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(54) **A numerical control machine for through cutting of hard materials such as stone**

(57) A numerical control machine for through cutting of hard materials such as stone, comprises:

- a resting table (17) for the material (13) to cut;
- means for supporting and sliding the material (13) along at least one direction (x) relative to the resting table (17);
- an abrasive cutting tool (1) of thin, elongate shape and circular in cross section, disposed perpendicular to the table (17) and slidable within a slot (16) thereof;
- locking means (7, 8) for locking the ends of the cut-

ting tool (1) at a distance greater than the thickness of the material (13) to cut;

- driving means (6) connected to the tool (1) for rotating the tool about its longitudinal axis (z);
- a support linkage for supporting tool locking means, wherein the support linkage has a reciprocating motion of translation in a vertical plane (yz) and a reciprocating motion of translation in a direction (y) perpendicular to the sliding direction (x) of the material (13).

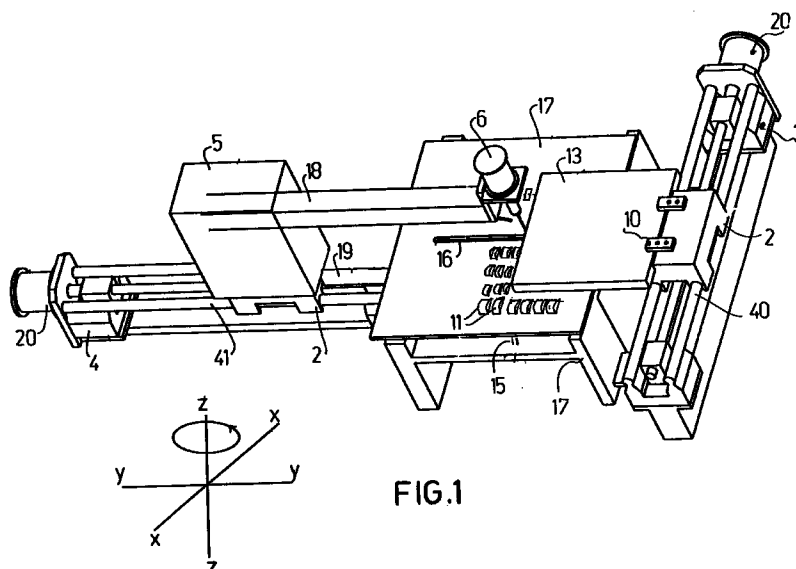


FIG.1

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Description

The present invention relates to a numerical control machine for through cutting of hard materials such as marble, granite and other kinds of stone.

Background of the invention

Conventional machines for cutting the above cited materials either make use of rotating cutting tools or percussion tools, driven pneumatically or by electric motors. Cutting machines employing a diamond steel wire have recently been developed. With such machines, the cutting wire is driven by a rotating wheel through a transmission means installed on a supports mounted on numerically controlled axles and capable of carrying out some special cutting operations for certain cutting patterns.

This system, which is acceptable for routing operations, encounters functional limits where an aperture is to be formed in the material. For each aperture, the cutting wire has to be divided, slipped through a bore previously obtained in the material and finally jointed again. These operations are repeated for each aperture to be cut. Besides involving considerable downtime, these conventional methods are scarcely reliable concerning the point of junction of the wire.

To cut out closed figures, also numerical control milling cutters are used. In this case, a practical limit is encountered in that the maximum length of the tool is limited. Where the tool is mounted projecting from the machine, only milling cutters of a rather short length can be utilised. Further, the minimum diameter of the tool cannot undergo a determined size.

In spite of this evolution, the time required for cutting stone panels with figures of a certain geometrical complexity is considerably long and requires an experienced operator. This aspect, in combination with defects in the final result attained (rough radiuses, non-uniformly cut surfaces, non perfect squareness of the walls) remains one of the major limits for the application of the above cited methods.

For cost reasons, marble, granite and generally stone workpieces have to be worked and finished rapidly. In the last 30 years, cutting techniques making use of diamond cutting tools have brought great advantages in the working of pieces having a relatively straight contour. However, although numerical control machines with a diamond wire or blade have dispensed from some manual finishing operations, in many cases the workpiece still has to be finished manually to remove the signs left by the tool's shape.

A recent innovative cutting method is the so called waterjet system wherein a jet of water mixed with abrasive material is used. This system allows to cut various straight or contoured shapes through slabs a few centimetres thick. A drawback with this system is that it is not possible to yield acceptable cuts (as to the smooth sur-

face and squareness of the cut with respect to the slab surface) when applied to slabs thicker than 3 or 4 centimetres.

5 Summary of the invention

It is an object of the present invention to provide a cutting machine capable of carrying out a new and advantageous process for working stones, particularly marble and granite, different from the above discussed prior art methods and requiring less expenditure of time so as to reduce manufacturing cost.

