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(54) **Method and apparatus for coil winding control of a wire shaped element**

(57) A method and an apparatus for coil winding control of a wire have been devised, in which provision is made for a step of winding the wire round the support body (2) in order to generate a winding (4), a step of defining an ideal profile (15) of the winding (4), a step of detecting a real profile (11) of at least one winding (4) portion, a step of comparing the real profile (11) of the winding with the corresponding ideal profile and a subsequent step of correcting the detected real profile of the winding to make it consistent with the defined ideal profile (15). The described method and apparatus enable the real coiling profile to be determined, controlled and corrected, if needed, during winding without the operator's intervention.

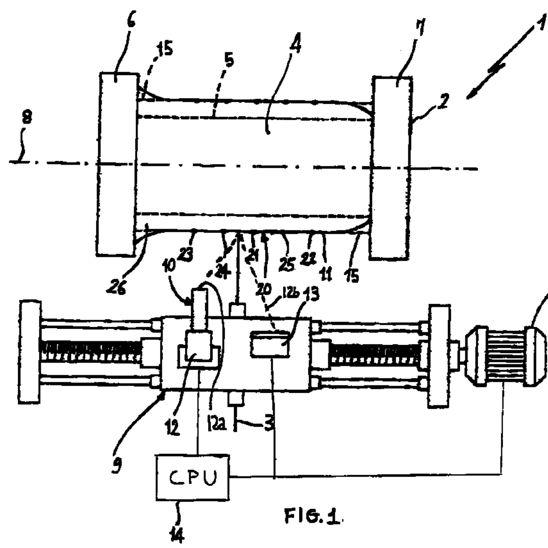

FIG.1

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Description

[0001] The present invention relates to a method and an apparatus for coil winding control of a wire-shaped element.

[0002] In particular, the method and apparatus in reference apply in the field of winding electric wires round reels intended for use in motor and transformer windings and the like.

[0003] However the method and apparatus in question can obviously also apply to windings of wire-shaped elements of different nature, such as telephone cables, electric cables, etc.

[0004] It is known that currently-employed winding apparatuses consist of a support body, generally a reel, intended to form a core for winding of a wire-shaped element.

[0005] The wire-shaped element, which may be a cable, a wire or a ribbon of various kind, is carried by a wire-guiding system capable of guiding it in a coil-making step.

[0006] Practically, the reel is driven in rotation about its own axis, whereas the wire guide carries out a reciprocating motion in a direction parallel to the reel axis.

[0007] Once the wire has been fastened to the reel, rotation of the reel combined with the translational motion of the wire guide gives rise to wire windings along the whole reel extension.

[0008] In order to achieve a coil profile as regular as possible, the rotation speed of the reel and the translation speed of the wire guide are interlocked to each other depending on the geometry and the desired wire distribution pitch.

[0009] It is to note that each reel is then generally provided with two flanges located at the axially opposite ends thereof and intended for retaining the wire windings. The wire guide stroke is directly in relation to the distance between the flanges close to which motion reversal occurs.

[0010] However, a winding thus made has serious drawbacks; it happens in fact that, due both to the extension and/or positioning tolerances of the reels, and to deformations caused by mechanical stresses exerted by the wound wire, un uneven winding profile is generated.

[0011] In more detail, if the previously entered reversal values for the reciprocating motion of the wire guide even slightly deviate from the ideal ones defined by the actual flange positioning, there is, at the areas close to the flanges, either generation of a winding piling up (if the residence time of the wire guide at said area is greater than necessary) or occurrence of a lack of windings (in the opposite case).

[0012] It is well apparent that a winding thus obtained is more subjected to overlapping and/or tension storage in the wires, which condition causes undesired cable breakages and damages during the unwinding step.

[0013] The known art has only partly obviated the above drawbacks by providing the winding apparatus with a photoelectric-cell system arranged to cause motion reversal when a wire guide reaches one flange.

[0014] In more detail, a photoelectric cell positioned on the wire guide coaxially with the cable is capable of detecting the instant that the wire guide reaches a flange thereby causing motion reversal of same.

