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(54) Method and apparatus for producing finned tubes.

(57) A method for producing finned tubes for heat exchangers starting from a cylindrical tube (I) which is cut along at least one helical cutting line by means of relative rotatory and linear traversing motions between the tube (I) and a cutting tool (3); a continuous shaving or rib is obtained which remains integral with the wall of the tube (I) and which is folded outwards to form a helical fin (II) by means of the bending and folding action of the cutting tool (3) which is provided with a sliding surface (3c) for the rib, running tangentially to the fin (II). The tube is suitably guided and supported close to the cutting area.

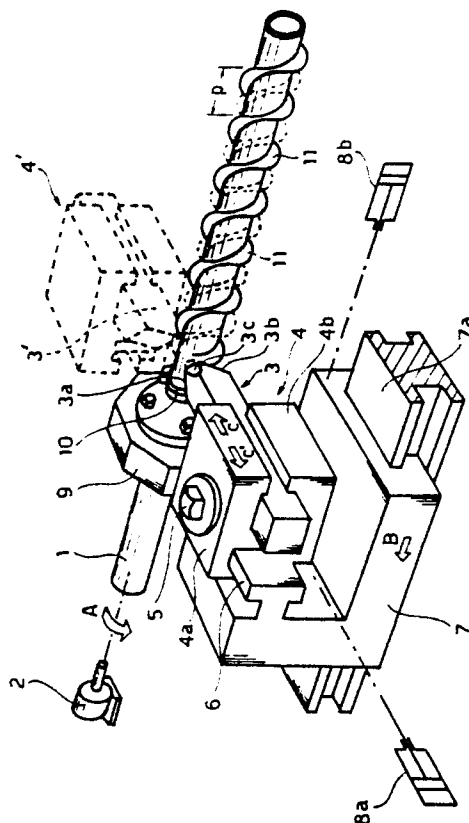


Fig. 1

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Method and apparatus for producing finned tubes

The finned tubes for heat exchangers known at present can be divided into two main categories: those having inserted fins and those having fins integral with the tube.

The finned tubes of the first category are made either by winding a strip of sheet metal in spiral-fashion around a plain cylindrical tube, said strip being made of the same material as the tube or of other material, or by fitting a set of evenly spaced apart metal plates of annular shape over the tube. In all these cases, in which the fin consists of a thin metal plate, even though it is fitted tightly onto the tube, contact between the tube and the fin is not made over the entire theoretical fitting surface, but only in a few places; the rest of the fin either does not make contact, or makes contact by means of the film of oxides and/or foreign substances which are generally poor conductors and with which both the fin and the tube are covered.

It therefore follows that the heat transmitted from the tube to the fin encounters considerable resistance precisely in the most important point of contact between these two elements.

Although possible, a weld between the tube and the fin proves to be uneconomical and difficult to carry out.

The tubes of the second category, in which the fin is made in one piece with the tube by a process in which the fin is extruded and pressed from the ductile material of the tube in the grooves of a die, until it protrudes in the form of a fin, present the drawback that the fins cannot be made very thin, as is possible with inserted fins, and consequently the cost of the material required for manufacturing them comes to bear heavily upon the cost of the product.

Moreover, in view of the considerable pressures involved, the machines required for producing such finned tubes are rather heavy and expensive, and not easy to set.

Lastly, again because of the considerable pressures required for extruding the fin, the walls of the tube must be very thick, which also affects the manufacturing cost as well as the heat exchange.

Whenever tubes with a more limited thickness are required, it is necessary to place a metal bar, or a bar of very hard material, inside the tube, in order to prevent the tube from being squashed, through the effect of the external pressure required for extruding the fin.

For this reason, the finned tubes may be made relatively short in size and, nonetheless, the finning operation which also involves inserting and removing the bar from the tubes, proves to be complex and therefore detrimental to the economic advantage of producing such tubes.

In any case, with the above method, the internal surface of the tube becomes corrugated and scored in correspondence with the fins, that is to say, crosswise to the direction of flow of the fluid in the tube, with a consequent increase in the resistance of the duct.

Moreover, from the point of view of the mechanical strength and the tensile and flexural strain of the tube, this procedure undoubtedly weakens it.

Also known, from a previous patent CH-A423681 of the same applicant, is a method for manufacturing finned tubes for heat exchangers, which starts from a plain tube which is cut by means of a cutting tool so as to form a continuous rib. The method of this patent suggests operating by simply cutting into the material in an inclined direction with respect to the axis of the tube to be provided with fins, which is practically suitable only for making circular fins, due to the fact that in the practical application of this method numerous difficulties were encountered in carrying out the operation of bending and raising a continuous rib to form a helical fin, simultaneously to the cutting operation.

