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(54) **Continuous wire galvanizing method and corresponding galvanizing machine**

(57) Continuous wire galvanizing method for at least one wire that comprises the stages of cleaning wire (3), induction heating to a first temperature, cooling to a second lower temperature, galvanizing and draining, with said heating, cooling and galvanizing stages being carried out independently and separately for each of said wires (3) in an inert atmosphere. In the cleaning stage, wire (3) passes through a first bath (26) with a phosphoric acid aqueous solution, wherein wire (3) is cleaned by ultrasound. Also the method comprises a drying stage by evaporating the liquid from the surface of wire (3) between the cleaning and heating stages. The invention also proposes a machine for putting the method into practice.

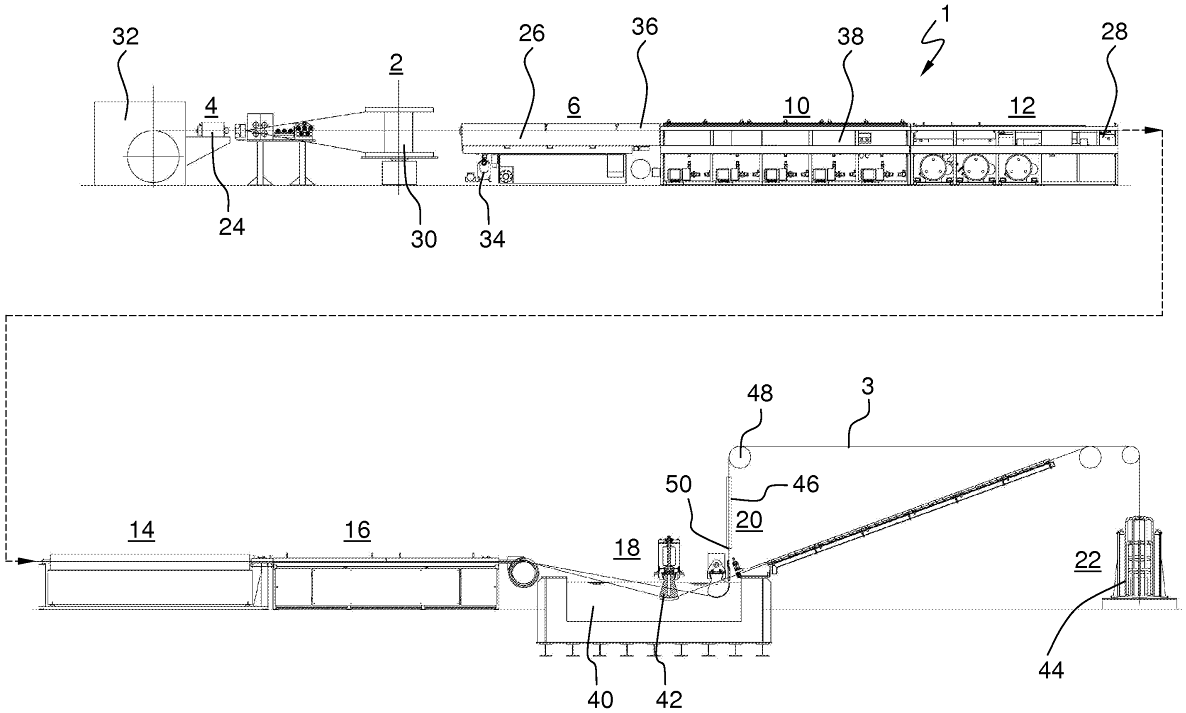

FIG. 1

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Description

Field of the invention

[0001] The invention relates to a continuous continuous wire galvanizing method for at least one wire that comprises the following stages: cleaning the surface of said wire, induction heating to a first temperature, cooling to a second temperature lower than said first temperature, galvanizing and final draining of said wire, with said heating, cooling and galvanizing stages being carried out individually and separately for each of said wires in an inert atmosphere.

[0002] Also the invention relates to a continuous wire galvanizing machine comprising a cleaning station, an induction oven for heating at least one wire to a first temperature, a cooling station for cooling said wire to a second temperature lower than said first temperature and a galvanizing station, with said induction oven, said cooling station and said galvanizing station being under an inert atmosphere and with said wire passing through the inside of a duct being guided under said inert atmosphere, and extending through said induction oven, said cooling station, into said galvanizing station.