[0015] In this manner the flange is caused to be correctly intercepted, irrespective of the reel tolerances at each passage of the wire guide so that winding of the wire is as uniform as possible.

[0016] It is to be pointed out however, that the device incorporating a single photoelectric cell appears to be critical in the case in which the reel intended for receiving the winding should have a biconical or triconical profile. As a matter of fact, profiles of this typology are not provided with true flanges, but with axially opposite end regions of an inclined profile; in this case wire guide reversal is determined by interception of the inclined profile of said opposite end regions of the reel by the photoelectric cell.

[0017] Since the photoelectric cell generally operates at a radially outer area relative to the actual winding, a delay occurs in intercepting the reel end regions.

[0018] In other words, the reversal value of the wire guide motion is controlled by the photoelectric cell after the wire has already reached the flange or the reel end region.

[0019] An improvement in the above mentioned photoelectric-cell system is achieved by use of two photoelectric cells mounted integrally with the wire guide at opposite positions relative to the wire guide itself along axes parallel to the reel axis.

[0020] In this apparatus, the photoelectric cell located at the advancing side of the wire guide intercepts the flange some instants before said flange is reached by the wire guide. Knowing the flange position in advance at the reversal instant enables, by setting an appropriate delay time, an increase in the winding precision to be achieved close to the flanges, above all in the case of inclined flanges.

[0021] In reality, winding apparatuses thus conceived suffer from serious drawbacks as well.

[0022] Firstly, it is to point out that use of photoelectric cells for the only purpose of detecting the correct position of the flanges does not enable any checking to be carried out on the actual coil profile. This means that if flanges are repeatedly intercepted in a correct manner and the right delay values have been entered, taking also into account the typology of the used wire and the reel geometry, then a correct winding can be presumed.

[0023] In reality, if one of these values should not be exact or should vary, the final profile would not be regular.

[0024] If for instance a reversal delay were wrong, at the flange-surrounding area a winding piling up or a lack of winding would be generated and consequently an error increasing without control at any subsequent wire winding would occur.

[0025] Possible structure defects and/or errors in positioning the reel in axis and possible radial deformations caused by tension on the coil could not be either controlled or mitigated and possibly eliminated.

[0026] It is also to note that, in case of use of reel profiles of the biconical, triconical or mixed type, the delay values vary on varying of the radial sizes of the coil.

[0027] Therefore since it is possible to previously set variations in the reversal delays, the profile being known, it is apparent that in these cases the winding precision is connected with several different parameters and, without a visual control by an operator, achievement of a good coil profile is rather difficult.

[0028] It is also to note that the photoelectric-cell intercepting system of the flanges operates by recognizing the flange due to its different radial extension relative to the coil extension.

[0029] In the final coil winding steps, that is when the radius difference between the coil and flange is minimum, it happens that the photoelectric cells do not succeed any longer in intercepting the flange both due to coil vibrations during motion (as a result of unhomogeneous mass distributions, for example) and to positioning of the photoelectric cell itself (since said cell is integral with the wire guide, it cannot be close to the flanges in order to avoid a possible interference with the already wound coil).

[0030] Under these conditions, there is the risk that an emptier coil than usually is obtained or that winding must be completed without the aid of any control.

[0031] Therefore, it is an object of the present invention to obviate the above mentioned drawbacks, by providing a method and a related apparatus for coil winding control of easy accomplishment.

[0032] It is a further object of the invention to control the coil profile during winding, while having the possibility of correcting any possible deviation from an ideal profile.

[0033] It is another object of the invention to carry out a method and an apparatus capable of correctly operating with reels of different profiles and sizes, while always ensuring an excellent coil winding.

[0034] The foregoing and further objects that will become more apparent in the progress of the present description are substantially achieved by a method and an apparatus for coil winding control of wire-shaped elements round a support body in accordance with the features recited in the appended claims.

[0035] Further features and advantages will be best understood from the detailed description of a preferred but non-exclusive embodiment of a method and an apparatus for coil winding control in accordance with the present invention. This description will be taken hereinafter with reference to the accompanying drawings given by way of non-limiting example, in which:

- Fig. 1 is a diagrammatic front view of an apparatus in accordance with the present invention;
- Fig. 2 is a detail to an enlarged scale of an error area of a winding profile of the apparatus shown in Fig. 1;
- Fig. 3 is a flow chart of the apparatus shown in Fig. 1.