In accordance with one aspect of the invention as claimed, this object is accomplished by the provision of a numerical control machine for through cutting of hard materials such as stone, characterised by comprising:

- a resting table for the material to cut;
- means for supporting and sliding said material along at least one direction relative to said resting table;
- an abrasive cutting tool of thin, elongate shape and substantially circular in cross section, disposed substantially perpendicular to said table and slidable within a slot of said table;
- locking means for locking the ends of said tool at a distance greater than the thickness of the material to cut;
- driving means connected to the tool for rotating said tool about its longitudinal axis;
- a support linkage for supporting said locking means, said support linkage having a reciprocating motion of translation in a substantially vertical plane and a reciprocating motion of translation in a direction substantially perpendicular to said sliding direction of the material.

Brief description of the drawings

In order that the present invention may be well understood there will now be described a few preferred embodiments thereof, given by way of example, reference being made to the accompanying drawings, in which:

- FIG. 1 is a perspective view of a machine according to the present invention;
- FIG. 2 is an enlarged view of the cutting tool of the machine of FIG. 1;
- FIG. 3 is a view of a linkage for supporting and driving the tool of the machine of FIG. 1; and
- FIGS. 4 and 5 are enlarged views of the device of FIG. 3.

Detailed description of a preferred embodiment

Referring initially to FIG. 1, reference numeral 2

designates a carriage slidably mounted along a pair of transversal horizontal guides 40. To the carriage 2 there is fixed a block 13 of stone that can so slide in the transversal direction (x) on the horizontal plane of the table 17. To facilitate such a sliding motion there are fitted on the table 17 a plurality of idle wheels or rollers 11 the axes of which are horizontal and parallel to a direction herein termed longitudinal, i.e. perpendicular to the guides 40. Preferably, the rollers or wheels 11 extend upwardly of the plane 17 by about 0.3-0.5 mm.

The cutting tool 1 (separately illustrated in FIG. 2) consists of a steel elongated member of circular shape in cross section and disposed perpendicular to the plane of the table 17. Preferably, the cutting tool 1 is covered with abrasive diamond scales. The upper end portion of the tool 1 is manually fixed by means of an upper gripper 7 rotatably driven about the vertical axis z by a variable-speed electric motor 6. The lower end portion of the tool is locked by a lower gripper 8 idly mounted for rotation about the vertical axis of the cutting tool 1. Grippers 7 and 8 are mounted to supports 34a, 34b, respectively. Supports 34a, 34b are vertically slidably mounted to the end portions of a pair of horizontal arms 18, 19, respectively. Arms 18, 19 are integral with a box-like frame 5 slidable in the longitudinal direction.

As will become more apparent during the following description, tool 1 is capable of accomplishing a composite movement of rotation about the vertical axis z, reciprocation along the vertical axis z and longitudinal translation in the direction of the axis y. As the block 13 of material to be worked is slidable in the horizontal direction x, the tool 1 and the block 13 can mutually accomplish a relative movement resulting from the combination of the above mentioned four movements (translation along the three axes x, y, z and rotation about axis z), which allows to cut shapes having any desired contour in the block 13.

As shown in FIG. 3, the box-like frame 5 is slidable in the direction of longitudinal axis y, being mounted on a carriage 2 movable along longitudinal guides 41 and driven by a direct current electric motor 20. By shifting the carriage 2, the cutting tool 1 moves in the horizontal, longitudinal direction y.

Within the box-like frame 5 there is fitted part of a linkage, separately illustrated in FIG. 3 and to an enlarged scale in FIGS. 4 and 5. Such a linkage is adapted to vertically reciprocate the cutting tool 1 parallel to the axis z.

With reference to FIG. 4, said reciprocating motion is provided by a variable speed direct current electric motor (not shown), which rotates a disc 21 wherein a diametrical groove 21a is formed. A pin 21b, integral with an end portion of a connecting rod 22, slidably engages the diametrical groove 21a. The opposite end portion of connecting rod 22 is pivotally mounted at 22a to an upper plate 23 in turn hinged at a fixed point 25 to the box-like frame 5. Owing to such an arrangement, rotation of disc 21 drives the plate 23 in reciprocating

oscillatory motion.

By adjusting the length of the connecting rod 22, the distance of pin 21a from the centre of disc 21 can be lengthened or shortened, whereby the amplitude of the oscillation can be adjusted.

A vertical rod 27 drives for oscillation, in unison with the upper plate 23, a lower oscillating plate 28 hinged at 29 to the box-like frame 5.

Referring to FIG. 5, the upper plate 23 is connected through an upper horizontal rod 24 to an L-shaped upper plate 40 hinged at 41 to an intermediate plate 42 (further described herein after). The intermediate plate 42 is lockable to with respect to the upper arm 18 proximate to the upper support of the cutting tool 1. Similarly, the lower oscillating plate 28 drives for oscillation, through a lower horizontal rod 30, a lower plate 31 hinged at 32 to the lower cutting tool support.

