space (41) along the tube advancement path;
- a pressurizing device (43) configured to direct, in use, a flow of sterile gas into the second space (42) for obtaining a second gas pressure within the second space (42) that is higher than a first gas pressure within the first space (41), wherein the control unit (17) is configured to control the pressurizing device (43) to vary the second gas pressure during the first variation of the advancement speed and during the second variation of the advancement speed.

13. The packaging machine (1) according to any one of the previous claims, wherein the package forming unit (16) is configured to operate cyclically leading to a cyclic profile of the advancement speed of the tube (3), and wherein the packaging machine (1) further comprises a tensioning device (32) arranged upstream of the tube forming device (13) along the web advancement path (P) and including:

- a main drive roller (33) rotatable around a main rotation axis;
- a main drive motor configured to actuate rotation of the main drive roller (33) around the main rotation axis;

wherein the control unit (17) is configured to control the main drive motor such that an angular speed of the main drive roller (33) is cyclically varied, and an advancement speed of the web (4) repeats according to a defined frequency.

14. A method for forming a plurality of sealed packages (2) filled with a pourable product, the method comprising the following steps:

- advancing a web (4) of packaging material along a web advancement path (P), through a conveying device (5);
- forming a tube (3) from the advancing web (4) of packaging material, through a tube forming device (13) extending along a longitudinal axis and being at least partially arranged within an inner environment (11) of an isolation chamber (10) containing a sterile gas;
- advancing the tube (3) along a tube advancement path (Q) ;
- longitudinally sealing the tube formed by the tube forming device (13) through a sealing device, being at least partially arranged within the inner environment (11) of the isolation chamber (10);
- continuously filling the tube (3) with a pourable product, through a filling device (15);
- forming and transversally sealing the packages (2) from the advancing tube (3), through a package forming unit (16) ;
- controlling the tension of the web (4) of packaging material and/or of the tube (3) through a tensioning device (32),

characterized in that it further comprises:

- varying an advancement speed of the tube (3) according to a first variation lasting a first time period,
- varying the advancement speed of the tube (3) according to a second variation lasting a second time period,

wherein the first time period is different from the second time period;
wherein the first variation is a speed variation from a first initial speed to a first target speed, and the second variation is a speed variation from a second initial speed to a second target speed, wherein the first initial speed is different from the second initial speed and/or the first target speed is different from the second target speed;
wherein an advancement acceleration of the tube (3) equals a predefined acceleration value during both the first variation and the second variation.

15. The method according to claim 14, further comprising the following steps:

- following the first variation, keeping the advancement speed of the tube (3) at the first target speed for an amount of time;
- following the second variation, keeping the advancement speed of the tube (3) at the second target speed for an amount of time.

16. The method according to claim 14 or 15, wherein:

- the first initial speed is zero, the second initial speed is zero, the first target speed and second target speed are different from zero and from

one another, or
- the first target speed is zero, the second target speed is zero, the first initial speed and the second target speed are different from zero and from one another.