State of the art

[0003] From document US 6,491,770, a method and a continuous wire galvanizing machine in an inert atmosphere are known. The machine comprises in a series a cleaning station, a first induction heating chamber, a second cooling chamber downstream from the heating chamber and finally a third chamber downstream from the cooling chamber.

[0004] The three chambers are connected to each other and they are under an inert atmosphere to prevent the wire from oxidising during the processing, due to the high temperatures.

[0005] Furthermore, in the cleaning station the wire is drawn through an alkaline bath of sodium hydroxide and sodium bicarbonate. The cleaning station obliges the wire to remain there a certain time so that the following stages of the method can be carried out correctly. Therefore, this method suffers from the drawback that it cannot be applied to continuously galvanizing wires at high speed. Furthermore, the residue from the alkaline bath are difficult to manage in ecological terms. Also the long time the wire remains in the bath means large size facilities have to be available. Evidently, the fact that a machine requires a greater space has considerable effect on the final cost of the processed product, as it must be placed in larger facilities.

Disclosure of the invention

[0006] The aim of the invention is to provide a continuous wire galvanizing method of the type indicated at the beginning, which allows processing the wire at high speeds and which at the same time is more efficient and environmentally friendly than the known methods. Another aim of the invention is to provide a machine for putting the method into practice, which also optimises the space necessary for carrying out the method.

[0007] This aim is achieved by means of a continuous wire galvanizing method of the type indicated at the beginning, **characterized in that** in said cleaning stage said wire passes through a first bath containing a phosphoric acid aqueous solution, wherein said wire is cleaned by ultransounds and in that said method also comprises a drying stage by evaporating the liquid from the surface of said wire, said drying stage being provided between said cleaning stage and said heating stage.

[0008] The cleaning unit using the phosphoric acid and ultrasound, allows cleaning the soap remains that have been deposited on the surface of the wire during the wire drawing process prior to the method described herein. In addition, the phosphoric acid prepares the surface of the wire by means of chemical etching, which facilitates better zinc adherence to the surface of the wire.

[0009] Cleaning in an aqueous solution of phosphoric acid, preferably in a proportion lower than 7,5% by weight, applying simultaneously ultrasounds to the bath, allows reducing the time the wire remains in the bath, which has a positive effect both on the size of the wire processing machine, and on the processing speed, with the processing speed being considerably increased.

[0010] Another advantage associated with the invention consists in that the energy consumed by the bath is less. The solution only has to be heated between 45 ºC and 55 ºC, whereas the traditional alkaline bath must be heated to 90ºC. Furthermore, due to the lower temperature, in the bath there are fewer losses of reactant through evaporation.

[0011] The alkaline cleaning produces aggressive residues. Therefore, another additional advantage of the method according to the invention, consists in the fact that the cleaning with phosphoric acid is much less aggressive, and its residues are much more environmentally friendly. Also for the operator, the phosphoric acid is more ergonomic, as it is not harmful or irritant. Furthermore, the neutralization of the phosphoric acid is simpler and its elimination costs by reduction are much less than in other options.

[0012] Furthermore, the wire vacuum drying by evaporation allows entering the heating stage without loosing speed, as the drying is specially fast. A deficient drying leads to significant losses in the induction oven for heating, as part of the power applied to heat the wire is lost in evaporating the water that remains on the surface of the wire. By contrast, in the invention thanks to the effect of the vacuum the drying of the wire is carried out at very low temperatures and the wire enters the heating stage in a dry state, which naturally leads to a reduction in energy costs. This is due to availing of all the energy of the induction oven applied to the wire, as losses do not occur through burning or evaporating other elements such as water, soaps, oils, emulsions, cutting fluid, etc.

[0013] Also, the invention covers a series of preferable characteristics which are the object of the depending claims and the use of which will be highlighted later in the detailed description of an embodiment of the invention.