[0036] With reference to the drawings, an apparatus for coil winding control of a wire-shaped element has been generally identified by reference numeral 1.

[0037] The apparatus consists of a predetermined support body 2, or reel, generally defined by a revolution body around which the wire-shaped element 3 is wound for generating a winding 4.

[0038] Reel 2, as in the example shown in Fig. 1, can have a central body 5 of substantially cylindrical form and two disc-shaped flanges 6,7 of greater radial size than the cylindrical body 5 and located at opposite ends along the longitudinal axis 8 of reel 2.

[0039] In this case the outer surface of the cylindrical body 5 is designed to form the coil core, whereas flanges 6, 7 hold the windings thereby enabling a better laying down of the wire-shaped element 3 at the coil ends.

[0040] Due to this structure of the support body 2, a correct development or shape of the profile during winding of wire 3 is of rectilinear type and parallel to the coil axis.

[0041] Alternatively, the support body 2 can have a different geometry; in typologies more commonly used the central body can be of frustoconical shape, provided with flat flanges (conical coil) or provided with flanges of frustoconical shape as well which are identical (biconical coil) or different (triconical coil).

[0042] In the last-mentioned cases a rectilinear winding profile parallel to the side surface of the core is wished to be obtained.

[0043] It is to note that the coil could also be of a mixed type (having any profile), but in any case it will be provided with two flanges 6, 7, located at opposite positions along a longitudinal-extension axis 8 of the support body 2, intended for holding winding 4.

[0044] The wire-shaped element 3, such as a metal cable adapted to make windings in electric motors for example (but generally a wire, a ribbon or flexible tube of the most different typologies and sizes and for the most diversified uses) is carried by guide means 9 arranged to wind it around the support body 2.

[0045] The guide means 9, currently known as wire guides, are moved with a reciprocating translational motion along a direction parallel to the reel axis 8.

[0046] Motion reversal of the wire guide takes place at reversal positions that are substantially close to flanges 6, 7.

[0047] Practically, the reel is driven in rotation around its own axis 8, while the wire guide is moved with a rectilinear motion, laying down wire 2 with the desired pitch on the support body 2.

[0048] Obviously, the rotation and translation speeds, as well as the reversal positions and motion synchronisms can be changed in order to obtain the best winding with the different typologies of reels and wire-shaped elements used.

[0049] The apparatus further comprises detecting means 10 to detect a real profile 11 of at least one portion of winding 4.

[0050] This detecting means 10 is capable of stating the actual distance of one point of the profile 11 from the axis 8 of the support body 2, even during the winding procedure.

[0051] This means comprises an emitter 12 sending a signal 12a to winding 4 and a receiver 13 for picking up the return signal from the winding.

[0052] Generally, emitter 12 is of a preferably IR, laser type capable of generating a signal 12a consisting of a collimated beam and then impinging on a precise and circumscribed region of profile 11 at the point where the wire is being wound; a receiving device 13 of known and conventional type receives the return signal 12b generated by impact of signal 12a onto winding 4. More specifically, device 13 determines the distance of emitter 12 from the hit point; the geometry of the support body 2 and positioning of its axis 8 relative to the emitter being known, device 13 enables a processing unit 14 to find the radial position of said point relative to the rotation axis 8.

[0053] It is to note that the apparatus is always provided with at least one processing unit 14 capable of defining an ideal profile 15 of the winding, comparing a portion thereof with the corresponding real profile 11 previously detected and causing a relative axial displacement between the support body 2 and guide means 9, in order to correct the real profile 11 of the detected winding portion and make it consistent with the corresponding portion of the ideal profile 15.

[0054] Practically, the command for the relative displacement between winding 2 and guide means 9 is obtained by the processing unit 14 by varying the reversal positions of the wire-guide motion.

[0055] For carrying out what above stated, the processing unit 14 receives the signals relating to the ideal profile 15, compares them and generates an output signal by which a power unit 16 moving the guide means 9 is controlled.

