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(54) **Process and device for bending tubes, wires or strips of metal into a helical coil or spring comprising a plurality of turns**

(57) The present invention concerns a procedure and a machine for bending filiform material such as a tube, a wire, a bar, a strip of metal into coil or spring, preferably helicoidal, comprising continuously bending a single filiform material (3) into a coil or a spring so that the filiform material (3) assumes a helical course comprising a plurality of turns (S). The procedure comprises the steps of measuring the radius of curvature (R) of a

first bent portion (3c) comparing it with a pre-defined ideal radius of curvature (R^I), applying a correction if necessary. The procedure also comprises measuring the diameter (D) of a turn (S^I) during the bending and comparing it with a pre-defined ideal diameter (D^I). On the basis of this comparison, the ideal radius of curvature (R^I) is modified to correct the course of the curvature. The machine employs a sensor (8) and a CPU.

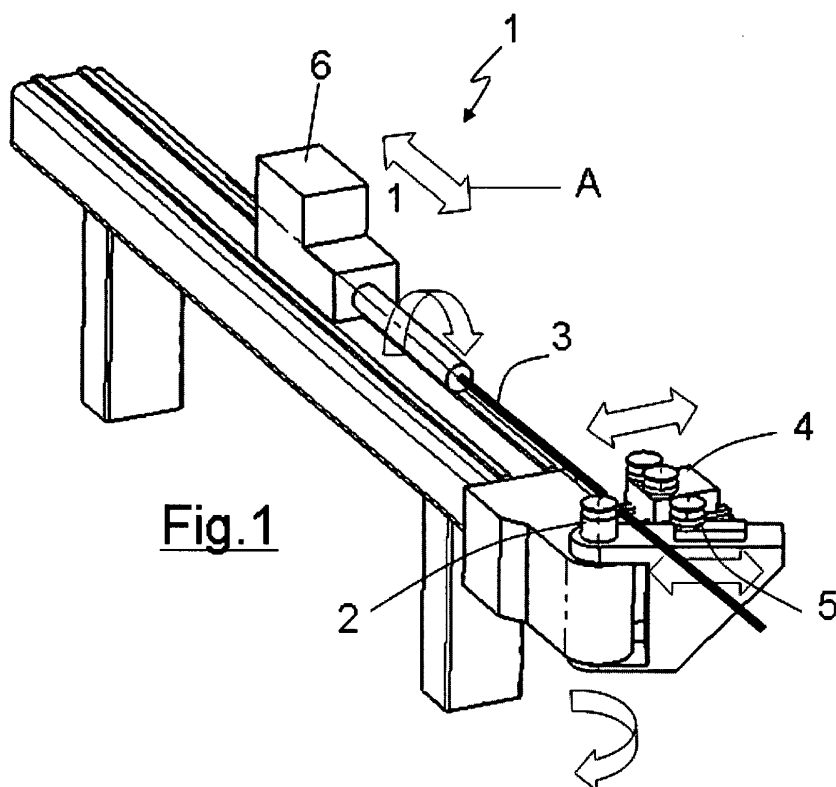


Fig.1

Description

Objet of the invention

[0001] The present invention concerns a procedure for bending filiform material such as a tube, a wire, a bar, a strip of metal (*in short*: tube) to manufacture a coil or strips for example used as a heat exchanger or for the formation of springs, both having a helical course comprising a plurality of turns.

[0002] Furthermore, the subject of the present invention concerns a machine for bending said filiform material for making coils starting, for example, from a substantially rectilinear tube.

State of the art

[0003] The subject of the present invention is used in the industrial sector of tube bending machines or similar machines capable of making coils starting, for example, from a substantially rectilinear tube.

[0004] As is known, coiled tubes or coils used in heat exchangers have a helical conformation comprising a plurality of turns wound in succession.

[0005] In accordance with a known procedure based on the use of corresponding tube bending machines, rectilinear tubes are suitably bent bit by bit as they advance on such machines. In this way a succession of turns are formed, which extend helicoidally to form a coil.

[0006] Tube bending machines used for making the above-mentioned coils are equipped with a curving or bending die, against which the tube is held in position by a clamping block. The die and the clamping block are aligned in a direction perpendicular to the direction of advancement of the tube. Inside the tube to be processed, a mandrel is provided which extends near to the clamping block to prevent undesired deformation of the tube before it is processed.

[0007] Tube bending machines are also equipped with a pushing tool capable of operating on the tube itself downstream the clamping block, to deform it suitably according to the processing specified.

[0008] While the tube advances in the direction of advancement towards the bending die, the pushing tool is rotated around its own axis by a rotation head through which the tube passes in deformed mode exiting from the machine as turns of helicoidal shape.

[0009] Although the above-mentioned procedures and the above-mentioned tube bending machines enable to make coils of more than satisfactory manufacture, the Applicant has discovered that the known tube-bending process and machines are not exempt from a number of disadvantages and are improvable in various respects. In particular such improvements can be achieved for coils whose windings or turns must have almost identical diameters in order to come within pre-established tolerances. By a non-exhaustive example, we might consider the heat exchangers installed inside machines which require

very precise overall dimensions.

[0010] In particular, the Applicant has discovered that it is particularly difficult to make coils having turns with the same diameters or with a tolerance less or equal to the 10% of the desired diameter.

[0011] During the bending of said tubes they are bent by an appropriate group of tools which determine the radius of curvature of the tube. However we have to consider that said tools operate in the bending area. Notwithstanding the tools act on the tube always in the same manner, the ideal or desired course of the turns is not guaranteed. The coils which are formed bending the tube may have a larger or smaller diameter along an extension which is not suitable for the desired use.

[0012] This problem requires continuous controls of the bending process, as well as continuous controls of the coils during the production and after the production. We have also to consider that once the maximum tolerance limit acceptable for each application of the coils produced is exceeded, the latter must be scrapped, with a consequent of the losses of materials and costs.

[0013] The problems described above in relation to the manufacture of coils used as heat exchangers are encountered in the manufacture of springs, particularly for helicoidal metal springs used in numerous industrial sectors.

Disclosure of the invention

[0014] A principal object of the present invention is to propose a process for the bending of filiform material such as a tube, a wire, a bar, a strip of metal (*in short*: tube) for the bending of tubes or strips having a coil shape, spring shape with a helical course comprising a plurality of turns and a machine for bending said material to bend the tubes or strips having a coil shape, a spring shape with a helical course comprising a plurality of turns, able to solve the problems of the state of art.

[0015] One of the purposes of the present invention is to ensure each turn of a coil or spring to have a diameter substantially corresponding to a pre-established diameter during the manufacturing of the above mentioned coil or spring.

[0016] A further purpose of the present invention is to ensure the manufacture of coils having the turns with a diameter within the limits tolerated for the desired applications.