[0014] Preferably said vacuum drying stage is carried out inside a drying device that comprises a chamber traversed by said wire, there being created in said chamber a negative vacuum pressure between 500 and 1000 mbar. In these ranges of depression the evaporation is produced at atmospheric temperature.

[0015] Preferably the method further comprises a pre-cleaning stage of said wire, prior to said cleaning stage, wherein the surface of said wire is scrapped and cleaned by means of a cleaning substance when passing through a scrapping device and in a specially preferable way said scrapping device in said pre-cleaning stage is a drawing die. This has the advantage of reducing the amount of dirt prior to dipping the wire into the first bath in the cleaning stage. In particular, the cleaning is an alkaline bath requires that the wire remains in the bath approximately 10 seconds, whereas thanks to the combination of a pre-cleaning stage by scrapping together with the cleaning by ultrasounds in an acid bath, the residency time is reduced to approximately 2 seconds.

[0016] The pre-cleaning allows preparing the extent of dirt that exists on the wire. This dirt comes from the sodium and calcium stearates that are used in the process for lubricating the wires during the wire drawing process. The ideal degree of cleaning to be obtained via the pre-cleaning unit is 0.5 to 1 g/m^2.

[0017] Preferably the method further comprises a first draining stage, at the exit of said cleaning stage, by projecting a gas or fluid blown by a nozzle onto the surface of said wire, with the excess liquid on said wire being returned to said first bath and with said method further comprising a rinsing stage after said draining stage and prior to said drying stage. Preferably, the wire passes through the nozzle, so that the surface can be drain in a uniform manner. The nozzle allows guaranteeing the state of the rinsing bath in perfect conditions as the transfer and consequently the contamination of the rinsing bath by phosphoric acid aggregate is avoided.

[0018] Advantageously the method comprises a second draining stage by passing said wire through a draining device at the exit of said galvanizing stage for removing the excess coating deposited on the surface of said wire and a cooling stage of said coating by passing said wire through a vacuum chamber for cooling with a cooling liquid. This allows even and concentrated layer thicknesses, and also less maintenance for this draining stage in the machine. It is worth mentioning that in the state of the art, usually this draining is carried out using scrapping pads known in the art as "pads", which need the operator to spend a long time adjusting and retightening. This adjustment operation is a delicate and dangerous task for the operator.

[0019] As already mentioned, another objective of the invention consists in providing a machine that allows galvanizing wire continuously according to the proposed method. This aim is achieved by means of a continuous wire galvanizing machine of the type indicated at the beginning, **characterized in that** said cleaning station comprises a first bath with a phosphoric acid aqueous solution and an ultrasound generating device for cleaning the surface of said wire and in that said machine further comprises a drying station with a drying device by evaporation downstream from said cleaning station. Preferably the solution comprises phosphoric acid in a proportion less than 7.5% by weight and in a specially preferable way, in a proportion of 2% by weight. Furthermore, it is worth mentioning that the machine can process several wires at a time in parallel.

[0020] Advantageously, the machine also comprises a pre-cleaning stage that comprises a device for scrapping the surface of said wire arranged upstream from said washing station.

[0021] Advantageously the vacuum drying device by evaporation comprises a chamber traversed by said wire, with said drying device being suitable for creating a negative vacuum pressure between 500 to 1000 mbar. The chamber consists of a tube that is traversed by the wire to be dried originating from the cleaning bath, in the inside of which a negative depression is created, by applying a liquid ring vacuum pump and some guides adjusted to the size of the wire to be processed. This causes the water to evaporate at room temperature within the drying chamber due to the negative pressure created inside it.

[0022] Preferably the machine comprises a first draining station between said cleaning station and said drying station which comprises a nozzle that is adaptable to projecting a gas or liquid onto the surface of said wire.

[0023] Preferably the machine comprises a second draining station at the exit of said galvanizing station, with said second draining station comprising at least one draining device for removing the excess coating deposited on the surface of said wire and a vacuum chamber for cooling with a cooling liquid.

[0024] Also, the invention covers other detail characteristics illustrated in the detailed description of an embodiment of the invention and in the accompanying figures.