[0056] Advantageously, the detecting means 10 is mounted integrally with the wire guide and it carries out detection of the positions of profile 11 points during winding.

[0057] The method for coil winding control (diagrammatically shown in Fig. 3), in addition to the steps of arranging a predetermined support body (denoted by reference numeral 17) and winding the wire-shaped element around said support body for generating a winding (reference numeral 18), also involves the further step of defining an ideal profile of the winding (reference numeral 19).

[0058] This step 19 is accomplished by identifying at least one sampling portion 20 of the real profile 11, which portion preferably is at a central region of the winding profile, and determining the ideal profile based on the identified sampling portion 20.

[0059] Taking into account the fact that generally the profile at the central region of a coil is regular even in the case in which winding has been carried out without any control, calculation of the ideal profile 15 can be based on this central region of the real winding profile 11.

[0060] In greater detail, provision is made for detecting the position of at least two points of the sampling portion and mathematically interpolating them in order to define the ideal profile.

[0061] In order to achieve a better approximation, the method provides for detecting the position of five points of the central region of the real profile. Practically, the position of a central point 21 of the real profile 11 is detected, as well as the position of the respective medium points 22, 23 of each of the two halves into which the profile is divided by said central point 21 and the position of the respective medium points 24, 25 of each of the two gaps defined between the medium points 22, 23 of the halves and the central point 21 of the real profile.

[0062] Through an interpolation, by adopting the least squares method for example, a straight line is defined that approaches the development or shape of the real profile 11 at the central region of winding 4 and supplies an indication of the desired shape at the axially opposite end regions 26 of the coil.

[0063] It is to note that defining an ideal profile 15 of substantially rectilinear shape appears to be a preferential solution, but in any case any shape of the ideal profile can be obtained.

[0064] Clearly the ideal profile shall always be parallel, point by point, to the profile of the central body 5.

[0065] The method in accordance with the present invention further comprises a step of detecting a real profile of at least one portion of the winding (referenced by 27 in Fig. 3); this step involves detecting of the position of a predetermined number of points spaced apart at a region of the winding according to a desired pitch so that the real portion shape 11 can be extrapolated.

[0066] Generally, the axially opposite end regions 26 of the profile are those much more subjected to have irregularities in the profile during the coil manufacture (see, in this connection, coil shown in Fig. 1).

[0067] For the above reason the method provides for detection of the winding portion at at least one axial end region 26 of the winding and preferably at both axially opposite ends.

[0068] Once the real profile 11 has been acquired and the ideal profile 15 calculated, the method involves a step 28 of comparing the corresponding parts of the real and ideal profiles, 11 and 15 respectively.

[0069] Practically, a geometric-deviation parameter between the real profile 11 of the winding portion and the corresponding portion of the ideal profile 15 is identified.

[0070] The deviation parameter is an index of how much the real profile deviates from the desired shape and may consist of, for example, an area 29 defined between the ideal profile 15 of the winding portion and the corresponding portion of the real profile 11.

[0071] The processing unit 14 is entrusted with the task of calculating this parameter; it receives the position of the points of the end regions 26 from the detecting means 10 and, since it knows the distance between two successive points, it can calculate the area of the rectangles 30 subtended to the arc (see Fig. 2).

[0072] The sum of the rectangle 30 areas defines the deviation parameter to be minimized in order to eliminate the error. A null area means a real profile 11 coincident with the ideal profile 15.

[0073] It is to note that said steps of defining (19) an ideal profile 15, detecting (27) a real profile 11, comparing (28) the real profile with the ideal profile and correcting (31) the real profile are successive to each other in time and are cyclically repeated during winding.

[0074] The method then involves a step 31 of correcting the real profile 11 of the winding portion 4 with a corresponding portion of the ideal profile 15. The correcting step 31 further comprises the sub-step of varying a time law or space law regulating said winding step 18 in order to minimize said deviation parameter.

[0075] Advantageously, in addition, a starting step (denoted by reference numeral 32 in Fig. 3) can be provided for identifying a real positioning of each flange located on the support body in order to eliminate possible tolerance errors and/or positioning errors of the support body.