[0017] It is likewise a purpose of the present invention to eliminate all the operations to control the course of the extension of the coils, either when bending has occurred or during the bending of said material, being the latter achieved by the known bending machines with the machine stopped. It is also a purpose of the present invention to reduce or eliminate the scrapping of coils when the bending has been performed.

[0018] It is also a purpose of the present invention to increase the production of coils by reducing or eliminating machine stoppages for the checks mentioned above for

ascertaining that the diameter of the turns of the coils comply with the tolerances allowed by the desired uses. In case of non-compliance to the mentioned tolerance, the coils manufactured must be discarded and the machine must be rectified to resume production of coils with the allowed tolerances.

[0019] The purpose specified above and others are substantially achieved by a process to bend tubes having the coil shape and a tube-bending machine to manufacture a coil having a helical course comprising a plurality of turns, as described in the following claims.

Description of the drawings

[0020] There will now be set forth, by way of example, the description of a process to manufacture tubes having the coil shape and a tube-bending machine to manufacture a coil having a helical course comprising a plurality of turns, capable of resolving the problems encountered in the prior art.

[0021] Such a description will be illustrated in the following with reference to the attached drawings, provided by way of non-limitative example only, in which:

Figure 1 is a schematic perspective view of a tube-bending machine to manufacture a coil having a helical course comprising a plurality of turns, in accordance with the present invention;

Figure 2 is a plan view of the machine of the mentioned figure 1 in a first relevant condition;

Figure 3 is a plan view of the machine of the previous figures in a second relevant condition;

Figure 4 is a plan view of the machine of the previous figures in a third relevant condition;

Figure 5 is a plan view of the machine of the previous figures in a fourth relevant condition;

Figure 6 is a plan view of the machine of the previous figures in a fifth relevant condition;

Figure 7 is a plan view of a detail of the previous figure 6;

Figure 8 is a plan view of the detail of the previous figure 7, wherein the tube during the bending has a high degree of curvature;

Figure 9 is a plan view of the detail of Figures 7 and 8, wherein the tube during the bending has a low degree of curvature;

Figure 10 is a plan view of the detail of Figures 7-9, wherein a first sensor for measuring the radius of curvature of the tube during the bending is illustrated;

Figure 11 is a plan view of the detail of Figures 7-10, wherein the first and the second sensors for measurement of diameter of the turn of the tube during the bending are illustrated;

Figure 12 is a plan view of the machine of the previous figures in a relevant condition wherein the tube during the bending has a high degree of curvature;

Figure 13 is a plan view of the detail of Figures 12, wherein a sensor for measurement of diameter of

the turn of the tube during the bending with the three tangential points is illustrated;

Description of the process

[0022] In accordance with the present invention, a process is provided to manufacture the tube (3) having a coil shape comprising the step of subjecting to a process of continuous bending a single tube (3) in order to form a coil so that said tube (3) has a helical course comprising a plurality of turns (S).

[0023] As figures 1 and 2 show, at the beginning of each cycle of the process according to the present invention, an appropriate machine is suitably configured for bending at least one substantially rectilinear tube (3).

[0024] Once the machine is configured, tube (3) is suitably made to advance in the direction of advancement (A) up to reach the bending die 2 (figure 3). Subsequently, tube (3) is transversely locked at least by the clamping block (4), preferably also by the pushing tool (5), which is suitably aligned to the clamping block (4) in a direction substantially parallel to the longitudinal extension of tube (3).

[0025] Once it is transversely locked, tube (3) is made to advance while pushing tool (5) is activated in rotation to bend the portion (3c) of the tube (3) on which it is operating (figure 5).

[0026] The advancing of tube (3) and the position of the pushing tool (5) bring the formation of a turn (S¹) around the related centre of rotation (C) helicoidally (figures 6 to 11).

[0027] In order to obtain optimum winding of tube (3) according to accurate turns (S_i), the process provides measurement of the radius of curvature (R) of the first portion (3c) of the tube (3) during the bending.

[0028] Subsequently, the measured radius of curvature (R) is compared with a pre-defined ideal radius of curvature (R¹), after which, if necessary, the bending given to tube (3) is corrected in an appropriate way and adjusted in relation to the differences which have emerged from the comparison between the measured radius (R) and the ideal radius of curvature (R¹). Advantageously, the radius of curvature (R) of the first portion (3c) of the tube (3) during the bending it is exploited measuring the distance (B) between at least one point (P) situated on an outer zone (3b) and at least one comparison point (PC) located on the outside of tube (3), on the opposite parallel side with respect to the centre of rotation (C). Advantageously, the process previews an additional correction of the course and the extension of the forming turns (S). The process previews a step of measuring the diameter (D) of the formed turns of the tube (3) during the bending. In this way it is possible to verify whether the extension of at least one forming turn (S¹) corresponds to a predetermined ideal extension. The measurement of diameter (D) is performed downstream the measurement of the radius of the curvature (R) of tube (3).

[0029] Advantageously, the measurement of the actu-

al diameter (D) of at least one turn (S_i) of tube (3) during the bending also comprises a subsequent step to compare the measured diameter (D) with an ideal diameter (D^I) of the turn, pre-established by the operator. After the comparison, there can follow a step of correction of the ideal radius of curvature (R^I) used for the comparison of the measured radius (R). In detail, this correction is made when a difference, established by the operator, emerges between diameter (D) and the ideal diameter (D^I).

[0030] Advantageously, the steps of measuring and correcting the parameters explained above are reiterated with a predetermined frequency and rhythm by the operator also on the basis of the physical characteristics of the material to be bent in order to confer on tube (3) during the bending a course close to or identical to a pre-defined ideal course.

Description of the machine.

[0031] With reference to the attached figures, number 1 is related to the entire bending machine to manufacture a coil having a helical course comprising a plurality of turns, in accordance to the present invention.

[0032] The attached figures, the machine (1) comprises at least a bending die (2) against which the tube (3) to be bent is held in position.

[0033] Machine (1) comprises at least a clamping block (4) to keep the tube (3) to be bent against the bending die (2).

[0034] The bending die (2) and the clamping block (4) are aligned in a perpendicular direction to a direction of advancement (A) of the tube (3) to be bent.

[0035] Machine (1) also previews a mandrel (not represented because it is known) which extends near to the clamping block (4) to avoid the deformation of the tube (3) during the bending.

[0036] Machine (1) is also endowed with at least a pushing tool (5) suitable for operating on the tube (3) downstream the clamping block (4) to deform tube (3) according to a radius of curvature (R^I) (figures 6 to 11) pre-defined by the operator.

[0037] Advantageously, machine (1) is also provided with at least a rotation head (6) through which the tube (3) to be bent passes. The rotation head (6) axially rotates the tube (3) to be bent, to confer to said tube (3) a substantially helicoidal course after the bending.

[0038] With particular reference to figures 10 and 11, machine (1) comprises furthermore control and correction means (7) of the radius of curvature of tube (3).