Brief description of the drawings

[0025] Other advantages and characteristics of the invention can be appreciated from the following description, wherein, in a non-limiting manner, a preferable embodiment of the invention is described, with reference to the accompanying drawings.

[0026] The figures show:

Fig. 1, a schematic front view of a continuous wire galvanizing machine according to the invention.

Fig. 2, a top plan view of the machine in Figure 1.

Detailed description of an embodiment of the invention

[0027] The figures show the continuous wire galvanizing machine 1 according to the invention which for greater clarity is shown in two parts which in practice are assembled in series, but which in the figures have been joined together by a dotted line. Furthermore, in the figures, also in the interest of simplicity, one single wire 3 to be processed is shown, although preferably machine 1 is also suitable for processing several wires 3 in parallel simultaneously. It is worth mentioning that from the delivery station 2 to the bath in which they are galvanized, each wire is led and guided independently and separately.

[0028] In a delivery station 2, wire 3 to be processed is extracted from a coil 30 and led to a pre-cleaning station 4. In the pre-cleaning station 4 wire 3 passes through a scrapping device 24. Scrapping device 24 consists of a drawing die carrier for each individual wire, wherein the drawing die has the diameter of wire 3 to be processed originating from a previous wire drawing stage, which together with the action of a cleaning product, causes most of the soaps, that have been deposited during the previous wire drawing process, to be removed. After the drawing, the surface of wire 3 has sodium and calcium stearates from lubrication which must be removed in order to guarantee a correct galvanization. The purpose of the pre-cleaning station 4 is to scrape the surface of wire 3 in order to obtain a reduction in the stearates of the order of 0.5 to 1 g/m^2. Thanks to this pre-cleaning stage, the subsequent cleaning can be carried out at a greater speed.

[0029] Subsequent to the pre-cleaning stage, wire 3 passes via an unwinding reel 32 to the cleaning station 6 wherein a cleaning stage is carried out. In this embodiment, in cleaning station 6 wire 3 is dipped in a first bath 26 containing a phosphoric acid aqueous solution at 2% by weight. Cleaning station 6 comprises an ultrasound generating device 34 that subjects wire 3 to an ultrasound treatment during its passage through first bath 26 which intensifies the cleaning. On the one hand, the cleaning stage allows removing the stearates that have not been removed in the pre-cleaning stage, and on the other handy it slightly etches the surface of wire 3 so as to improve the adherence of the zinc in a subsequent galvanizing stage. This cleaning stage 6 allows passing wire 3 at high speed as in the embodiment shown it only needs a residency time of 2 seconds in first bath 26. Also, the phosphoric acid solution only needs to be heated to between 45º and 55º, thereby improving energy consumption with respect to traditional alkaline baths and reducing reactant losses through evaporation. Finally it is worth highlighting that the phosphoric acid is not harmful, or irritant, and that its removal is easier and more economical.

[0030] At the exit of first bath 26, wire 3 passes through a draining stage in a draining station 8 via a nozzle 36, that projects a gas onto the surface of wire 3. Nozzle 36 can be either a subsonic nozzle, or a supersonic one. This removes the liquid coming from first bath 26 from the surface of wire 3. This introduces essentially two advantages: the first consists in that the following stages of the method do not become contaminated with phosphoric acid, and the second consists in the fact that the phosphoric acid solution is not unnecessarily drawn from the cleaning stage, whereby the consumption of the acid solution from first bath 26 is reduced. If it desirable to specially avoid any type of corrosion of the surface, optionally the gas used can be nitrogen.

[0031] After passing through draining station 8, wire 3 passes through a rinsing stage in a rinsing station 10 wherein wire 3 passes through a second bath 38 of water. This rinsing allows removing any residue of phosphoric acid that may be on the surface of wire 3, in spite of the previous draining by means of nozzle 36.

[0032] At the end of the rinsing stage in second bath 38, wire 3 passes through a drying stage by means of a drying device 28. In detail, drying device 28 consists in passing wire 3 through a tubular shaped vacuum chamber. Thanks to the effect of the vacuum, the liquid evaporates at room temperature. Thus drying energy is saved and furthermore wire 3 enters the following heating stage completely dry. The correct drying allows processing wire 3 at high speeds, since the total absence of humidity allows that the induction oven does not consume additional power to evaporate the rinsing water or to burn lubrication products from previous stages or from the drawing.