[0076] The invention achieves important advantages.

[0077] Firstly, it is to note that the method being the object of the present invention enables a control to be carried out on the actual correctness of the coil profile, by automatically varying the winding parameters in order to eliminate profile errors or irregularities.

[0078] It is also to point out that the presence of a preliminary step of intercepting the real position of the flange enables values of the reversal positions to be previously entered in a right and accurate manner so as to correct errors due to longitudinal-extension or positioning tolerances.

[0079] The described method and apparatus enable errors in winding, due to shape defects in the support body and/or variations in the motion reversal positions of the wire guide to be corrected without the operator's intervention, and also enable correction of errors resulting from vibrations of the support body during winding.

[0080] Furthermore, it is to note that this method can be implemented in a simple manner and can be applied to all different typologies of reels used, while always ensuring a regular profile.

[0081] A further advantage is connected with the fact that this method and apparatus, by ensuring a regular winding without being it necessary to intercept the flanges at each cycle, enable a complete and correct control of the coil profile until complete filling of said coil.

Claims

1. A method of controlling coil winding of a wire-shaped element comprising the following steps:

   - arranging a predetermined support body (2); and
   - winding the wire-shaped element (3) round said support body (2) for generating a winding (4), characterized in that it further comprises the following steps:
   - detecting a real profile (11) of at least one winding (4) portion;
   - defining an ideal profile of the winding (4);
   - comparing the real profile of said winding (4) portion with a corresponding portion of the ideal profile (15); and
   - correcting the real profile (11) of the detected winding (4) portion to make said winding consistent with the corresponding portion of the ideal profile (15).

2. A method of controlling winding as claimed in claim 1, characterized in that said step of defining the ideal profile (15) comprises the following sub-steps:

   - identifying at least one sampling portion (20) of the real profile (11); and
   - determining the ideal profile (15) based on said sampling portion (20).

3. A method of controlling winding as claimed in claim 2, characterized in that said step of defining the ideal profile (15) further comprises the sub-steps of:

   - detecting the position of at least two points of the sampling portion (20) of the real profile (11); and
   - interpolating said points in order to define the ideal profile (15) of the winding (4).

4. A method of controlling winding as claimed in claim 2, characterized in that said sampling portion (20) of the real profile (11) is located at a central region of the winding (4) profile.

5. A method of controlling winding as claimed in claim 3, characterized in that said sub-step of detecting position of the points comprises the further sub-steps of:

   - detecting the position of a central point (21) of the real profile (11);
   - detecting the position of the respective medium

points (22, 23) of each of the two halves into which the profile is divided by said central point (21); and
- detecting the position of the respective medium points (24, 25) of each of the two gaps defined between the medium points (22, 23) of the halves and said central point (21) of the real profile (11).

6. A method of controlling winding as claimed in one or more of the preceding claims, characterized in that said step of defining the ideal profile (15) involves definition of a profile of a substantially rectilinear shape.

7. A method of controlling winding as claimed in claim 1, characterized in that during said detecting step, it is determined the real profile (11) of a winding (4) portion positioned at at least one axial end region (26) of the winding profile and preferably at both axially opposite end regions.

8. A method of controlling winding as claimed in claim 1, characterized in that the step of detecting the real profile (11) of at least one portion of the winding (4) comprises the sub-step of:

- detecting the position of a predetermined number of points of said winding (4) portion.

9. A method of controlling winding as claimed in claim 1, characterized in that the comparing step comprises the sub-step of identifying a geometric-deviation parameter between the real profile (11) of said winding (4) portion and the corresponding portion of the ideal profile (15) and in that said step of correcting the real profile (11) comprises the sub-step of varying a time law or a space law regulating said winding step in order to minimize said deviation parameter.

10. A method of controlling winding as claimed in claim 9, characterized in that said deviation parameter is an area (29) defined between the real profile (11) of the winding (4) portion and the corresponding portion of the ideal profile (15).

11. A method of controlling winding as claimed in claim 1, characterized in that it comprises the further step of identifying a real positioning of each flange (6, 7) exhibited by the support body (2).