[0039] Advantageously, the control means (7) are capable to measure the diameter (D) of each turn (S^1) of the forming coil by the bending of tube (3).

[0040] In detail, the control and correction means (7) are configured for continuously checking the course of the bending of tube (3) to compare it continuously with one or more comparison parameters relating to the ideal or desired course of the bending of tube (3).

[0041] Figures 10 and 11 show the control and correc-

tion means (7) comprise a first sensor (8) connected, preferably but not obligatorily, with pushing tool (5) and active on tube (3) during the bending. The first sensor (8) is suitable for measuring the radius of curvature (R) of a first portion (3c) of tube (3) during the bending.

[0042] In detail, first sensor (8) measures the distance (B) between at least one point (P) located on an outer zone (3b) of portion (3c) of tube (3) and at least one comparison point (PC) located on the pushing tool (5).

[0043] Figures 10 and 11 show the outer zone (3b) of the tube (3) which is located on the opposite parallel side with respect to a centre of curvature (C) of tube (3) and the comparison point (PC) which is distanced on the outside of tube (3) on the opposite parallel side with respect to the centre of rotation (C).

[0044] By the use of an appropriate programmable electronic unit, also named CPU (not illustrated because it is known), the first sensor (8) is capable to calculate the value of the radius of curvature (R) of a first portion (3c) of the tube (3) from the distance (B) measured.

[0045] By said CPU which is programmed or programmable, the first sensor (8) is able to compare the measured radius of curvature (R) of the first portion (3c) of the tube (3) with an ideal radius of curvature (R^I) pre-defined by the operator.

[0046] Also by said CPU, first sensor (8) is able also to correct the curvature of tube (3) when the comparison between the measured radius of curvature (R) and the ideal radius of curvature shows a difference, aligning said radius of curvature (R) to the ideal radius of curvature (R^I).

[0047] With reference to figure (11) the control and correction means (7) comprise a second sensor (9) operatively connected to first sensor (8) to operate on tube (3) during the bending downstream the first sensor (8). The second sensor (9) is suitable for measuring at least 3 points PT tangent to the forming turn (S_i) which is being formed during the bending of the related tube (3). Through the position of the three tangential points PT measured, the CPU calculates the diameter (D) of the forming turn (S^1).

[0048] Once the diameter (D) is calculated, the CPU compares it with a pre-defined ideal diameter (D^I). If the diameter (D) differs from the ideal diameter (D^I), the CPU modifies the value of the ideal radius (R^I) on the basis of the difference detected between diameter (D) and the ideal diameter (D^I). This difference proves to be an indicator that the turns produced with the initial radius of curvature (R) were not perfectly circular and in this way the error is corrected.

[0049] With reference to the attached figures 1-5, 12 and 13, The purpose of the present invention can be also reached by a simplified machine. This other embodiment of the present invention does not employ the sensor (8) substituting the work made by said sensor (8) and the CPU with experimental work made by the operator.

[0050] This simplified machine (1) obviously bends a filiform material such as a tube, a wire, a bar, a strip of

metal (*in short*: tube) for the manufacturing of a coil or a spring, preferably helicoidal, having a helical course comprising a plurality of turns (S) having predetermined course and development. It comprises, as the machine above, at least a bending die (2) against which the tube (3) to be bent is held in position, at least a clamping block (4) for holding said tube (3) to be bent against said bending die (2). Said bending die (2) and said clamping block (4) being aligned in a perpendicular direction to the direction of advancement (A) of said tube (3) to be bent. It also has at least a mandrel extending until near the clamping block (4) to prevent undesired deformation of said tube (3) during the bending. The simplified machine (i) partially differs from the machine above by at least a pushing tool (5) suitable to operate on said tube (3) downstream said clamping block (4) for deforming said tube (3) according to the radius of curvature (R^S) experimentally defined by the operator and at least a rotation head (6) through which said tube (3) passes during the bending. Said rotation head (6) axially rotating said tube (3) during the bending to give it a substantially helicoidal course comprising the control and correction means (7) of the radius of curvature (R^T) of said (3) during the bending. The control and correction means (7) of the simplified machine comprises a CPU. They are suitable: (i) to compare the radius of curvature (R^T) of said tube (3) during the bending with the radius of curvature (R^S) experimentally defined by the operator being the measurement of said radius of curvature (R^S) previously entered into the CPU; (ii) to correct the radius of the curvature (R^T) of said tube (3) during the bending to align it to the radius of the curvature (R^S) experimentally defined. Said control and correct means (7) comprises at least a sensor (9) suitable to measure at least three points (PT) tangent to a coil (S¹) during the forming of the tube (3) and said CPU programmed or programmable to calculate the diameter (D) of the coil (S¹) during the forming in accordance with the three tangential points (PT) detected by said sensor (9) being said control and correction means (7) suitable to correct the radius of curvature (R^T) of the tube (3) during the bending in accordance with the difference between the diameter (D) and a diameter (D^S) experimentally defined by the operator.

[0051] The purpose of the present invention solves the problems of known art and presents particular advantages.

[0052] Above all, the purpose of the present invention allows accurate manufacture of the turns of the coils, because the control and correction system for the course of said turns is able to manage the bending tools in such a way to deform the tube during the bending so that said tube has the configuration closest to the ideal and desired configuration. In other words, the sensors which control the radius of curvature and the diameter of the turns enable continuous correction of the deformation of the tube during the bending to ensure that the tube has the correct curvature.

[0053] It should also be taken into consideration that

the purpose of the present invention makes possible the elimination of the continual operations of the control performed during the manufacture of coils or after their formation, because the control and correction system performs these control operations automatically and in real time, avoiding the stop the machine. We have also to consider that, in accordance with the present invention, the scrapping of coils is reduced and at least eliminated, because all the coils produced fall within the allowed tolerances.

Claims

1. Procedure for bending filiform material such as a tube, a wire, a bar, a strip of metal (*in short*: tube) into coil or spring, preferably helicoidal comprising the phase to process of continuous bending a single tube (3) in order to form a coil or a spring so that the tube (3) assumes a helical course comprising a plurality of turns (S) having a course and a development predetermined by the operator, comprising the following steps, all preferably repeated with frequency and rate predetermined by the operator:

- (a) to measure the radius of curvature (R) of a first portion (3c) of a tube (3) during the bending;
- (b) to compare the radius of curvature (R) of said first portion (3c) of the tube (3) with an ideal radius of curvature (R^I) pre-defined by the operator;
- (c) to correct the curvature of said tube (3) in accordance with a predetermined processing program when the comparison between the measured radius of curvature (R) and the ideal radius of curvature (R^I) shows a difference being the radius of curvature (R) of said first portion (3c) of said tube (3) during the bending determined measuring the distance (B) between at least one point (P) situated on an outer zone (3b) of tube (3) and parallel to a centre of curvature (C) of said first portion (3c) during the bending of said tube (3) and at least one comparison point (PC) situated on an outer zone of said tube (3) and parallel to the centre of rotation (C) **characterized in that** the ideal radius (R^I) is determined according to the following procedure having the following steps:

- (a) to measure the diameter (D) of at least a turn (S¹) of the tube (3) during the bending, performing said measurement downstream of the measurement of the radius of curvature (R);
- (b) to compare the diameter (D) measured with an ideal diameter (D^I) predetermined by the operator;
- (c) to correct the ideal radius (R^I) with respect to the difference detected between

the diameter (D) measured and the ideal diameter (D^I);

2. Machine (1) for bending filiform material such as a tube, a wire, a bar, a strip of metal (*in short*: tube) for the manufacturing of a coil or spring, preferably helicoidal, having a helical course comprising a plurality of turns (S) having predetermined course and development, said machine (1) comprising:

(a) at least a bending die (2) against which the tube (3) to be bent is held in position;
 (b) at least a clamping block (4) for holding in position said tube (3) to be bent against said bending die (2), said bending die (2) and said clamping block (4) being aligned in the perpendicular direction to the direction of advancement (A) of said tube (3) to be bent;
 (c) at least a mandrel extending until near the clamping block (4) to prevent undesired deformation of said tube (3) during the bending;
 (d) at least a pushing tool (5) suitable to operate on said tube (3) downstream said clamping block (4) for deforming said tube (3) according to a pre-defined radius of curvature;
 (e) at least a rotation head (6) through which said tube (3) passes during the bending, said rotation head (6) axially rotating said tube (3) during the bending gives to said tube (3) a substantially helicoidal course comprising a control and correction means (7) of the radius of curvature (R) of a first portion (3c) of tube (3) comprising a CPU and a first sensor (8) connected to said pushing tool (5) and active on said tube (3) during the bending, said first sensor (8) being adapted to measure the radius of curvature (R) of a first portion (3c) of the tube (3) during the bending and send said measurement to the CPU which is suitable for: (i) comparing the radius of curvature (R) of said first portion (3c) of tube (3) measured by the sensor (8) with an ideal radius of curvature (R^D) pre-defined by the operator; (ii) correcting the radius of curvature (R) of said tube (3) for aligning it to the pre-defined ideal radius (R^D), if required, being said control and correction means (7) comprise a CPU and a first sensor (8) connected to said pushing tool (5) and active on said tube (3) during the bending, said first sensor (8) being adapted to measure the distance (B) between at least a point (P) located on an outer zone (3b) of the tube (3) and parallel with respect to a centre of curvature (C) of said first portion (3c) of said tube (3) during the bending and at least a comparison point (PC) located on said pushing tool (5), distanced from said tube (3) and parallel with respect to the centre of rotation (C) and the CPU being programmed or programmable for calculating the radius of cur-

vature (R) of said first portion (3c) of said tube (3) during the bending based on the measurement of said distance (B) **characterized in that** said control and correction means (7) comprise a second sensor (9) operatively connected to the first sensor (8) to operate on said tube (3) during the bending downstream of said first sensor (8), said second sensor (9) being suitable to measure at least three points (PT) tangent to a turn (S¹) during the bending and said programmed or programmable CPU for calculating the diameter (D) of the turn (S¹) during the bend in accordance with the three tangential points (PT) detected by said second sensor (9) correcting the radius of curvature (R^I) in accordance with the difference between the diameter (D) and an ideal diameter (D^I) pre-defined by the operator.

3. Machine (i) for bending filiform material such as a tube, a wire, a bar, a strip of metal (*in short*: tube) for the manufacturing of a coil or a spring, preferably helicoidal, having a helical course comprising a plurality of turns (S) having predetermined course and development, said machine (1) comprising:

(a) at least a bending die (2) against which the tube (3) to be bent is held in position;
 (b) at least a clamping block (4) for holding said tube (3) to be bent against said bending die (2), said bending die (2) and said clamping block (4) being aligned in a perpendicular direction to the direction of advancement (A) of said tube (3) to be bent;
 (c) at least a mandrel extending until near the clamping block (4) to prevent undesired deformation of said tube (3) during the bending;
 (d) at least a pushing tool (5) suitable to operate on said tube (3) downstream said clamping block (4) for deforming said tube (3) according to the radius of curvature (R^S) experimentally defined;
 (e) at least a rotation head (6) through which said tube (3) passes during the bending, said rotation head (6) axially rotating said tube (3) during the bending to give it a substantially helicoidal course comprising the control and correction means (7) of the radius of curvature (R^T) of said (3) during the bending comprising a CPU suitable to: (i) comparing the radius of curvature (R^T) of said tube (3) during the bending with the radius of curvature (R^S) experimentally defined by the operator being the measurement of said radius of curvature (R^S) previously entered into the CPU; (ii) to correct the radius of the curvature (R^T) of said tube (3) during the bending to align it to the radius of the curvature (R^S) experimentally defined **characterized in the fact that** said control and correct means (7) comprises at least

a sensor (S_9) suitable to measure at least three points (PT) tangent to a coil (S^t) during the forming of the tube (3) and said CPU programmed or programmable to calculate the diameter (D) of the coil (S_i) during the forming in accordance with the three tangential points (PT) detected by said sensor (S_9) being said control and correction means (7) suitable to correct the radius of curvature (R^T) of the tube (3) during the bending in accordance with the difference between the diameter (D) and a diameter (D^S) experimentally defined by the operator