Provided at the ends of arms 18, 19 are preferably aligned vertical guides 35a, 35b, respectively. The cutting tool upper support 34a and lower support 34b can slide along vertical guides 35a, 35b, respectively, as a unit with grippers 7, 8, electric motor 6 and cutting tool 1.

The two L-shaped plates 31, 40 are secured to upper and lower sliding supports 34a, 34b, respectively, by connecting rods 39, 33, respectively. Due to this arrangement, synchronous and reciprocating oscillation of the L-shaped plates causes the cutting tool supports to vertically reciprocate in unison, thereby provoking the cutting tool to reciprocate vertically.

Preferably, all the rods are length-adjustable by means of threaded bushings 26.

Still with reference to FIG. 5, the intermediate plate 42 is hinged at 46 to the upper rigid arm 18 and forms an ear 43 to which there is secured an end portion of a hydraulic cylinder 44 having its other end portion hinged at 45 to arm 18. As apparent from the drawings, extension of hydraulic cylinder 44 lifts the upper support 34a along the guide 35a, while its retraction lowers the upper support 34a. Hydraulic cylinder 44 has several functions:

- 1) it is extended to provoke the piercing of the material 13 to be worked;
- 2) it is extended to push the cutting tool 1 through the pierced bore in beginning to cut a new aperture;
- 3) it is retracted to lift and withdraw the cutting tool 1 after the aperture in the material 13 has been cut out;
- 4) during cutting, it is kept in a compressed condition so as to keep the cutting tool 1 constantly under tensile stress for it to be straight and yield perfectly straight cutting surfaces.

The above described linkage allows the cutting tool 1, rotationally driven by electric motor 6, to reciprocate along axis z while the whole assembly formed by the linkage and cutting tool slides along the longitudinal axis

y by means of electric motor 20. In accomplishing this movement, the cutting tool is free to slide in the slot 16 of plane 17.

The stroke in the direction of axis z can be varied by adjusting the length of the connecting rod 22 (FIG. 4) along groove 21a as a function of the thickness of the material to cut.

As the mobile frame 5 with the cutting tool 1 is slidable along the horizontal guides 41, the cutting tool 1, rotated about its vertical axis z by electric motor 6, moves along the axis y in the slot 16 of table 17. Simultaneously, the block 13 of material is made to slide in the transversal direction x, while the reciprocating motion of cutting tool 1 along the axis z is provided by the above described linkage. Obviously, the reciprocating motion that in this example is generated by means of an electro-mechanical system could as an alternative, be provided by a number of different hydraulic, pneumatic, etc. driving systems. The choice of the system will depend on costs and constructional features of the machine.

By co-ordinating the various motions it is possible to cut any shape at high speed, i.e. about 4 cm per minute, also with a thickness exceeding 10 cm. The speed of advancement in cutting is variable as a function of the tool, the block thickness, the tool rotational speed and the frequency of the vertical reciprocating motion of the tool.

In the initial steps, once the shape to be cut has been set by a CAD system and the path of the tool has been specified by a CAM system, providing for each figure a bore to slip the cutting tool 1 through, the block of material 13 to cut is fixed to the machine. A piercing tool (not shown) is locked in the upper gripper 7. The position of the axes is reset and for each figure a bore is pierced automatically, controlling the extension of hydraulic cylinder 44. On completion of these steps, the piercing tool is removed and the cutting tool is mounted, and the cutting of the desired figures begins. For each figure, after cutting the contour, the lower gripper 8 is automatically released and cylinder 44 is retracted to lift the cutting tool up and withdraw it from the block of material 13. Then, the tool is brought into alignment with the previously formed bore for cutting the following figure. The arm 18 is lowered and the tool 1 is slipped through the bore and the lower gripper 8. Upon reaching the desired depth, the gripper is locked, the tool is stretched and the cutting of the next figure is begun, proceeding automatically to complete the cutting operations.

The cutting operations can also be accelerated and carried out automatically by means of an automatic tool replacement system, per se known to those skilled in the art.

The fragments of the cuttings remain on the surface of the table 17. At the end of each cutting cycle, the finished workpiece and the fragments of the material are then removed.

As soon as the cutting step has begun, a pump (not

shown) supplies a constant flow of water through a water supply tube 14 (shown in FIGS. 3 and 5). Tube 14 has the dual purpose of cooling the cutting tool and remove the material being cut off, which drops into a special tank under the table 17 (FIG. 1) through a lower tube 15.