12. A method of controlling winding as claimed in claim 1, characterized in that said steps of defining an ideal profile (15), detecting a real profile (11), comparing the real profile (11) with the ideal profile (15) and correcting the real profile (11) follow each other in time.

13. A method of controlling winding as claimed in claim 1, characterized in that said steps of defining an ideal profile (15), detecting a real profile (11), comparing the real profile (11) with the ideal profile (15) and correcting the real profile (11) are repeated cyclically.

14. An apparatus for coil winding control of a wire-shaped element, preferably as claimed in one or more of the preceding claims, comprising:

- a support body (2);
- guide means (9) for winding the wire-shaped element (3) round said support body (2) and generating a winding (4), characterized in that it further comprises:
- detecting means (10) for detecting a real profile (11) of at least one portion of the winding (4);
- at least one processing unit (14) for defining an ideal profile (15) of the winding (4) and comparing the real profile (11) of said winding (4) portion with a corresponding portion of the ideal profile (15) and causing a relative displacement between the support body (2) and guide means (9) in order to correct the real profile (11) of the detected winding (4) portion and make it consistent with the corresponding portion of the ideal profile (15).

15. An apparatus for winding control as claimed in claim 14, characterized in that said detecting means (10) comprises an emitter (12) to send a signal to the winding (4) and a receiver (13) to receive the return signal from the winding (4).

16. An apparatus for winding control as claimed in claim 15, characterized in that said emitter (12) is a preferably IR, laser emitter.

17. An apparatus for winding control as claimed in claim 14, characterized in that said support body (2) comprises two flanges (6, 7) located at opposite positions along a longitudinal-extension axis (8) of the support body and intended to retain the winding, and in that said guide means (9) is driven in a reciprocating translational motion, their movement-reversal position substantially being close to the flanges (6, 7).

18. An apparatus for winding control as claimed in claim 17, characterized in that command of the relative displacement between the support body (2) and guide means (9) carried out by the processing unit (14) takes place by varying the movement reversal positions.

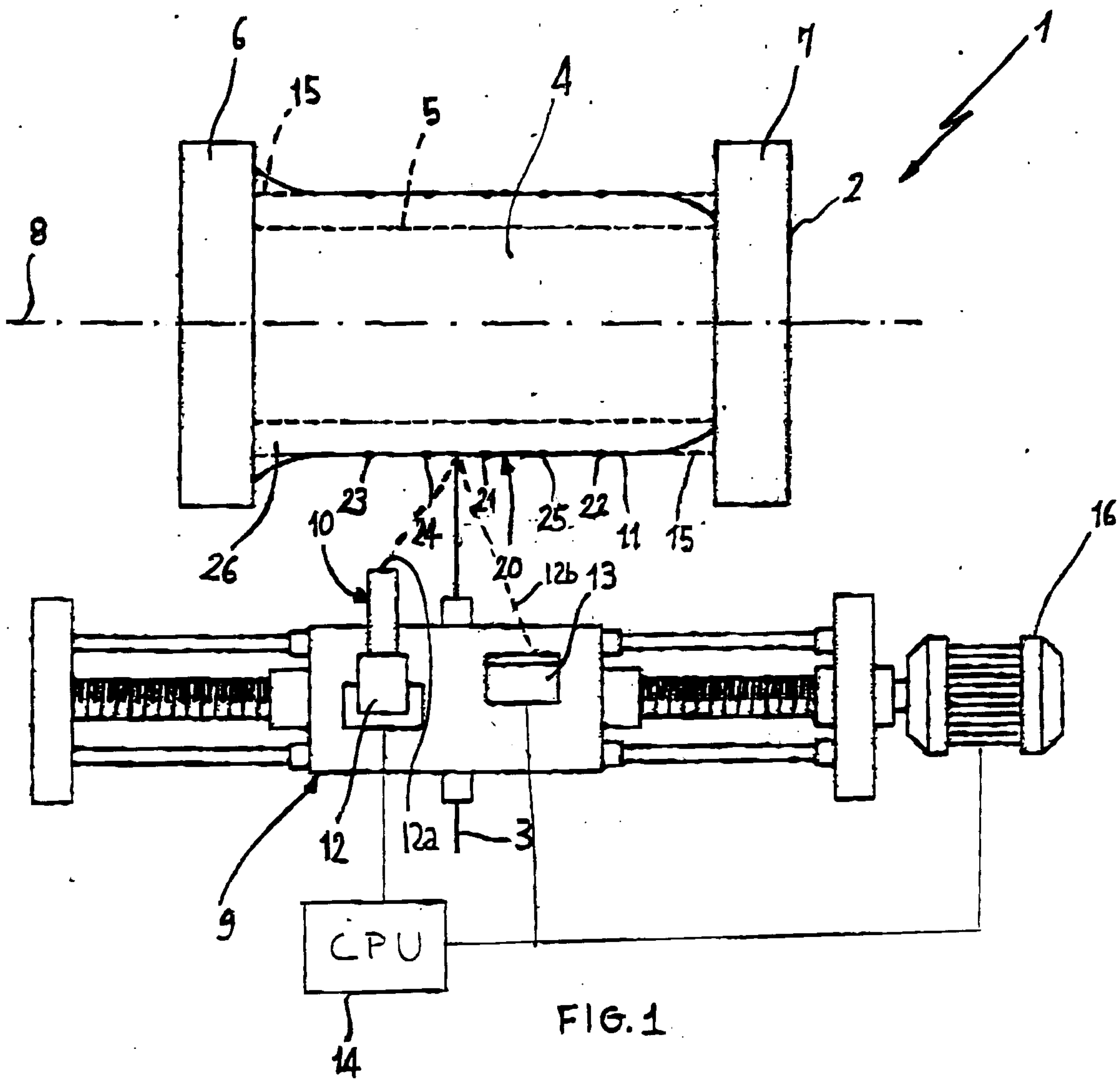
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FIG. 1