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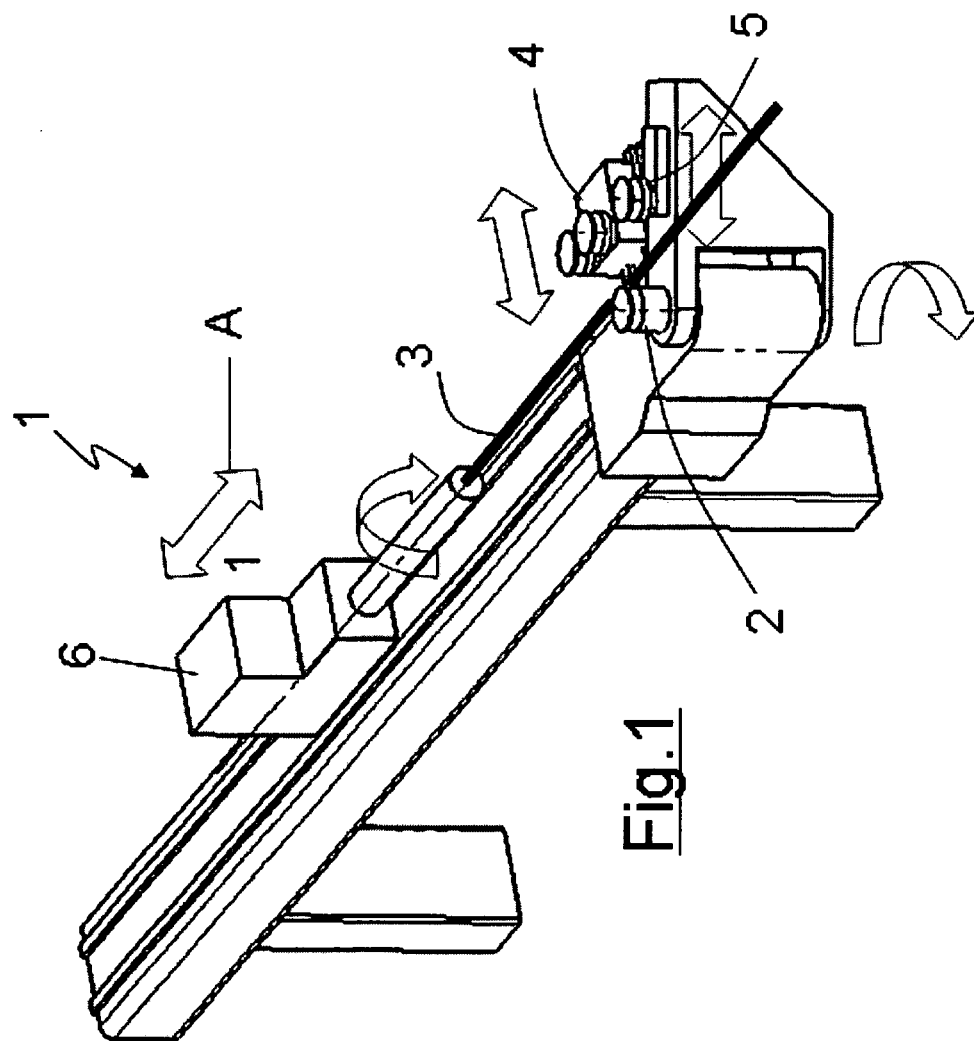
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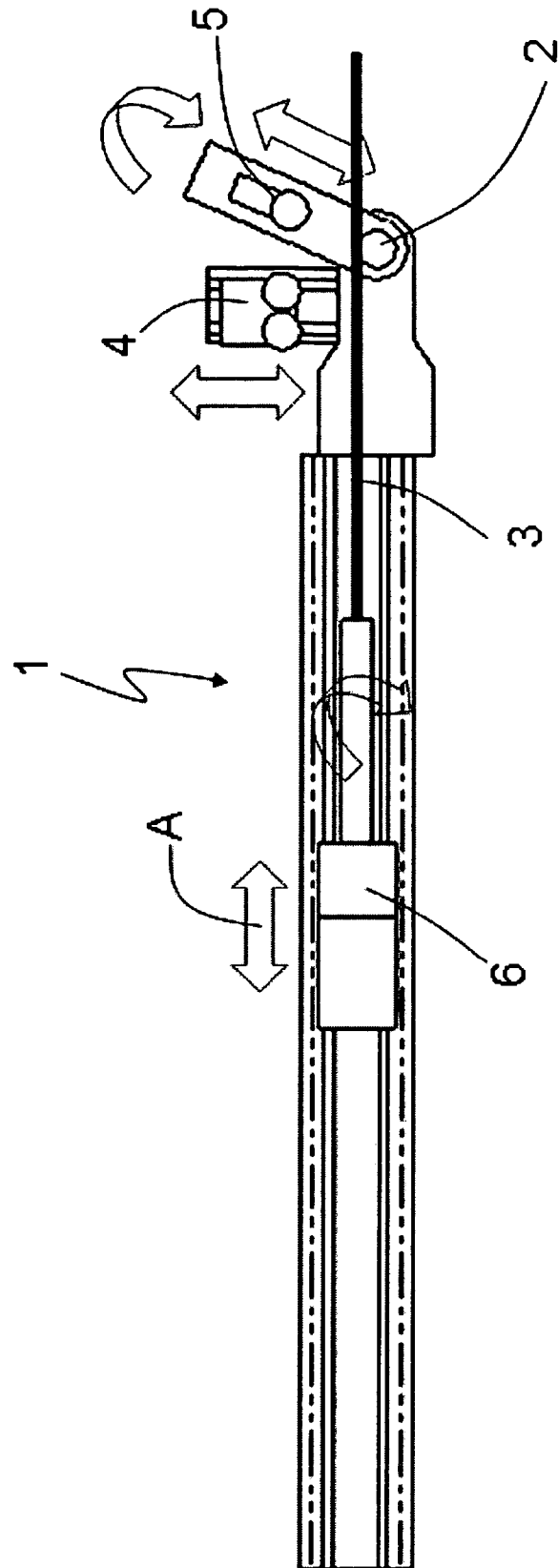