[0033] One of the problems associated with the galvanizing of steel wire through hot dipping in a zinc bath, consists in the inherent risk that wire 3 oxidises prior to the galvanizing stage. The risk of oxidisation is specially high in those stages where wire 3 is worked at high temperatures above 450 ºC. The oxidisation of the surface of wire 3 leads to faulty galvanizing with surface defects. Therefore, after the drying stage, wire 3 passes through a heating stage in an induction oven 14 in an inert atmosphere. Preferably each processed wire 3 passes through an individual tubular-shaped passage that extends between the entrance in the induction oven 14 and the entrance to the third bath 40 which contains zinc. In these passages an inert atmosphere is created by continually introducing nitrogen in the direction contrary to the wire conveying direction, in other words, in the direction of third bath 40 containing zinc towards induction oven 14, which guarantees the absence of oxygen in this stage of the method.

[0034] In induction oven 14 wire 3 undergoes an annealing or austenitizing treatment at a first temperature of approximately 750ºC in the case of annealing, or 1000ºC for austenitizing. The purpose of this treatment is to reduce any internal tension in the wire which may have been produced during the drawing stage prior to the method described herein.

[0035] At the exit of induction oven 14 wire 3 passes through a gradual cooling stage inside the same tubular passage independent of induction oven 14 to a second temperature close to the temperature of the zinc in liquid state, in other words, approximately 460ºC. This stage is also carried out in an inert atmosphere to prevent the possible oxidisation caused by the temperature.

[0036] From the cooling stage, wire 3 enters directly, still in an inert atmosphere, into the galvanizing stage. Here, wire 3 is dipped in a third bath 40 containing zinc, guided under a wire guiding device known in the art as a sinker 42. As already mentioned, machine 1 according to the invention is provided for processing multiple wires 3 simultaneously. So, preferably machine 1 comprises an individual sinker 42 for each wire 3 processed, with each of said sinkers 42 being movable between a dipped position wherein it is suitable for guiding said wire 3 dipped in said third bath 40 and a withdrawn position wherein said sinker 42 is above the surface of said third bath 40. This is specially advantageous because each of the sinkers 42 can rise or descend independently, so that the operator can thread wire 3 horizontally and then lower sinker 42. This considerably improves safety when using machine 1, as in the case of integral fixed sinkers for all the processed wires, which are common in the art, the worker is obliged to thread the wire by dipping it into the zinc bath and passing it under sinker 42. Individual and movable sinkers 42 are also advantageous for periods when there is no production. During these periods, sinker 42 rises and wire 3 remains above the bath. Thanks to this, wire 3 does not deteriorate by remaining submerged although it does not pass through machine 1.

[0037] Once wire 3 comes out of third bath 40 containing liquid zinc it passes through a polycrystalline drawing die 50 for draining, into a chamber 46 or vertical tube that has a vacuum, inundated by a cooling liquid, such as water, which reduces the excess liquid or semi-liquid zinc layer according to the diameter of its interior calibre. On the opposite side to the entrance of wire 3, the polycrystalline drawing die 50 is in contact with cold water which acts as a cooling element for the drawing die 50 and at the same time solidifies the liquid or semi-liquid zinc. This prevents damaging the galvanized layer before entering pulleys 48 and subsequent guidings, on the way towards the final take-up stage. Also with this, high processing speeds can be reached without losing galvanizing quality or concentricity with respect to wire 3. As an alternative to the polycrystalline die other draining devices can be used such as pads, gas jet nozzles also known as jet wipes or electromagnetic draining systems.

[0038] It is also worth mentioning that thanks to the vacuum existing in cooling chamber 46, the cooling height is drastically reduced, which allows building a more compact machine, but mainly allows hugely increasing the processing speed of wire 3, as with conventional cooling systems it would not be possible to work at such a high speed, in view of the height of the cooling jets that would be necessary.

[0039] Finally, wire 3 now coated can pass through an optional waxing stage, and it is led to a winding device 44 where galvanized wire 3 is shaped in a roll.