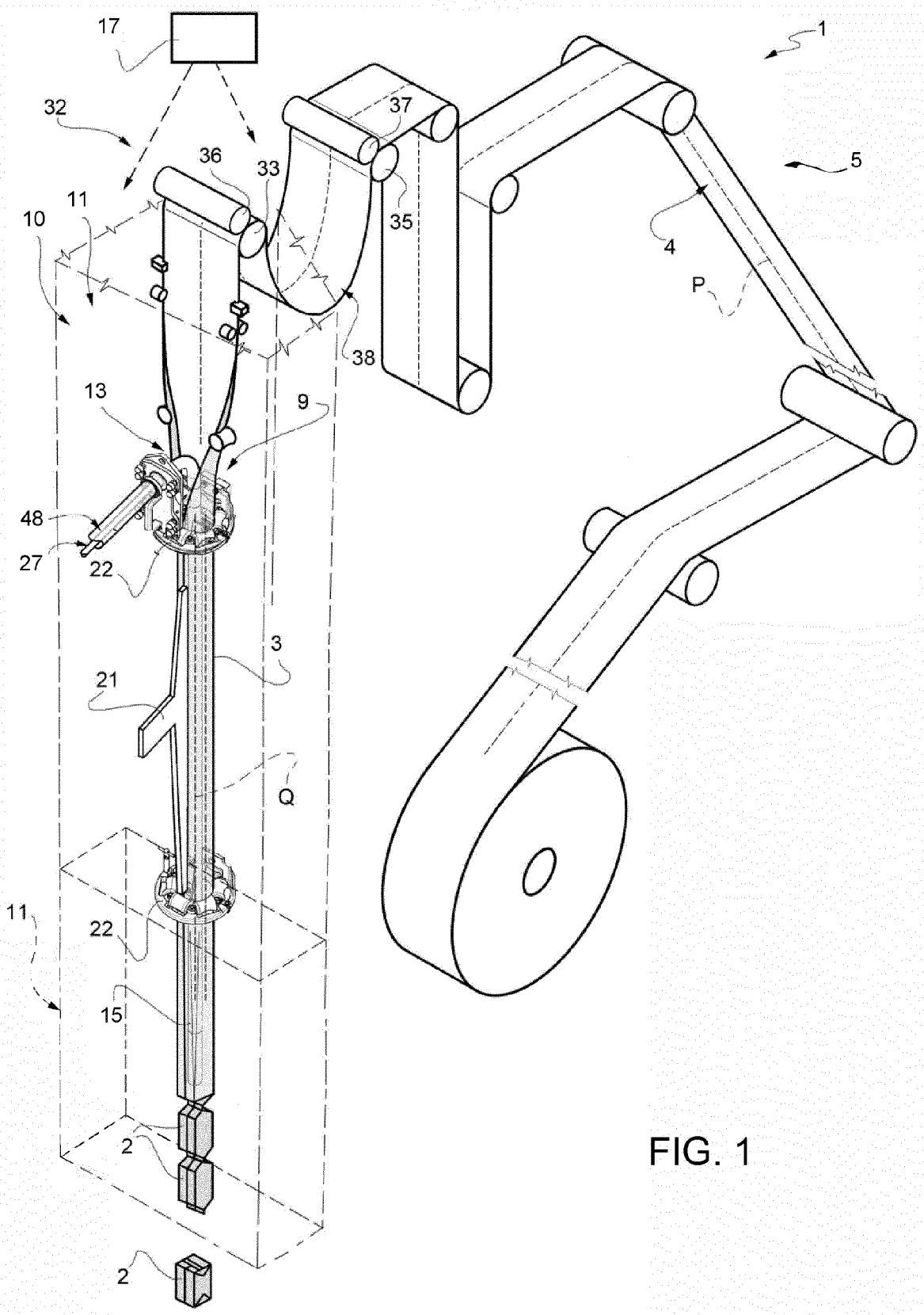
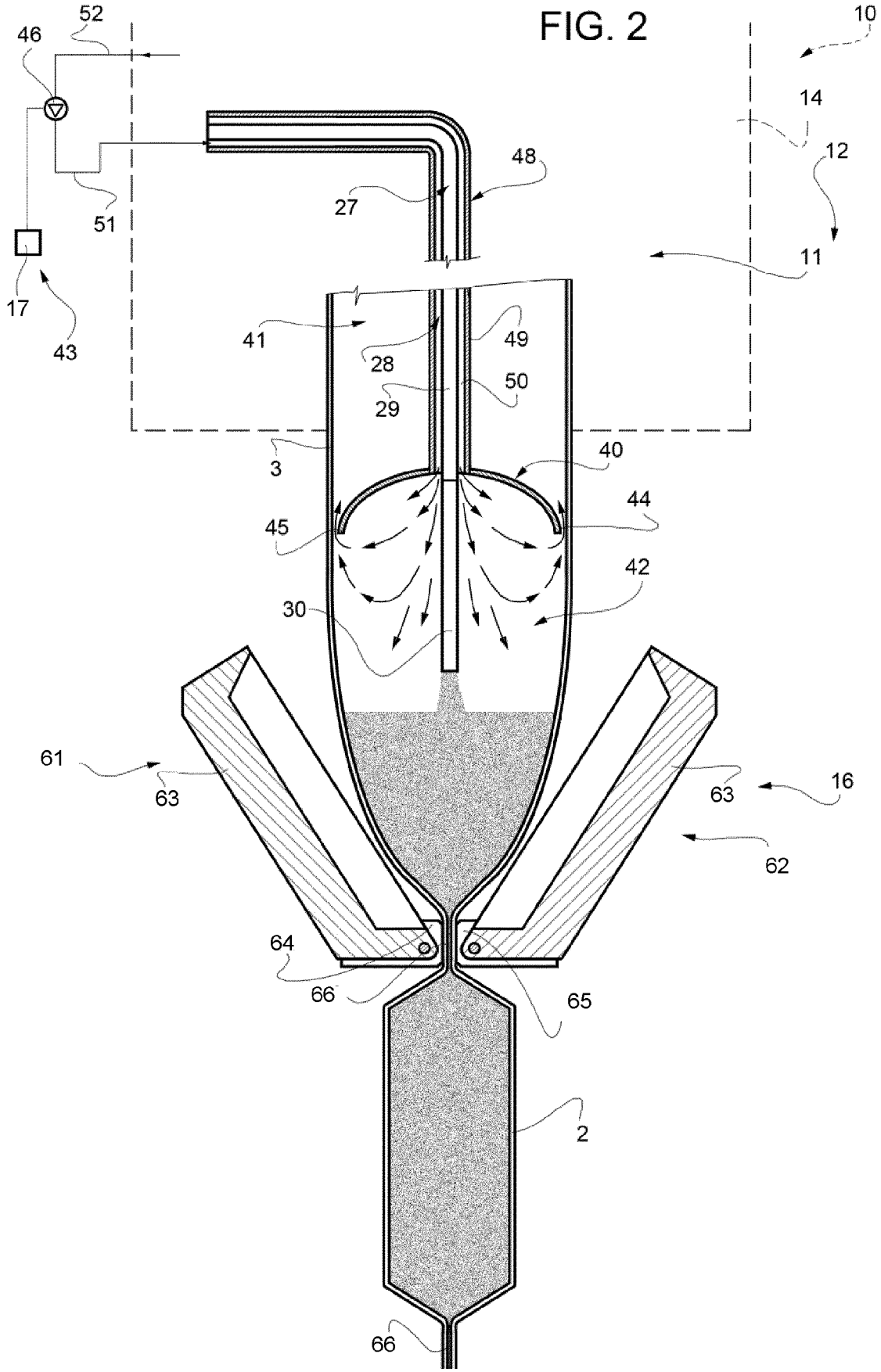