The present invention refers to a method for manufacturing finned tubes having fins made integral with the tube, but obtained by means of a cheaper and simpler system than those mentioned above, with the possibility of obtaining thinner fin thicknesses, with thin-walled tubes, and consequently with a higher heat exchange coefficient.

The method referred to in this invention starts from a plain cylindrical tube of adequate thickness and a suitably-shaped and positioned cutting tool provided with relative movement with respect to the tube to enable it to cut and shape, from the tube itself, thin fins arranged in spiral fashion around its outer surface.

If we call leading edge the cutting portion of the tool which, during the cutting operation, is the first part to encounter the surface of the tube and to make the cut, and trailing edge the portion of the tool which, during the cutting operation, is the last part to lose contact with the material of the tube, and let us assume, to start with, that the leading edge and the trailing edge are rectilinear and co-incident, then the following phenomena will occur:

If the aforesaid cutting edge is disposed perpendicular to the generating lines of the outer surface of the tube, and moves with relative rotatory motion around the axis of the tube, that is to say, perpendicular to them, the tool will make a circular incision on the tube, with a certain accumulation of material on either side of the cut, due to plastic deformation.

Whereas, if the leading edge of the tool, aligned with the trailing edge, is disposed on a slant with respect to the generating lines of the tube, and moves, as in the previous case, with a relative rotatory motion around the axis of the tube, it will cause a thin strip of material, generally called shaving or rib, to be cut and raised up from the tube.

But, as the trailing edge will also encounter the rib obliquely, the latter will either be bent and raised imperfectly or cut off at the base and removed.

Now, let us assume that the leading edge lies in a sloping plane crossing the axis of the tube according to a cutting line not in the same plane and forming angle smaller than 90° with respect to the generating lines of the tube and with the same relative motion around the axis of the tube, but that the trailing or rib-bending edge no longer coincides with it, but lies in a plane considerably perpendicular to the axis of the tube and is radiused with the leading edge; let us also assume that, in correspondence with the trailing edge or line of abandonment of contact with the rib, the tool is provided with a surface, even though rather small, whose points are provided with relative speeds directed tangentially both to the surface of the tool and to the lateral surface of the rib, in the points of contact, then between such surface and the corresponding contact surface of the rib, there will not be any interference, but a relative slow sliding motion.

In this case, the rib initially raised by the leading edge, will not be cut off by the trailing edge, but will be bent by the latter in a plane substantially perpendicular to the tube, while remaining integrally anchored to it. By creating a relative linear motion between the tube and the tool, a helical fin will be formed on the latter.

In the case in question, the finning or rib described above can be made in practice by giving the tube a rotatory movement with respect to its axis and by giving the tool a rectilinear movement parallel to the axis of the tube, in the direction of the non-finned portion of the tube, with a sufficient speed to ensure that the rectilinear displacements of the tool, for each turn of the tube, are the same as the desired pitch of the fin, which will be disposed around the tube according to a cylindrical spiral.

In this case, which is technically very interesting, the portion of surface adjacent to the trailing edge of the cutter, which comes into contact with the rib last, will be disposed and shaped according to the planes tangent to the surface of the cylindrical helicoid of the fin which is to be made.

Having stated this, it is necessary to bear in mind the need for finned tubes, in engineering, to be relatively long with respect to the diameters of the tubes and, therefore, an adequate reaction of the tube to the cutting action of the tool which normally proves to be of considerable intensity, is essential.

Using the term "slenderness" and the letter S to indicate the ratio between the free length L of the tube and the radius of gyration I of its cross-section, according to the formula $S = L/i$, the problem is not serious in cases in which the tube to be finned is of limited slenderness, that is to say, large in diameter and small in length.

However, in the majority of cases, the tubes to be finned are of considerable slenderness and consequently such manufacturing method could not be used without an adequate support for the tube and suitable positioning of the tool and the tube.

A first solution to this problem consists in providing an apparatus equipped with a support for the tube to be finned, positioned close to the tool, which, during the operation, reacts with a pressure identical and contrary to the action of the tool on the tube, without allowing excessive strain and, simultaneously, enables the tube to slide axially and rotate in said support.

By way of a non-restrictive example, an embodiment of such support consists of a bushing, if necessary made of special, hard or anti-friction material, fitted and secured in a special housing, fixed to the tool-holder structure.