Fig. 2

Fig.3

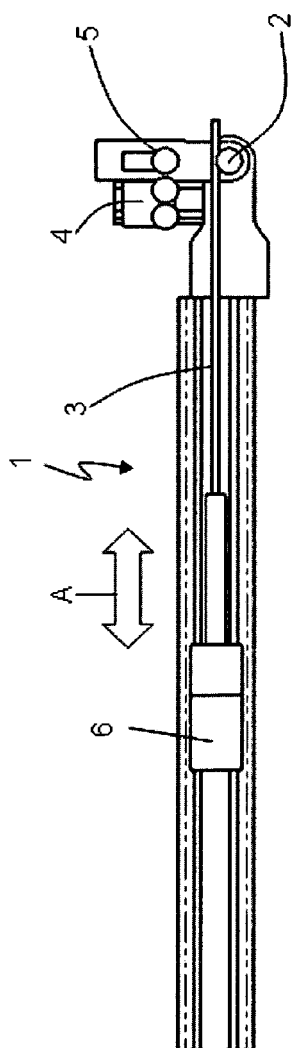


Fig.4

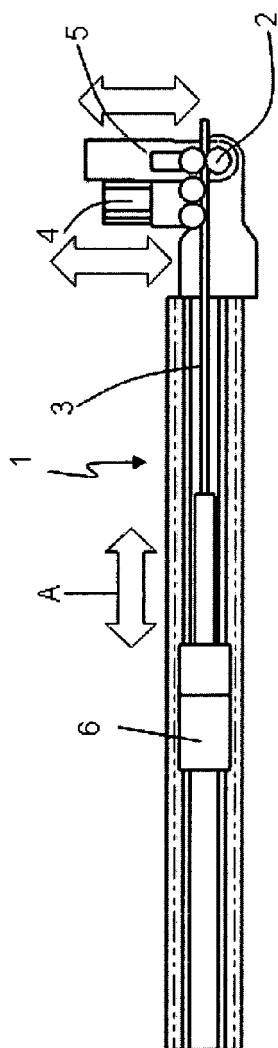


Fig.5

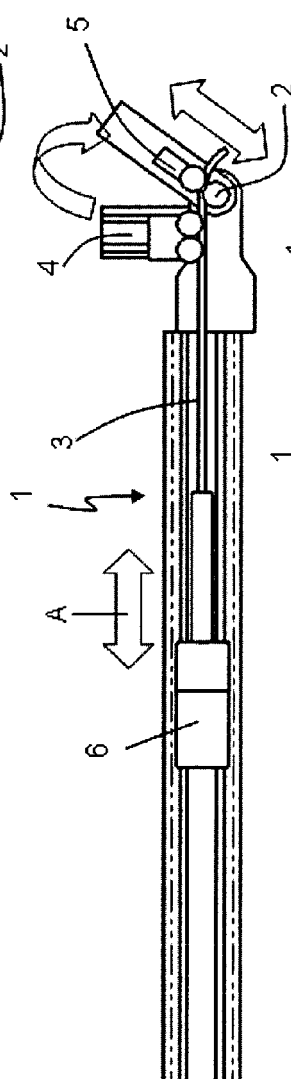
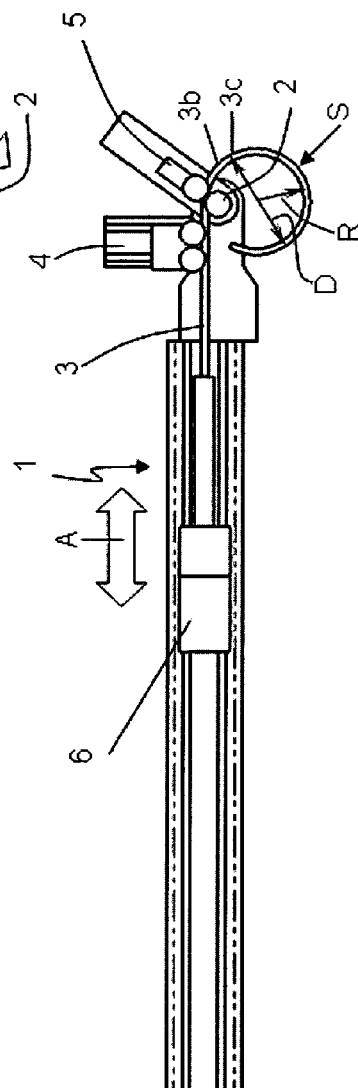
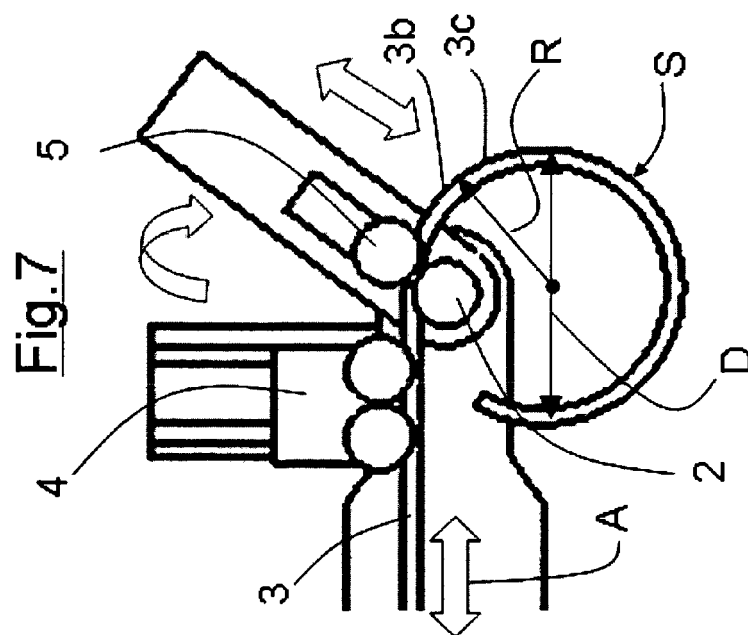
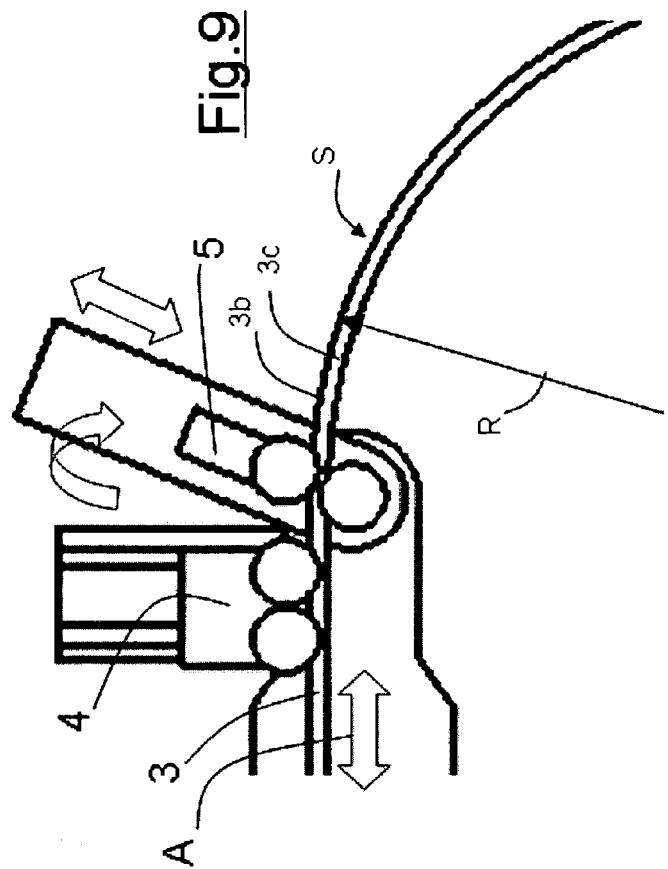
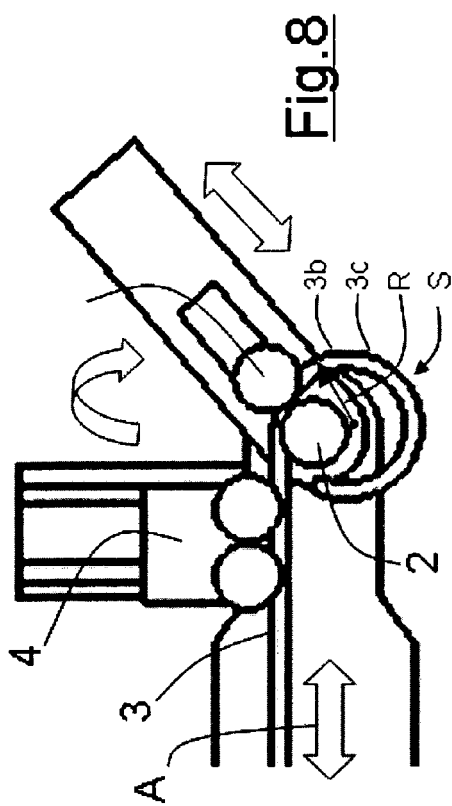