The movements along the horizontal axes y and x are individually controlled by a numerical control system that allows to obtain any contour. The cutting paths are determined by a CAM system of known kind. The cutting speed is automatically programmed by a CAM operator and vary as a function of the type of material, the material thickness, the kind of cutting tool and other cutting process parameters.

In order to ensure a quick and efficient process, there is provided a cutting tool of circular cross-section with a roughness on its surface. This feature can be attained either by providing a rough steel tool or by a tool on which a rough, abrasive material is deposited. Preferably, the cutting tool 1 of FIG. 3 is covered by a layer of natural or synthetic hard material such as garnet, diamond, etc., which can be of various sizes and shapes and be fixed to the cutting tool surface through an electrolytic process or other known methods. Advantageously, an electrolytic process may be used in which the binding element is nickel.

The preferred abrasive element is diamond dust in 0.5 mm scales with faceted faces. After the deposition process, the diamond scales are covered and fixed to the tool by a layer of nickel about 0.2-0.3 mm thick. Successively, the tool undergoes a sandblasting process to remove nickel deposits from the protruding surfaces of the diamond scales. Sandblasting can be also used to dress the cutting tool after it has undergone a relevant number of cycles.

During cutting, the contacting surfaces heat up and produce relevant amounts of dust and scales. In accordance with the present invention, the above discussed water jet is supplied to the whole surface of the cutting tool, cooling it and clearing it from the residual scales of the worked material.

The cutting machine of the present invention can rapidly carry out a large number of cuts at low costs.

Claims

1. A numerical control machine for through cutting of hard materials such as stone, characterised by comprising:

- a resting table (17) for the material (13) to cut;
- means for supporting and sliding said material (13) along at least one direction (x) relative to said resting table (17);
- an abrasive cutting tool (1) of thin, elongate shape and substantially circular in cross section, disposed substantially perpendicular to said table (17) and slidable within a slot (16) of

said table (17);

- locking means (7, 8) for locking the ends of said tool (1) at a distance greater than the thickness of the material (13) to cut;
- driving means (6) connected to the tool (1) for rotating said tool about its longitudinal axis (z);
- a support linkage for supporting said locking means, said support linkage having a reciprocating motion of translation in a substantially vertical plane (yz) and a reciprocating motion of translation in a direction (y) substantially perpendicular to said sliding direction (x) of the material (13).

2. A machine as claimed in claim 1, characterised in that said support linkage comprises a pair of rods (24, 30) each having a first end secured to a respective plate (23, 28) in synchronous oscillatory motion, and a second end secured to respective articulated means (41, 39, 34a; 31, 33, 34b) for driving in synchronous reciprocating motion of translation said cutting tool locking means (7, 8) along a substantially vertical direction (z).
3. A machine as claimed in claim 2, characterised in that said articulated means (41, 39, 34a; 31, 33, 34b) are located at the ends of a pair of horizontal rigid arms (18, 19) spaced apart in the longitudinal vertical plane (yz) and secured to a carriage (2) slidable along horizontal longitudinal guides (41).
4. A machine as claimed in claim 3, characterised in that one of said articulated means (41, 39, 34a) is mounted to an intermediate plate (42), said intermediate plate being pivotally mounted to one of said rigid arms (18, 19) and connected to actuator means (44) adapted for driving one (7) of said tool locking means (7, 8) in such a direction so as to keep the cutting tool (1) constantly stretched.
5. A machine as claimed in claim 1, characterised by comprising a liquid supply system for cooling the cutting tool (1) and removing fragments of material being cut off.
6. A machine as claimed in claim 1, characterised in that idly mounted to the table (17) is a plurality of roller means (11) with axes of rotation parallel to said direction (x).
7. A machine as claimed in claim 6, characterised in that said roller means (11) protrude from said table (17) by 0.3-0.5 mm.