In particular, said tube supporting bushing can be arranged in correspondence with the cylindrical portion of the tube, not yet finned, and the tool can be supported so that the rectilinear movement of the tool is directed towards such bushing.

Again by way of a non-restrictive example, said bushing can be fitted to rotate in a support consisting of a roller bearing or can consist of the inner ring of the bearing itself; moreover, said support may not necessarily consist of a complete ring, but may also just consist of one or more parts of it, provided that it is capable of supporting the tube subjected to the thrust of the tool, which otherwise would distort it.

A further embodiment of the function of the aforesaid bushing, namely the support for the tube, may consist of a structure disposed around the tube, close to the tool, upon which are secured, if

necessary in an adjustable position, one or more backup or thrust rollers which, during the finning operation, are disposed and positioned around the tube, so as to prevent any lateral displacement.

By way of a non-restrictive example, a further embodiment of the invention for achieving a valid support and positioning for the tube consists in using two or more tools, disposed symmetrically with respect to the tube and spaced angularly apart from each other in such a way that their actions upon the tube cancel each other out.

For the sake of simplicity, a description was given of how the helical fin is formed on the originally plain tube, assuming it to be provided with rotatory motion around its axis, with the cutting tool provided with uniform rectilinear motion parallel to the axis of the tube; however, for the purposes of producing such finned tubes, according to this invention, without changing the speeds and relative positions of the tool or tools with respect to the tube, it would make no difference whatsoever if the tools were to be provided with rotatory motion around the axis of the tube, and the latter provided with uniform rectilinear motion, in the direction of its axis.

In order to produce finned tubes according to this invention, it is thus possible to envisage at least two embodiments according to the choice of absolute motion given to the tube and to the tools.

Purely by way of example and without this constituting any restriction whatsoever in the application of the invention, whereas the first case in which the tube is provided with rotatory motion and the tools with rectilinear motion is more suitable for producing relatively short finned tubes, the second case, namely in which the tools are provided with rotatory motion and the tube with rectilinear motion, is more suitable for finning even very long tubes.

The scopes of the invention can be achieved with a method for producing finned tubes according to claim 1.

The invention will be described in detail hereunder with reference to the examples of the accompanying drawings, in which:

Fig. 1 shows a perspective view of a first embodiment of an apparatus operating according to the method of this invention;

Figs. 2, 3 and 4 show further possible solutions regarding the method of supporting the finned tube, close to the cutting tool;

Fig. 5 shows a perspective view of an alternative solution, with the tools rotating and the tube provided with linear feed motion;

Figs. 6 and 7 show possible solutions for controlling the feeding of the tube into the device of fig. 5.

With reference to the foregoing description and to figure 1, reference 1 indicates the originally smooth tube which is made to rotate in the direction of the arrow A by a motor means 2, shown - schematically in the drawing, which also has the task of helping to keep the axis of the tube in a steady position during its rotation.

Reference 3 indicates a cutting and finning tool, supported and locked by means of a fastening member or clamp 4 whose upper jaw 4a locks the tool 3 in a seat in the lower jaw 4b by means of a securing screw 5.

The clamp 4 can be made to slide or move along the guide 6 by means of a servo control 8a such as a piston, cam or other control device capable of shifting the tool 3 close to the tube 1 and of positioning it in the exact working position, or of shifting it away from the tube according to movements indicated respectively by the arrows C and C'.

The cross guide 6 is provided on a slide 7 running along a longitudinal guide 7a by which it is possible to move the tool 3 with rectilinear motion in the direction of the arrow B, driven by any type of actuating means 8b, such as for example, a hydraulic or pneumatic cylinder, worm screw, chain or other equivalent drive means.

A device 9, integral and movable with the slide 7, is provided for centering and supporting the tube 1, said device being provided, in an appropriate position close to the tool 3, with a fixed or rotating cylindrical bushing 10 having its axis coinciding with that of the tube 1 to be finned which crosses it, with the possibility of sliding and rotating.