Fig.6





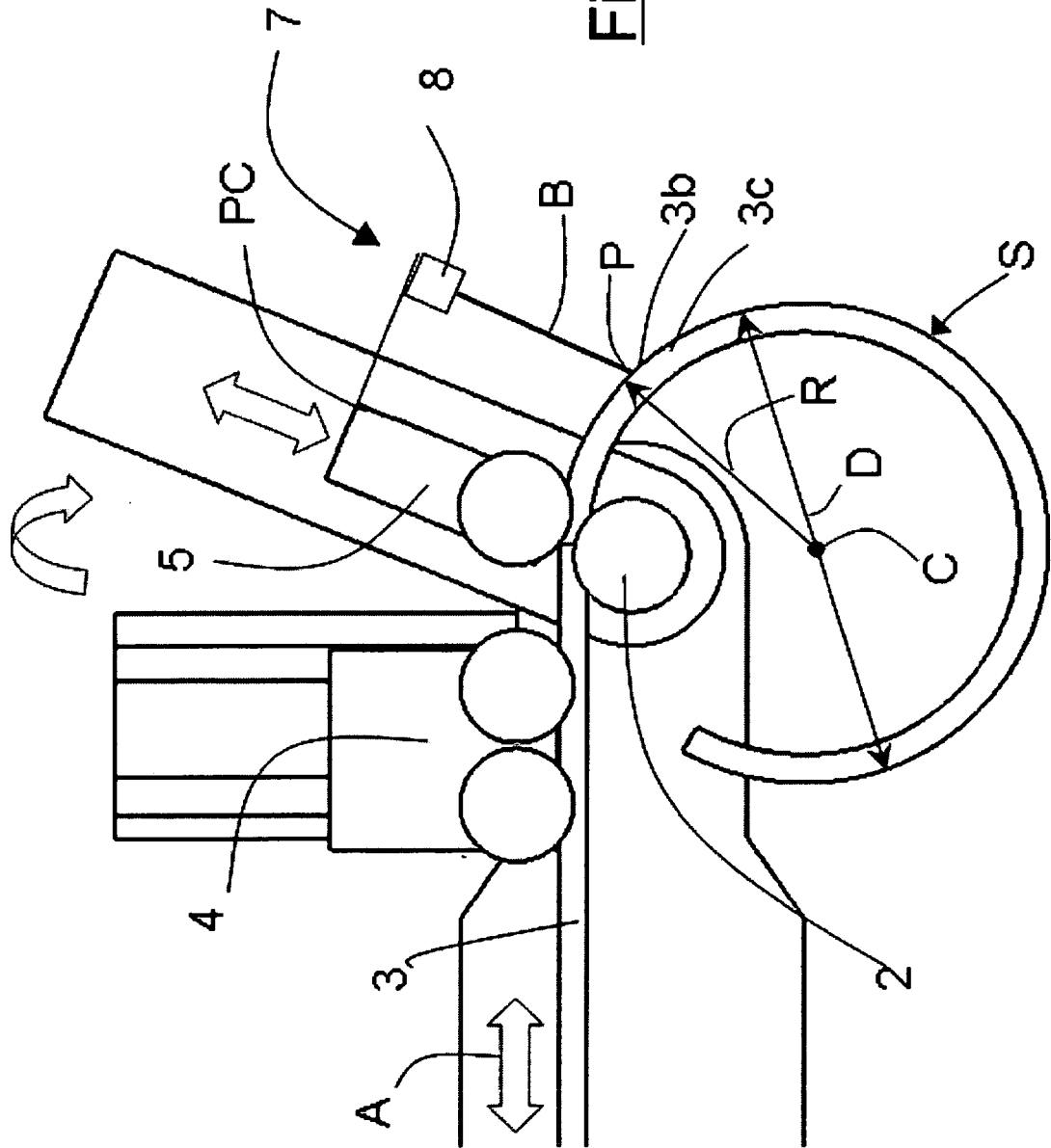


Fig. 10

Fig.11

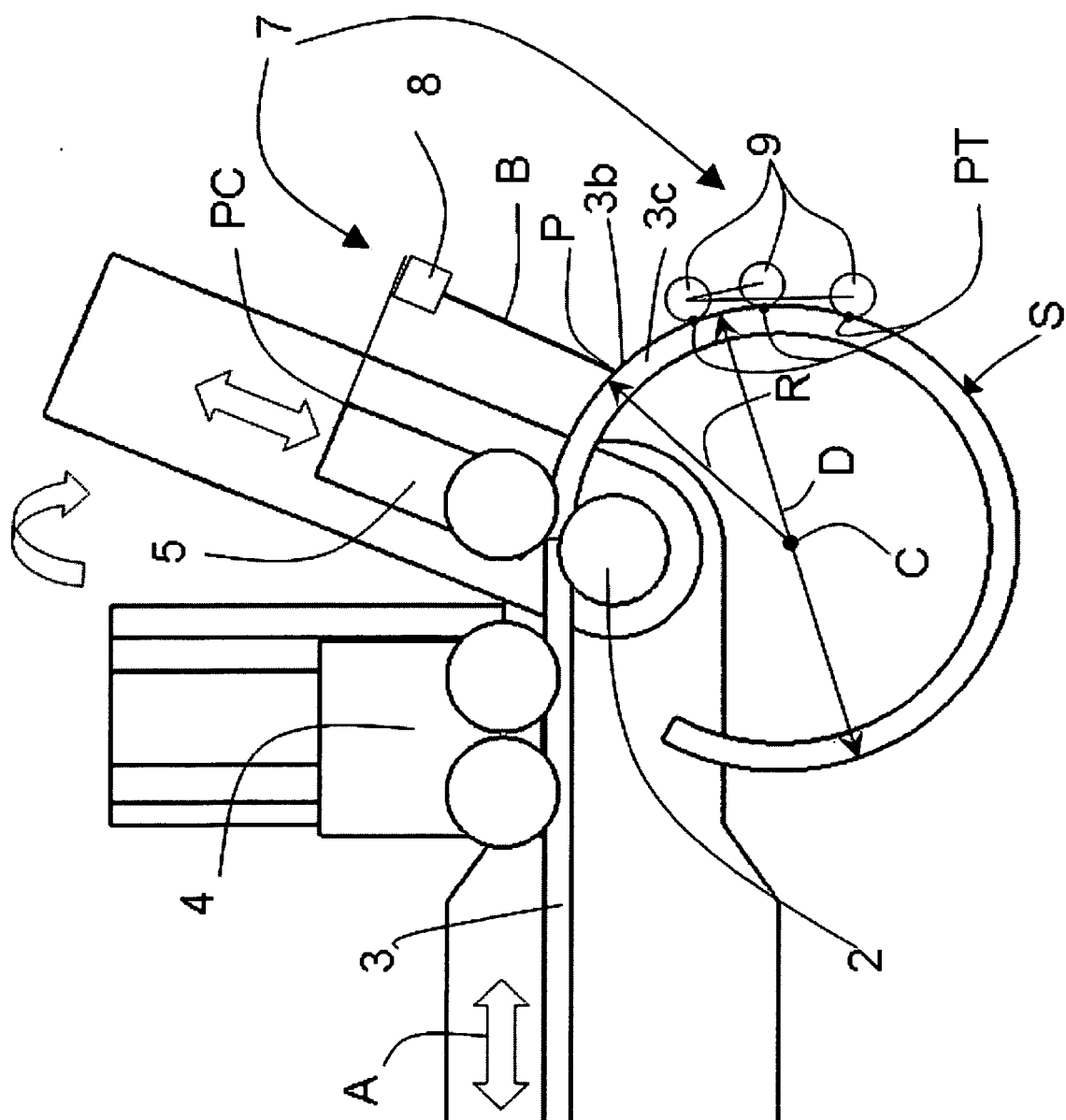


FIG.12

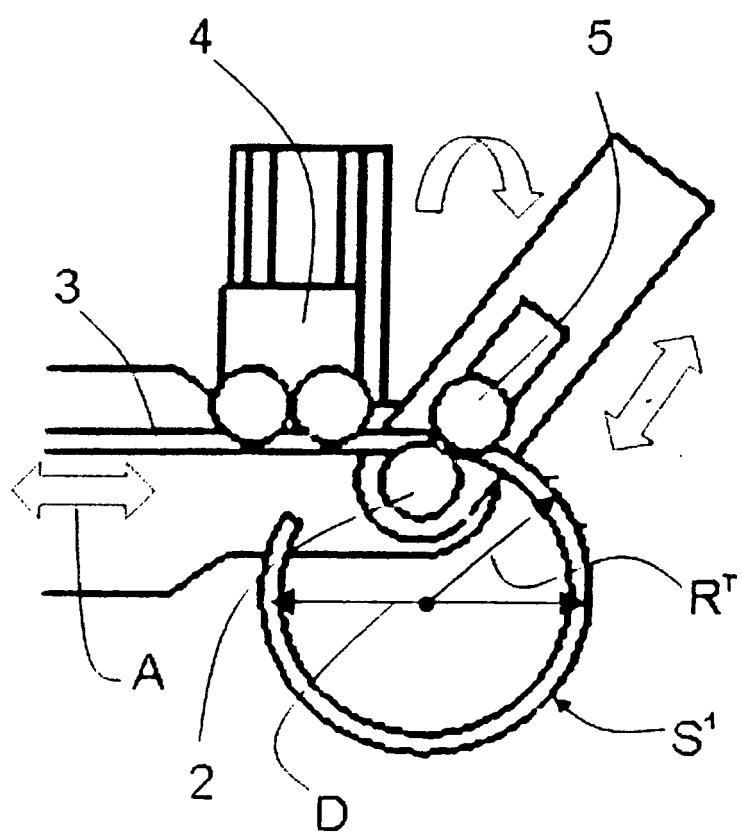