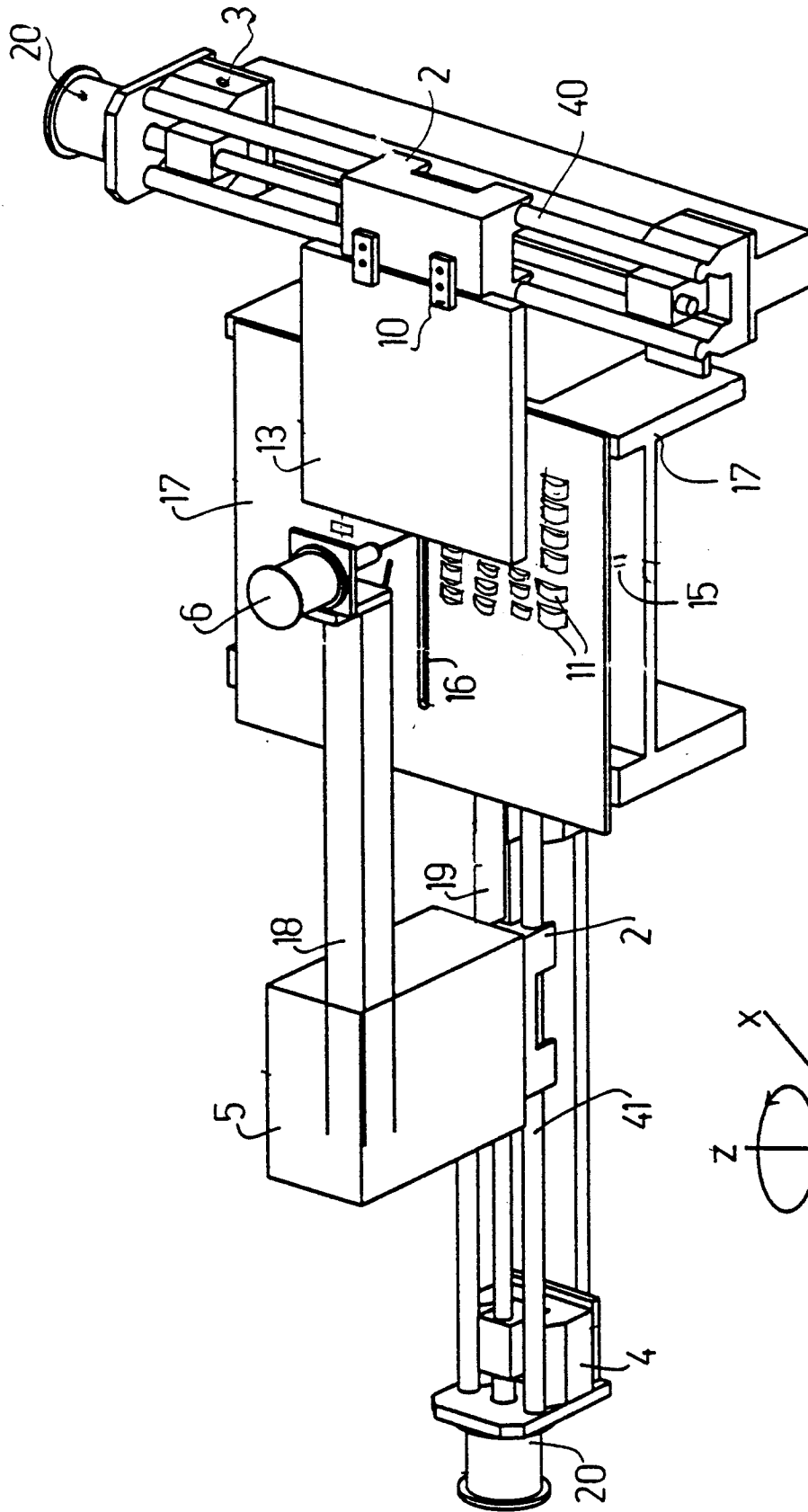
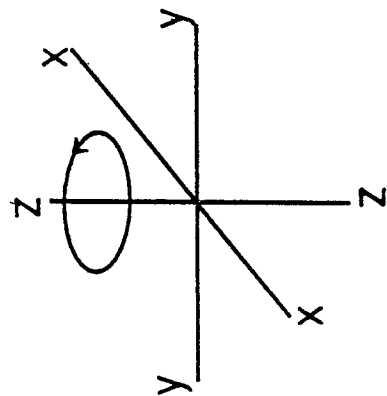