The cutting tool 3, as mentioned previously, presents a first cutting edge 3a, also referred to as leading edge due to the fact that it is the first to encounter the surface of the tube 1 to be cut, and a second edge 3b, also referred to as trailing edge due to the fact that, during the cutting operation, it is the last to lose contact with the material of the tube, which is radiused to the leading edge 3a as shown. The leading edge 3a which makes the cut along a helical line in the wall of the tube 1, lies in a slanting plane crossing the axis of the tube 1 whose cutting line is oblique and forms an angle of less than 90° with the generating lines of the outer surface of the tube itself, so as to allow an action of cutting the wall of the tube, and an action of raising a continuous strip which will then be bent and folded outwards to the side to form a continuous helical fin 11 on the outer surface of the tube itself. Whereas the trailing edge 3b of the cutting tool 3 lies in a plane substantially at right angles to the axis of the tube 1 and, in correspondence with the area merging with the leading edge 3a, in which the tool loses contact with the fin 11, presents a surface 3c directed tangentially to the lateral sur-

face of the fin II; thus, during the relative movement between the tool 3 and the fin II, their points of contact close to the trailing edge 3b will have relative speeds directed tangentially both to the surface of the fin and to the cutting tool itself, thus giving rise to a plane sliding movement between the contacting surfaces which eliminates any interference whatsoever, allows the rib to be bent correctly and raised to form the helical fin.

The device of fig. 1 for forming a helical fin II on the tube I operates as follows:

If the tube I is set in uniform rotatory motion, with a constant speed of rotation in the direction of the arrow A, and the slide 7 is made to move with a uniform rectilinear motion in the direction of the arrow B, and if immediately after the control device which causes the clamp 4 supporting the tool 3 to move in the direction C is put into operation and then stopped in the working position, the tool due to its particular conformation, will run with its cutting edge 3a around the surface of the tube I, thus creating a helical-shaped shaving or rib which remains integral with the latter at the base and anchored to the wall of the tube, and which is then bent and raised to form the fin II.

The pitch p of the fin II will depend upon the ratio between the traversing speed of the tool and the peripheral speed of rotation of the tube.

In the solution of a machine with several tools for forming double-start fins, an embodiment of the invention is also indicated in figure 1, by taking into account the part in dotted lines in which the pressure exerted by the tool 3 on the tube is balanced by a second tool 3', held by a clamp 4' on a slide identical or similar to the one supporting the tool 3 so that the actions of the tools 3 and 3' are, as far as possible, equal and opposing.

In this case, the leading edge of the tool 3' will be situated, with respect to the tool 3, further along the axis of the tube by a distance equal to half the pitch p .

In the solution of a machine with three tools for simultaneously forming three helical fins on the same tube, the tools will be arranged at 120° from one another, in perpendicular planes to the axis of the tube, and their leading edges will be shifted, along the axis of the tube, by a third of a pitch p .

In the solutions with more than three tools, the same criteria of symmetry are followed.

In combination with the finning tools, the described equipment may present a tool for automatically cutting the finned tube into tubular sections of a pre-established length; said tool, as in the case of the finning tools, is mounted on a slide movable in a crosswise direction to the tube, driven by control

means and mechanical, hydraulic and/or pneumatic servomechanisms controlled by sensing means whose position can be varied and adjusted according to specific requirements.

In fig. 1, the tube centering member 10 mounted on the support 9, integral with the tool-holding slide 7, is indicated for the sake of simplicity simply as a bushing, however, without deviating from the sphere of this invention, it can be made in numerous different ways provided that they are capable of keeping the tube centered and of counteracting the thrust of the finning tool 3, and at the same time allowing the tube to slide freely.

By way of example, and in no way restrictive, the tube supporting and positioning device could be made as shown in figures 2, 3 and 4.

In the solution shown in fig. 2, secured to the support 9 integral with the tool-holding slide on the side facing towards the tools themselves, are a number of pins 12 around which rotate, idle, the same number of backup rollers or rolling bearings 13, said rollers being disposed around a hole 14 through which the tube I passes.

The backup rollers 13 can be disposed with their axes parallel to the axis of the tube, or with their axes perpendicular to the cylindrical spiral in the points of contact of the rollers with the tube itself, in order to obtain as little slip as possible between the rollers and the tube.

Fig. 2 shows three rollers, however, there may be any number of them; moreover, without deviating from the sphere of this invention, the pin 12 of the backup rollers 13 may either be in a fixed position with respect to the supporting plate 9 or movable and positionable at will, to enable tubes of different diameters to be machined or, if necessary, for taking up slack.

A further embodiment is illustrated in fig. 3 which shows a single idle backup roller 15 supported by a pin 16 in a fixed position, or adjustable by means of a supporting arm 17 having a slot 18 penetrated by a bolt 19 by means of which the arm 17 can be secured to the tool-supporting clamp 4 in such a way that the tube centering device can also move forward and position itself at the same time as the tool at the beginning of the tube-cutting operation.

A further embodiment of the centering device is shown in fig. 4, where the plate 9 around the hole 14 for the tube I is provided with three angularly spaced apart fixed backup elements 20 having rigid surfaces 21 destined to come into contact with the tube I to be finned and to hold it in position by counteracting the thrust of the tool and of the finning tools 3, 3'.