FIG. 1

FIG. 2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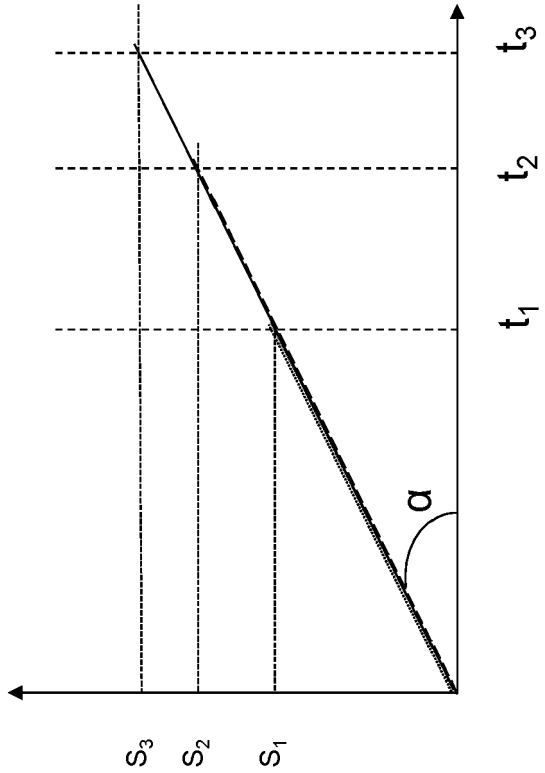

Fig. 4

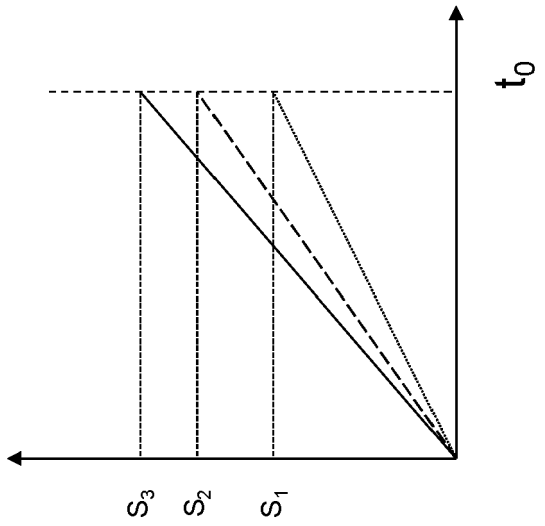

Fig. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 24 16 9371

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	5 September 2024	Paetzke, Uwe

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