[0040] In this embodiment machine 1 succeeds in processing wire 3 at a speed of 450 m/min, which speed is much higher than in the state of the art machines which usually process the wire at speeds of about 120 to 180 m/min

Claims

1. Continuous wire galvanizing method for at least one wire that comprises the following stages :

   [a] cleaning the surface of said wire (3),
   [b] induction heating to a first temperature,
   [c] cooling to a second temperature lower than said first temperature ,
   [d] galvanizing and
   [e] final draining of said wire (3),

   with said heating, cooling and galvanizing stages being carried out individually and separately for each of said wires (3) in an inert atmosphere, **characterized in that** in said cleaning stage said wire (3) passes through a first bath (26) containing a phosphoric acid aqueous solution, wherein said wire (3) is cleaned by ultrasounds and **in that** said method also comprises a vacuum drying stage by evaporating the liquid from the surface of said wire (3), said vacuum drying stage being provided between said cleaning stage and said heating stage.

2. Method according to claim 1, **characterized in that** said solution comprises phosphoric acid in a proportion less than 7.5% by weight.

3. Method according to claim 1 or 2, **characterized in that** said vacuum drying stage is carried out inside a drying device (28) that comprises a chamber traversed by said wire (3), there being created in said chamber a negative vacuum pressure between 500 and 1000 mbar.

4. Method according to any of the claims 1 to 3, **characterized in that** it further comprises a pre-cleaning stage of said wire (3), prior to said cleaning stage, wherein the surface of said wire (3) is scrapped and cleaned by means of a cleaning substance when passing through a scrapping device (24).

5. Method according to claim 4, **characterized in that** said scrapping device (24) in said pre-cleaning stage is a drawing die.

6. Method according to any of the claims 1 to 5, **characterized in that** it further comprises a first draining stage, at the exit of said cleaning stage, by projecting a gas or fluid blown by a nozzle (36) onto the surface of said wire (3), with the excess liquid on said wire

(3) being returned to said first bath (26) and with said method further comprising a rinsing stage after said draining stage and prior to said drying stage.

7. Method according to any of the claims 1 to 6, **characterized in that** it comprises a second draining stage by passing said wire through a draining device at the exit of said galvanizing stage for removing the excess coating deposited on the surface of said wire (3) and a cooling stage of said coating by passing said wire (3) through a vacuum chamber for cooling with a cooling liquid.

8. Continuous wire galvanizing machine comprising a cleaning station (6), an induction oven (14) for heating at least one wire (3) to a first temperature, a cooling station (16) for cooling said wire (3) to a second temperature lower than said first temperature and a galvanizing station (18), with said induction oven (14), said cooling station (16) and said galvanizing station (18) being under an inert atmosphere and with said wire (3) passing through the inside of a duct being guided under said inert atmosphere, and extending through said induction oven (14), said cooling station (16), into said galvanizing station (18), **characterized in that** said cleaning station (6) comprises a first bath (26) with a phosphoric acid aqueous solution and an ultrasound generating device for cleaning the surface of said wire (3) and **in that** said machine (1) further comprises a drying station (12) with a vacuum drying device (28) by evaporation downstream from said cleaning station (6).

9. Galvanizing machine according to claim 8, **characterized in that** said solution comprises phosphoric acid in a proportion less than 7.5% by weight.

10. Galvanizing machine according to claim 8 or 9, **characterized in that** it further comprises a pre-cleaning station (4) that comprises a scrapping device (24) for the surface of said wire (3) arranged upstream from said washing station (6).

11. Galvanizing machine according to any of the claims 8 to 10, **characterized in that** said vacuum drying device (28) by evaporation comprises a chamber traversed by said wire (3), with said drying device (28) being suitable for creating a negative vacuum pressure between 500 to 1000 mbar.

12. Galvanizing machine according to any of the claims 8 to 11, **characterized in that** it further comprises a first draining station (8) between said cleaning station (6) and said drying station (12) that comprises a nozzle for projecting a gas or fluid onto the surface of said wire (3) at subsonic speed.