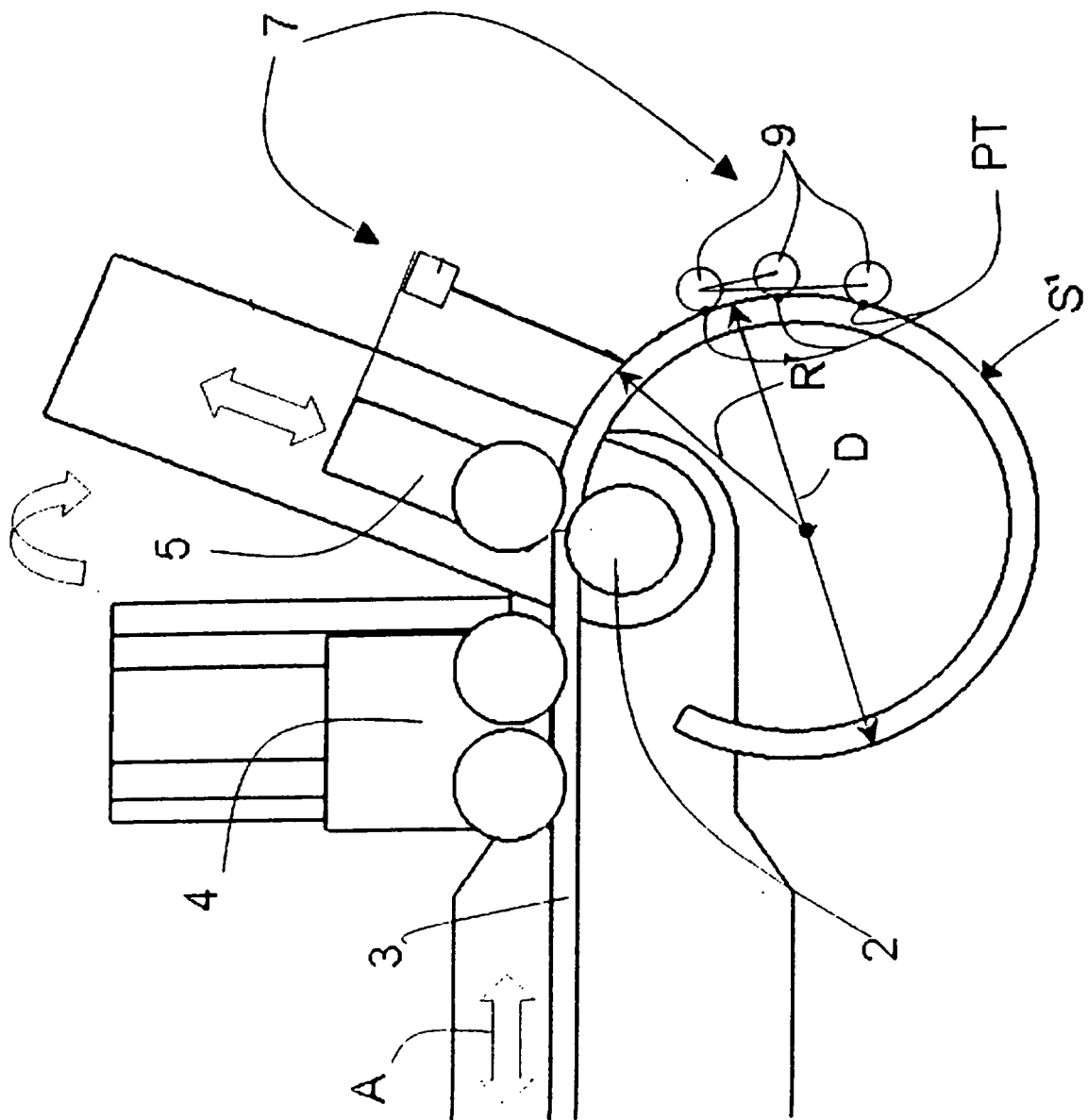


FIG.13





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Application Number
EP 11 00 5022

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