Said backup surfaces 21 may be made of special, hard or anti-friction materials constituting the backup elements 20, or of inserts.

In the case of tubes to be finned having a high slenderness ratio, it is advisable to use the second type of machine, in which the tool or tools move with a uniform rotatory motion around the tube and the tube moves with a rectilinear motion, along its axis; there is no difference with respect to the previous case, as long as the relative speeds, instead of the absolute speeds of the tube and the tools are taken into consideration.

What will change are the means for supporting and centering the tube which must now be guided in its longitudinal motion, the tools, their movers and the servomechanisms responsible for keeping them in movement.

As the latter can be differently made and are not specific for this invention, they have been intentionally omitted in the descriptions and in the drawings.

In the embodiment of the machine with the tube in rectilinear motion, the latter will be moved in an axial direction by a drive system commonly used for rectilinear movements of this type, whereas the tool or tools will be disposed on a head revolving around an axis coinciding with the axis of the tube.

Figs. 5, 6 and 7 show, by way of a non-restrictive example, several embodiments of these members according to this invention, for the type of machine with a tube provided with rectilinear motion and tools provided with rotatory motion.

The solution of fig. 5 shows one of the possible embodiments of a rotatory tool-holding device, consisting of an annular head 25 provided with angularly spaced apart radial guides 26, in which supports 27 slide; the tools 3, together with all the regulating and drive members previously described being secured to said supports 27.

Said head 25 defines a hole 28 with a larger diameter than the tube 1, and is supported to rotate around an axis coinciding with the axis of the tube 1 by means of rolling bearings or bushings housed in the supporting block 29 comprising means for guiding the tube itself.

Said head 25 receives its rotatory movement from a usual driving means (not shown) and may comprise, in particular, all the devices for automatically positioning the tools 3 close to the tube 1, for the beginning and end of the finning operation.

The slides 27 of the head 25 can be provided with devices for centering the tube similar to those described for the apparatus with the rotating tube.

The solution of fig. 6 shows a device for feeding the tube 1 by means of a series of pairs of opposing splined rollers 22, 22' which are made to rotate with constant speed by any type of mechanical drive system.

The solution of fig. 7 shows another system for feeding the tube obtained by means of one or more pairs of endless conveyor chains or belts 23, 23' provided at pre-established intervals with pads 24, 24' shaped according to the shape of the tube 1.

Claims

1. -Method for producing finned tubes, in particular for heat exchangers, starting from a plain tube (I) which is cut at least along one helical line by means of relative rotatory and linear traverse movements between the tube (I) and at least one cutting tool (3; 3'), so as to obtain a continuous rib which remains integral with the wall of the tube (I) and is then bent outwards to form a continuous helical fin (II), characterized by the fact of making a helical cut in the wall of the tube (I) by carrying out, with the cutting edge of the tool (3; 3'), a cutting action lying in a slanting plane crossing the axis of the tube (I) and along an oblique cutting line forming an angle of less than 90° with the generating lines of the tube itself; of supporting said tube (I) close to the cutting area by exerting a contrasting thrust which counteracts the cutting action of the tool (3; 3'); of bending the cut rib to one side and shaping it into a helical fin (II) by making it run along a bending surface (3c) on the tool (3; 3') which is directed tangentially to the surface of the fin (II).

2. -Method as claimed in claim 1, characterized by the fact of making the tube (I) rotate with a uniform rotatory motion around its own axis and of moving the cutting tool (3; 3') with a uniform rectilinear motion, parallelly to the axis of the tube (I) and towards the smooth part of the tube (I) not yet finned.

3. -Method as claimed in claim 1, characterized by the fact of feeding the tube (I) with a linear motion and of making the cutting tool (3; 3') rotate around the tube (I) itself, guiding the tube (I) as it slides.

4. -Apparatus for producing finned tubes according to the method claimed in the previous claims, characterized by the fact of comprising: means (9) for supporting the tube (I); at least one cutting tool (3; 3') positioned to the side of the tube (I) and having a first cutting edge (3a) lying in a slanting plane crossing the axis of the tube (I) and according to a cutting line forming an angle smaller than 90° with the generating lines of the tube (I), as well as a second or rib bending edge (3b) lying in a plane substantially at right angles to the tube (I) and connected to the cutting edge (3a) by means of a rib sliding surface area (3c) directed tangentially towards the fin (II); means (4; 4') for support-

ing the cutting tool (3; 3') and the tube (I) to be finned, respectively, and for providing them with a relative rotatory and linear motion, and means (10; 13; 15; 20) for positioning the tube and for guiding the tube lengthwise along its axis in the vicinity of the cutting tool.