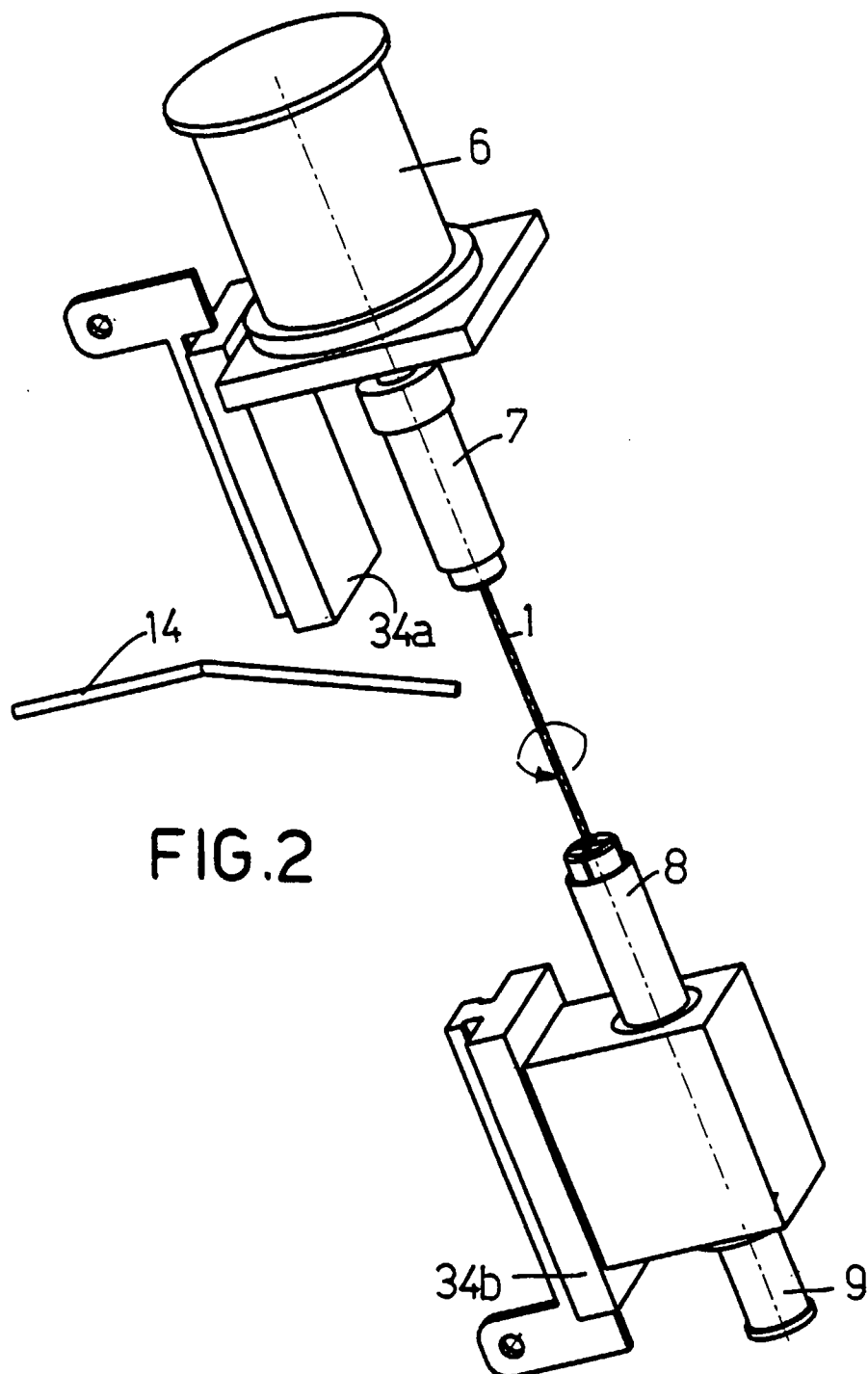