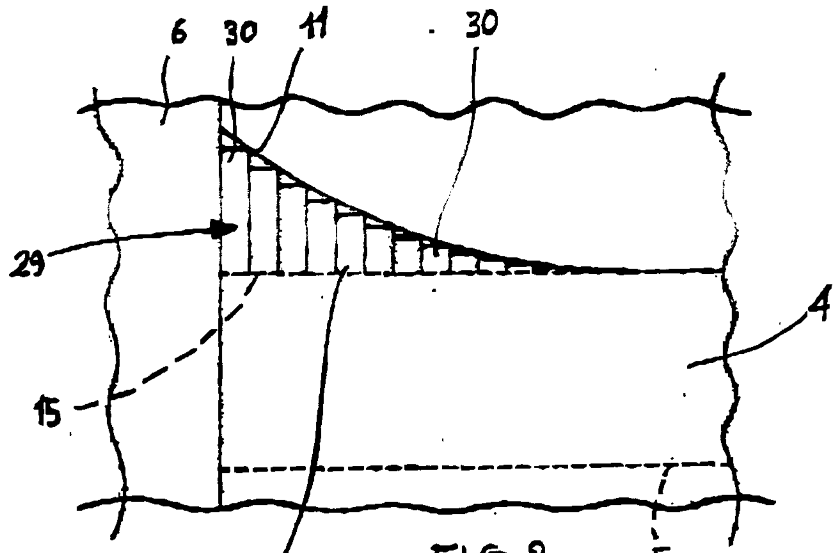
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FIG. 2