5 5. -Apparatus as claimed in claim 4, characterized by the fact that it comprises means (4a; 4b; 6; 8a) for clamping and for moving the cutting tool (3; 3') towards the tube to be finned.

10 6. -Apparatus as claimed in claim 4, characterized by the fact that it comprises means (7, 7a; 8b) for moving the cutting tool (3; 3') parallelly to the tube (I) to be finned as well as for making the tube (I) rotate around its axis.

7. -Apparatus as claimed in claim 4, characterized by the fact that the means for positioning and guiding the tube (I) are in the form of a cylindrical bushing (10).

8. -Apparatus as claimed in claim 4, characterized by the fact that the means for positioning and guiding the tube (I) comprises at least one idle roller (15) in contact with the tube (I) in correspondence with the cutting tool (3; 3').

9. -Apparatus as claimed in claim 8, characterized by the fact that said idle roller (15) is provided on an arm (17) movable radially to the tube (I) and adjustable in position.

10. -Apparatus as claimed in claim 9, characterized by the fact that said idle roller (15) is provided on an arm (17) secured to the clamping means (4) for the cutting tool (3; 3').

11. -Apparatus as claimed in claims 4 and 8, characterized by the fact that the means for positioning and guiding the tube comprise a supporting member (9) provided with an aperture (14) for the tube (I) and positioning means for the tube (I) in the form of idle rollers (15) angularly spaced apart on said supporting member (4), around the aperture - (14) for the tube.

12. -Apparatus as claimed in claim 11, characterized by the fact that the idle rollers (15) have their axes parallel to the longitudinal axis of the tube (I).

13. -Apparatus as claimed in claim 11, characterized by the fact that the idle rollers (15) have their axes inclined with respect to the longitudinal axis of the tube (I).

14. -Apparatus as claimed in claims 4 and 8, characterized by the fact that the means for positioning and supporting the tube (I) comprise a supporting member (9) provided with an aperture - (14) for the tube (I), and fixed positioning members (20), each having a tube sliding surface (21), said positioning members (20) being provided on said supporting member (9) around the aperture (14) for the tube (I).

15. -Apparatus as claimed in claim 4, characterized by the fact that it comprises means for supporting and for making the tube (I) slide longitudinally to its axis, as well as means (25) for supporting and for making the cutting tools (3) revolve around the tube (I).

16. -Apparatus as claimed in claims 4 and 15, characterized by the fact that the means for supporting the cutting tool are in the form of an annular head (25) supported to rotate co-axially to the tube (I) to be finned.

17. -Apparatus as claimed in claim 16, characterized by the fact that each cutting tool (3) is provided on a slide (27) movable within radial guides (26) on the rotary head (25).

18. -Apparatus as claimed in claims 4 and 17, characterized by the fact that the means for supporting the tube (I) are in the form of an idle roller - (15) provided on an arm (17) secured to the slide - (27) supporting the cutting tool (3).

19. -Apparatus as claimed in claim 15, characterized by the fact that the means for making the tube (I) slide comprise opposing pairs of splined rollers (22, 22') connected to a drive system.

20. -Apparatus as claimed in claim 15, characterized by the fact that the means for making the tube (I) slide comprise a pair of endless chains (23, 23') or belts provided at pre-established distances with opposing shaped pads (24) and connected to a drive system.