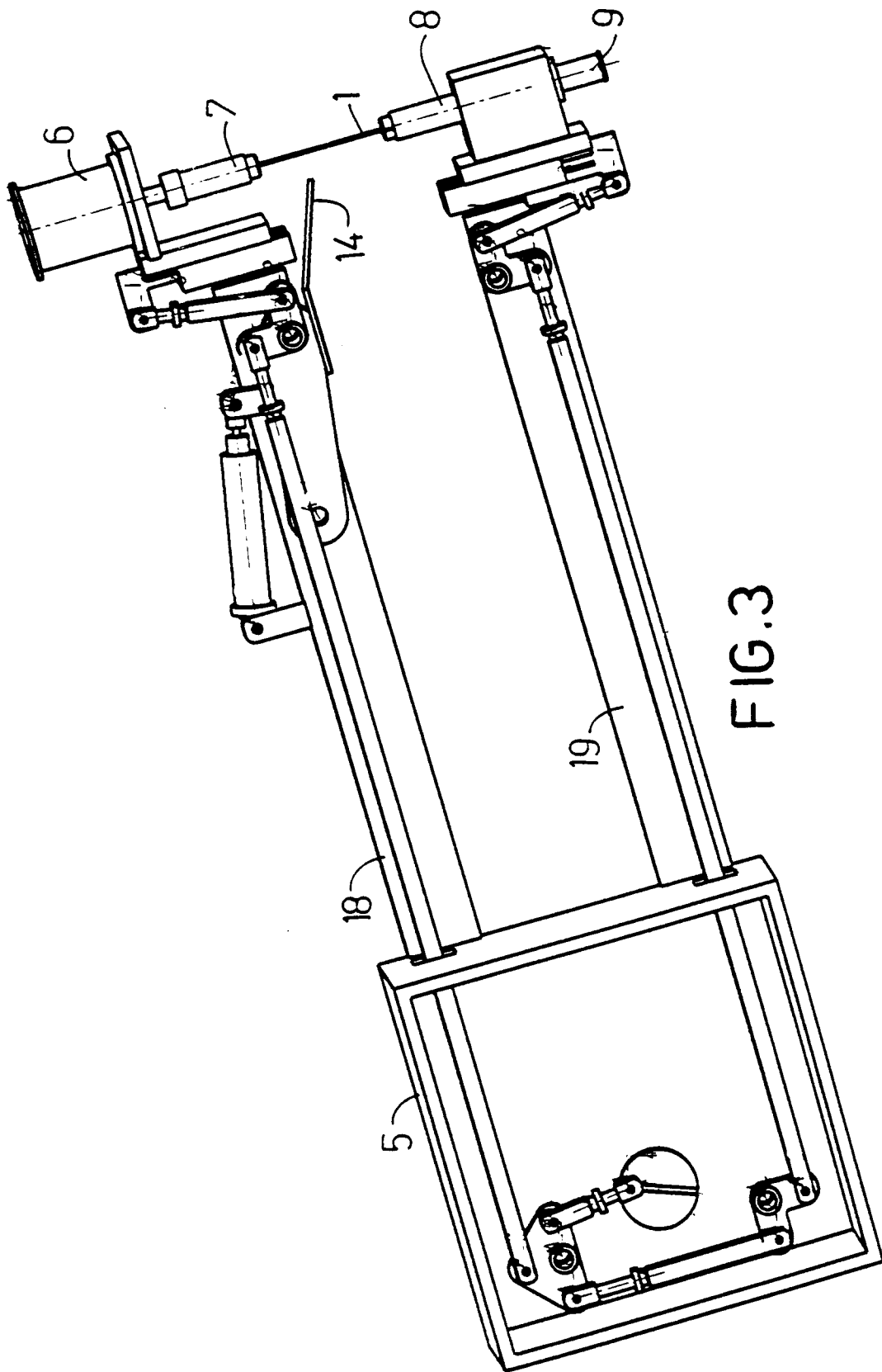
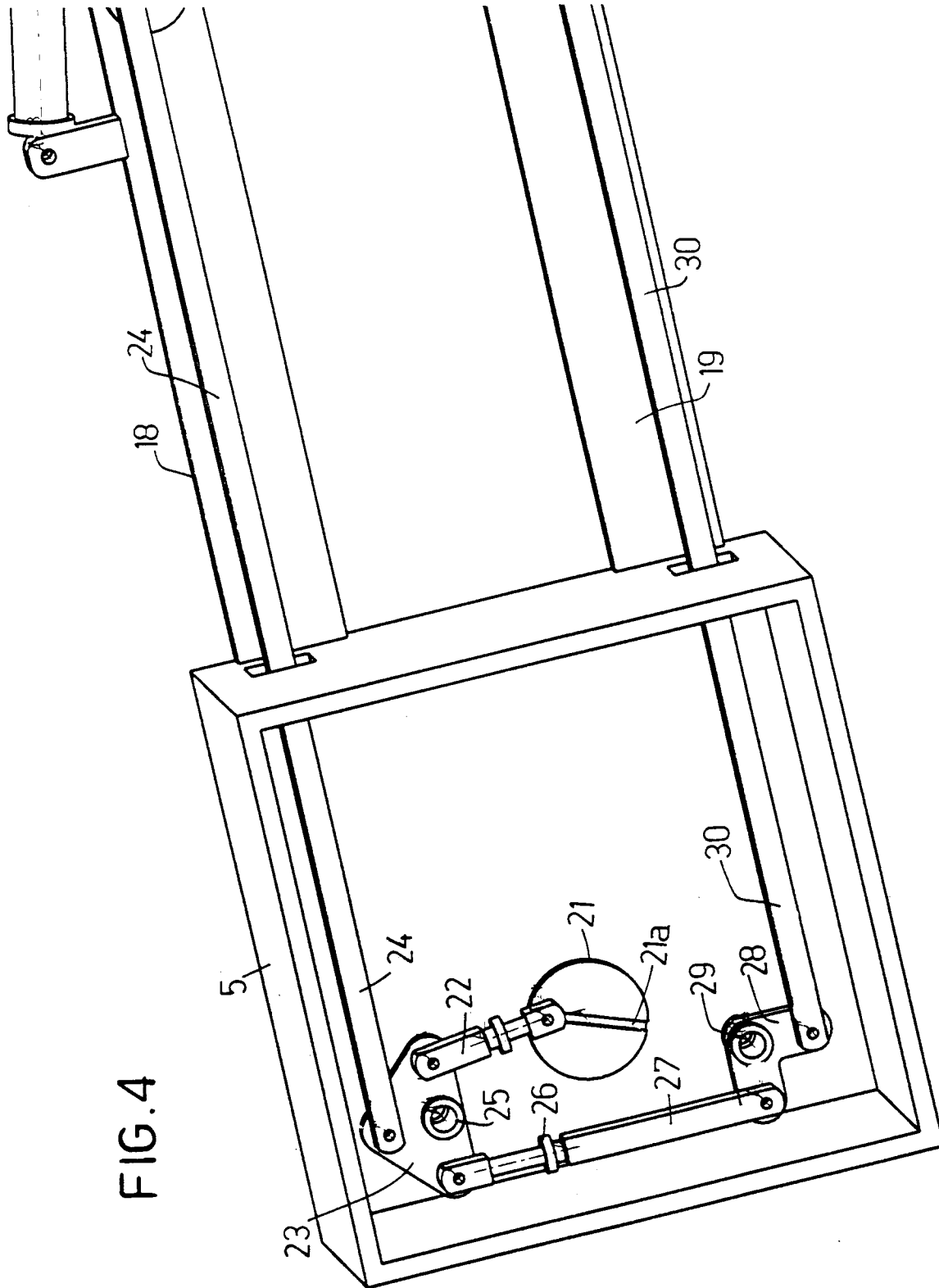