13. Galvanizing machine according to any of the claims 8 to 12, **characterized in that** it comprises a second draining station (20) at the exit of said galvanizing station (18), with said second draining station (20) comprising at least one draining device for removing the excess coating deposited on the surface of said wire (3) and a vacuum chamber for cooling with a cooling liquid.

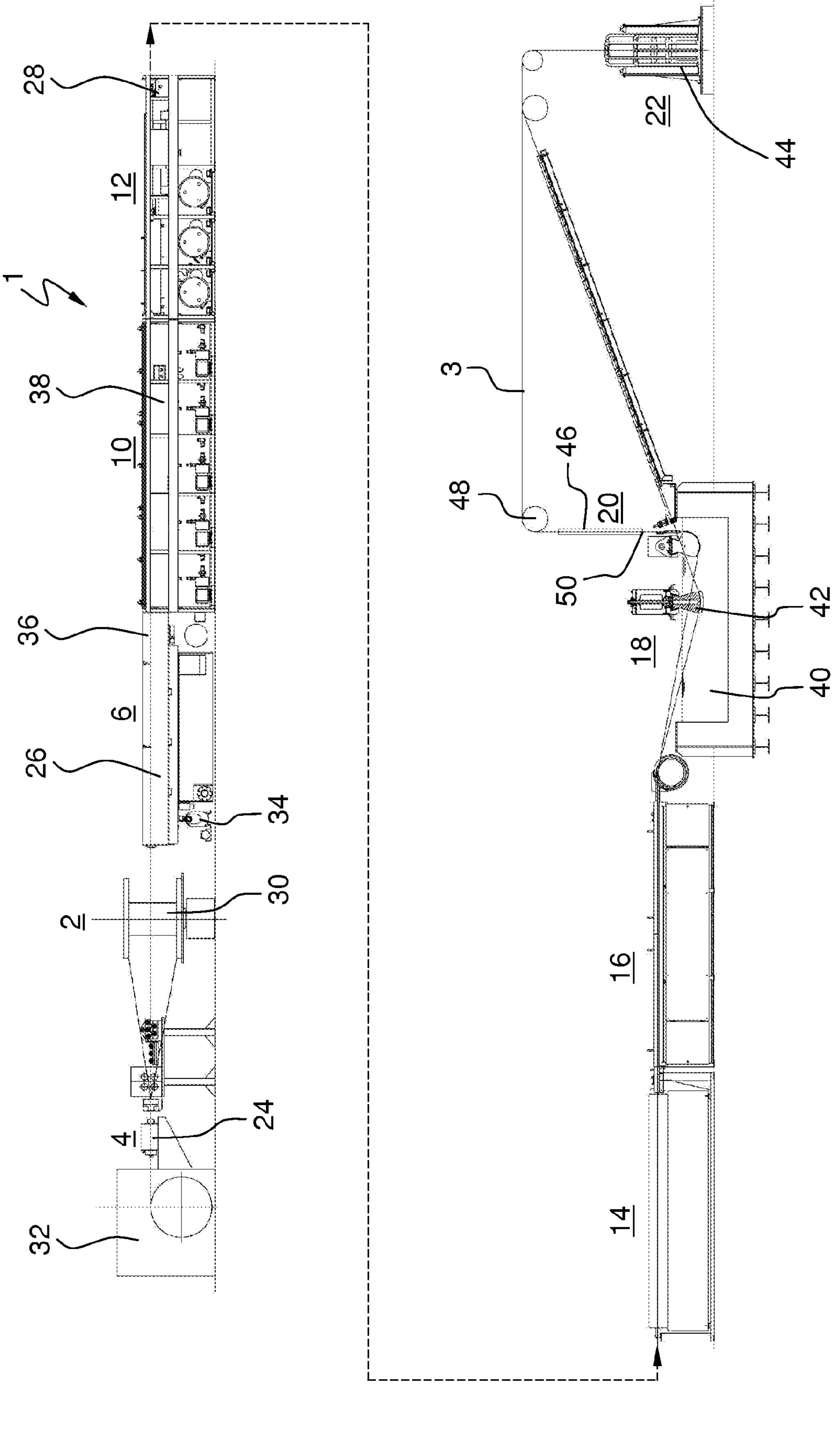

FIG. 1

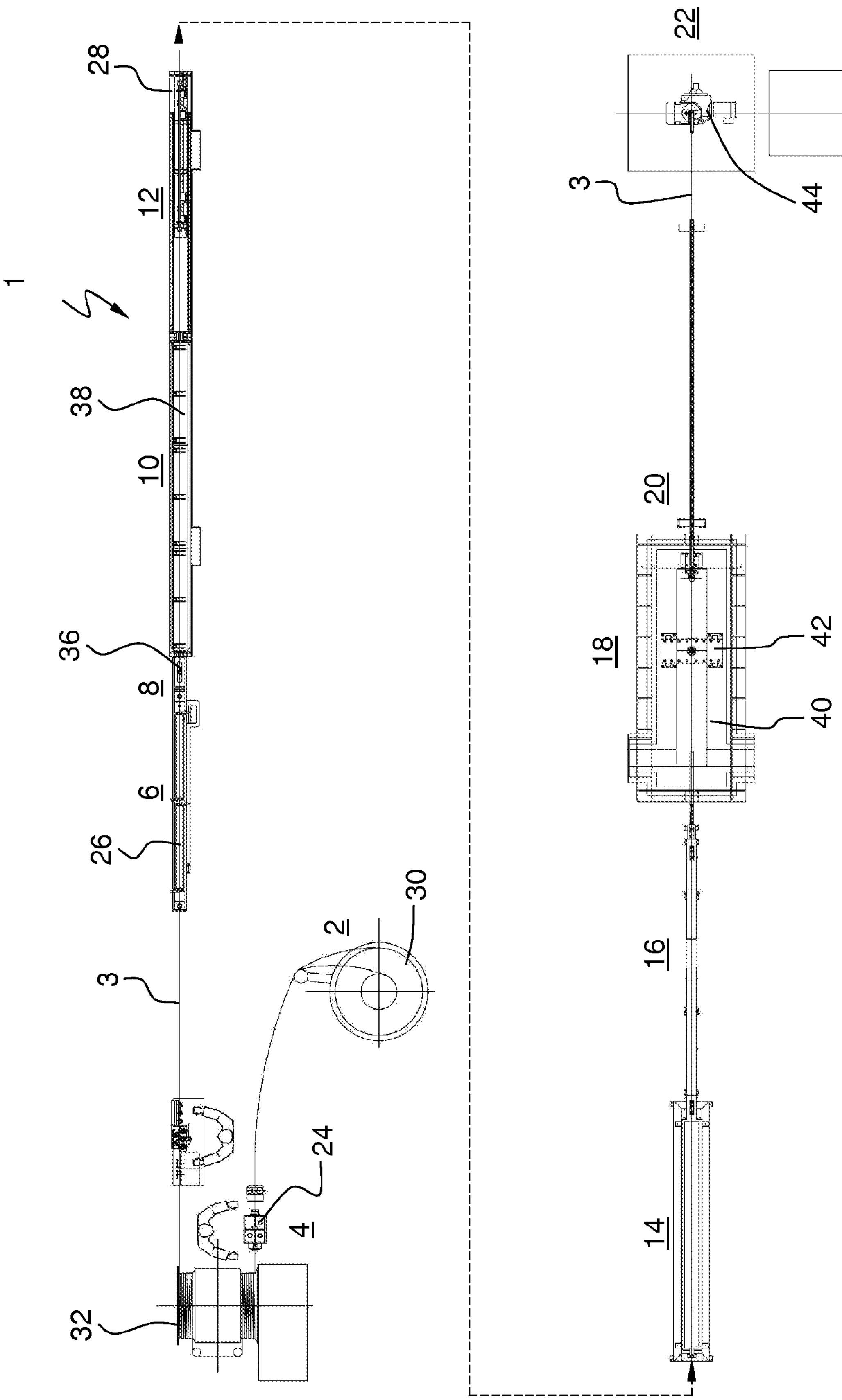

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 10 17 0263

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

C23C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	17 November 2010	Oliveras, Mariana

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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