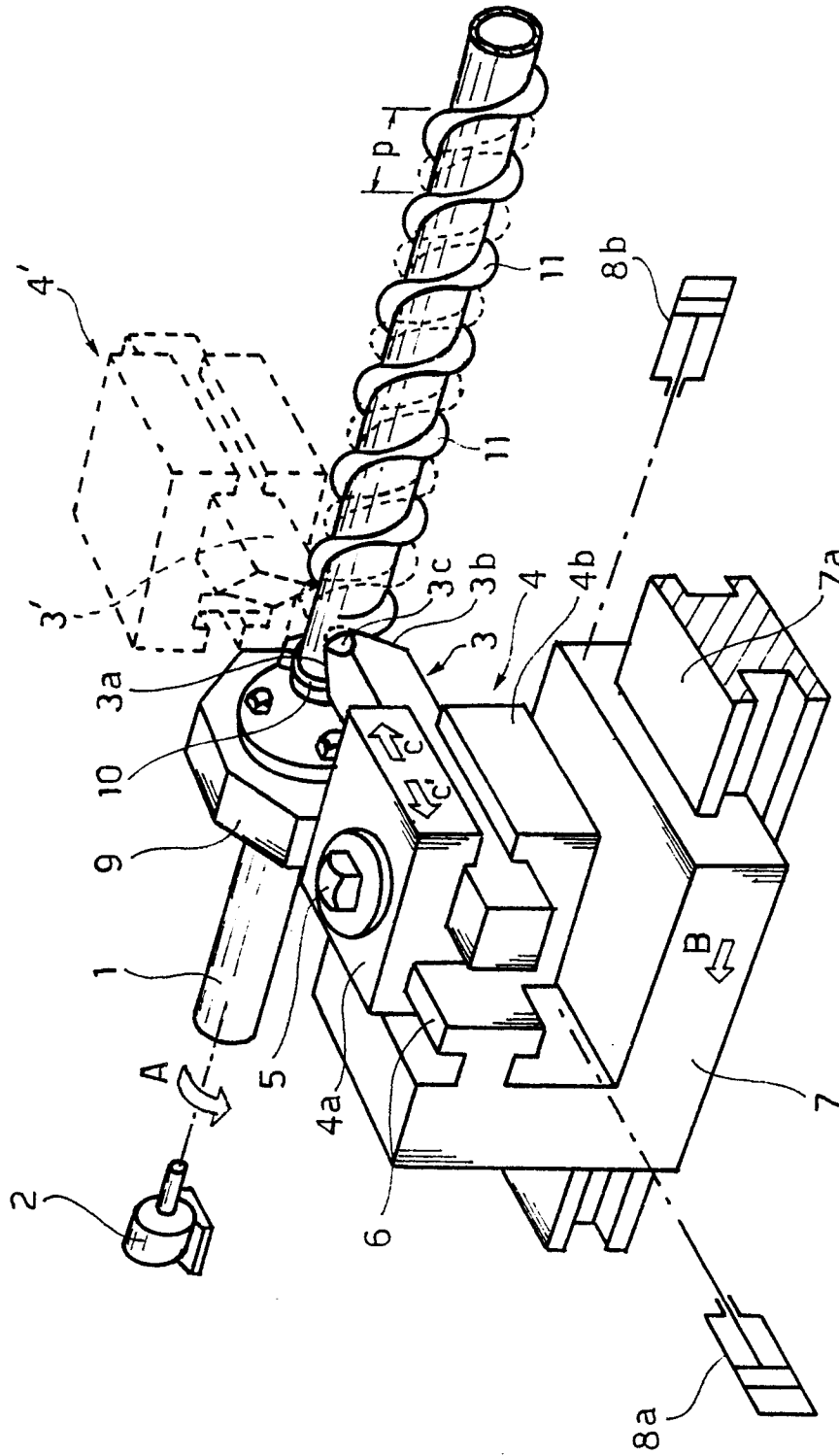


Fig. 1

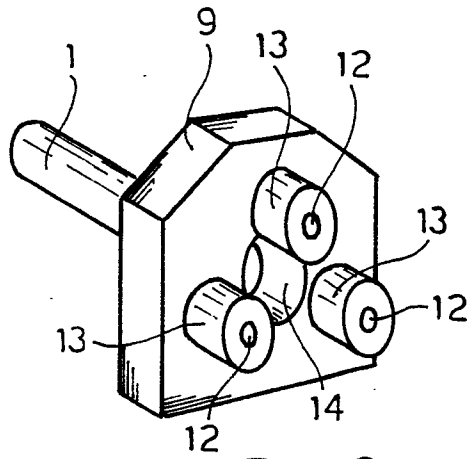


Fig. 2

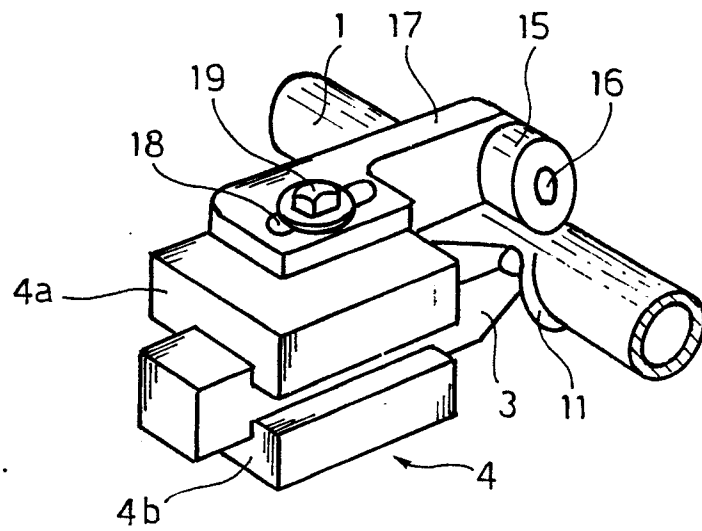


Fig. 3

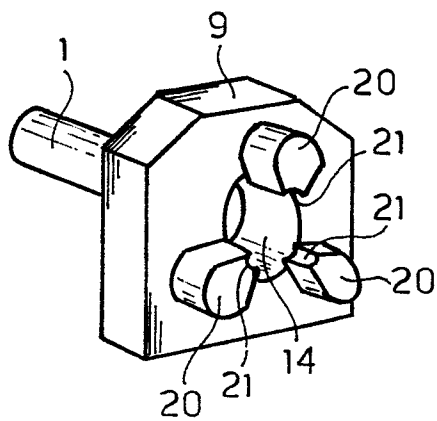