FIG.1









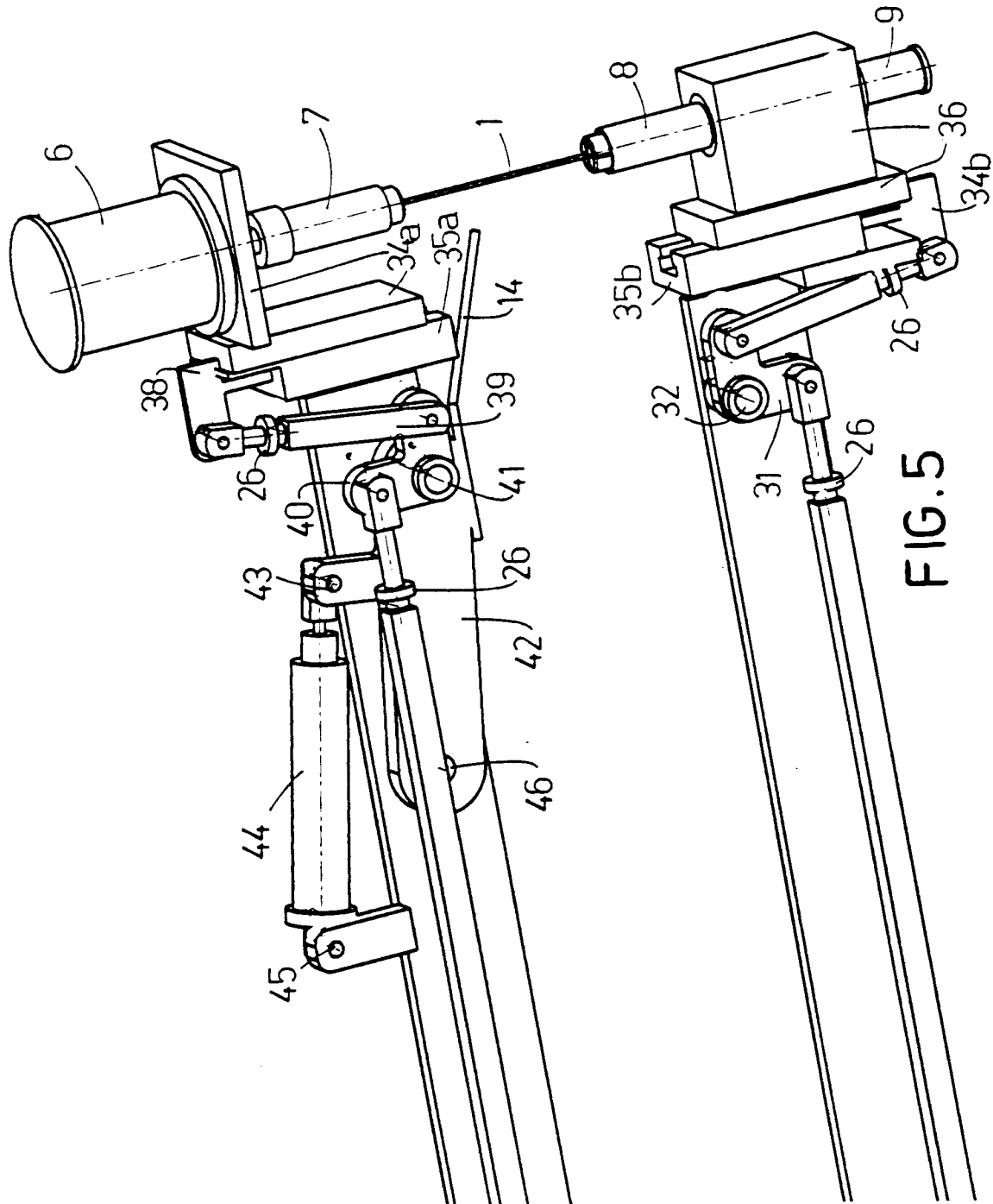


FIG. 5