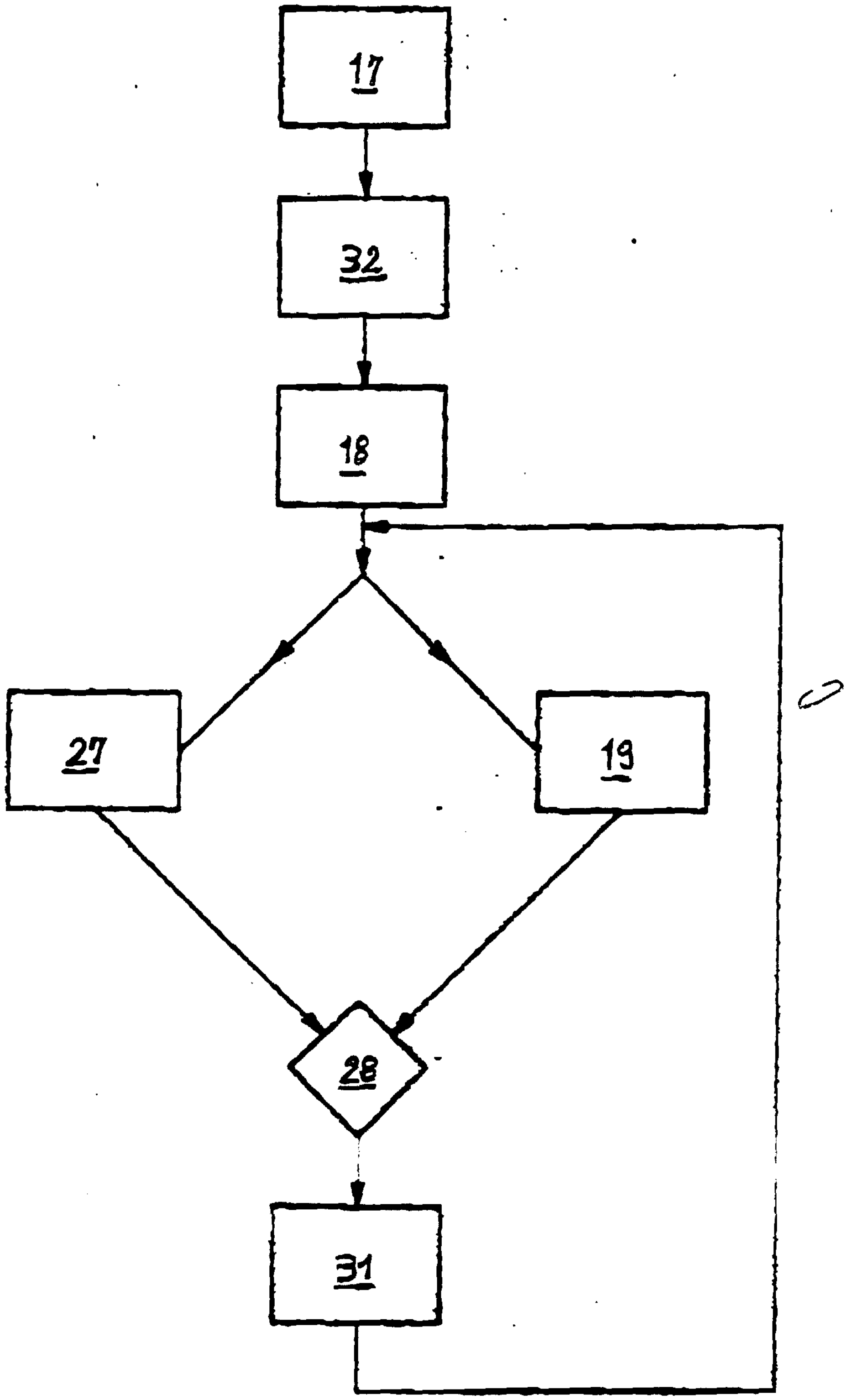

FIG.3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 83 0020

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE 195 07 020 A (BOLL PETER DR ;KRABBE CARSTEN ING GRAD (DE)) 5 September 1996	1	H01F41/06 B65H54/28
A	* column 3, line 59 - column 5, line 21; figures *	2,6-9, 11-14	
X	US 4 456 199 A (SEIBERT GERHARD) 26 June 1984	1	
A	* column 4, line 10 - column 5, line 47; figures *	2,6-9, 11-14	
A	GB 2 221 227 A (CEAT CAVI SPA) 31 January 1990 * abstract; figures *	1,14-16	
A	US 4 004 744 A (HOORELBEKE LUC) 25 January 1977 * abstract * * column 6, line 1 - line 12; figures 1-3B *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 010, no. 275 (E-438), 18 September 1986 & JP 61 097908 A (JEOL LTD), 16 May 1986, * abstract *	1	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)** H01F B65H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 June 1998	Marti Almeda, R

CATEGORY OF CITED DOCUMENTS

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