Fig. 4

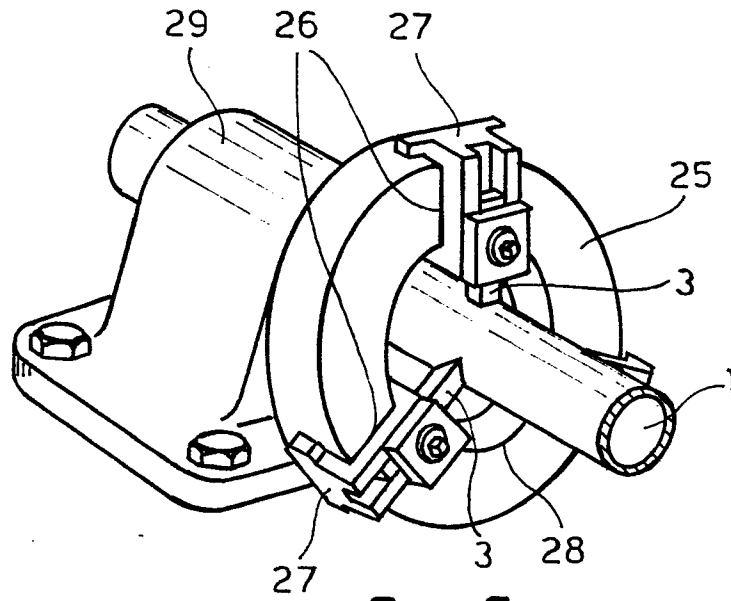


Fig. 5

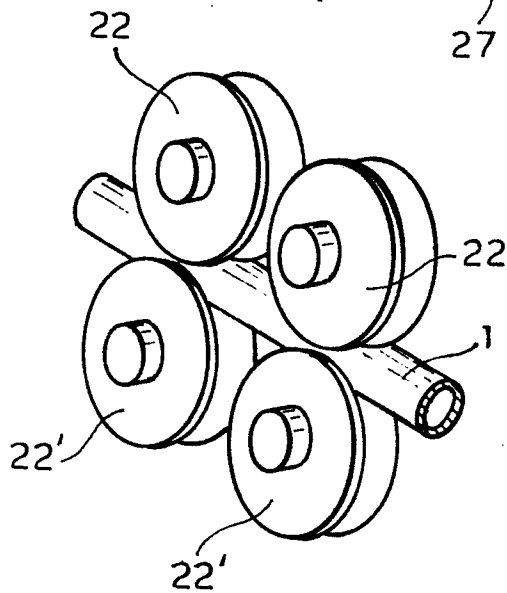


Fig. 6

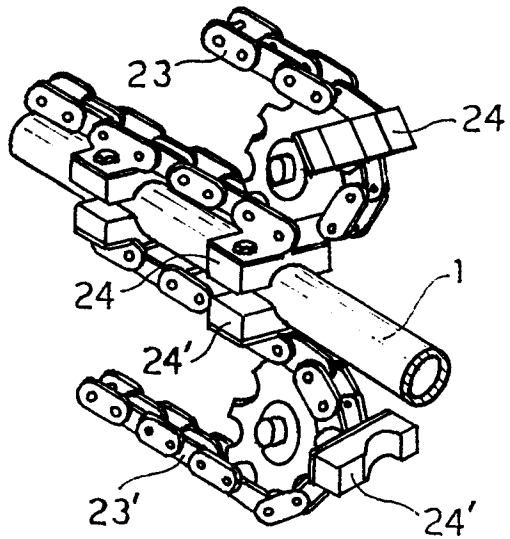


Fig. 7