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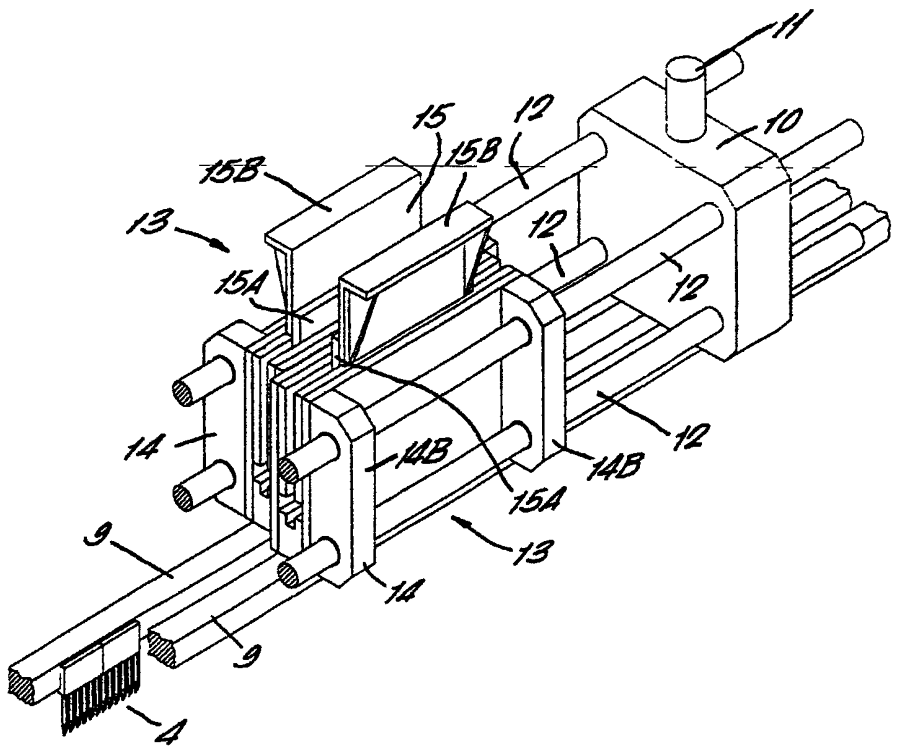
(54) Title: A TUFTING MACHINE



(57) **Abstract:** A tufting machine in which the needle bar (9) is driven laterally by one or more linear motors (13).

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A TUFTING MACHINE

The present invention relates to a tufting machine used for carpet manufacture.

Tufting machine are distinguished over other carpet making methods in that loops of yarn which constitute the pile of the carpet are inserted in a backing medium or cloth, which may be fibrous or woven according to the carpet application. The loops are held in place by the retentive pressure of the backing cloth having been expanded locally through the insertion of the yarn. A subsequent operation covers the rear face of the yarn and backing cloth with a retaining adhesive. The adhesive also holds a further layer of backing material, usually hessian.

The yarn is inserted into the backing cloth by a multiplicity of needles which perform a reciprocating motion. The needles have eyes at the lower extremities through which yarn is both fed and captured. The needles are usually connected to one or more transverse bars known as needle bars so that all needles can be reciprocated synchronously. There are also alternative mechanisms in which the needles are capable of individual selection so that only those needles selected are subject to the reciprocation, whilst those not selected are not reciprocated. The reciprocating action is usually delivered through a series of pistons coupled to a rotating main-shaft driven by electric motor or similar means. The coupling mechanism is of a crank-shaft type so that the extent of the needle motion is the throw of the crank. Other more complex arrangements are also known which endow features to enable the motion envelope of the needle to be controlled and easily set to any desired range.

The loops of yarn may be of varying heights on the face side of the carpet in order to provide a patterning effect. There are several techniques for causing this effect, such as changing the tension of yarn from low to high from one insertion of a yarn loop to the next (high pile to low pile). Yarn tension may be set by modulating the speed of the yarn feed mechanism controlling the length of yarn delivered for each loop (stitch). A simple form of yarn feed mechanism uses a pair of rollers with a high friction surface between which the yarn is pinched. Variations in the speed of the rollers allows control of the length of yarn delivered for each tuft of carpet pile. There are many more complex mechanisms for exerting control over the yarn delivery. Some of these deliver control over individual strands of yarn, some over subsets of all the strands.

Additional patterning features include the use of cut pile as opposed to pile formed from loops. The cut pile effect is achieved usually during the tufting process by catching the loops formed by the insertion of yarn through the backing cloth on a suitably formed hook on the face (lower) side of the carpet. A knife shears the yarn on one side of the hook after several further loops have been inserted in the backing material. The knife is articulated to move in synchronism with the insertion of yarn. The hooks involved in the loop capture during yarn insertion are also arranged to move into position in synchronism with the yarn insertion process.

The foregoing is a non-exhaustive illustration of some of the features of tufting machines and the mechanisms for controlling carpet patterning. Further features of tufting machines include the ability to introduce a plurality of colours. Tufts of different coloured yarns can be made to form attractive carpet patterns such as can be achieved in woven carpets in which any chosen colour may be inserted in any location in the carpet by correct design of the patterning commands. One way in which this can be done is by burying one coloured yarn by giving it a very low pile height in an area of higher pile height of different colour. When the buried colour is required, the pile height is set high whilst that of the other colour in that area is set lower. This results in patches of different colours but has a number of disadvantages in the wastage of yarn which cannot be seen and in the straight line arrangement of the coloured yarn. Means for altering the lateral position of the yarns have consequently been developed to overcome some of these limitations.

There are normally up to two needle bars on a machine although more may be fitted. These are reciprocated by the main-shaft rotation and crank means in the vertical direction. An additional degree of freedom of motion is afforded to the needle bars by a mechanism which allows side to side motion, that is across the width of the tufting machine laterally. Yarns may thus be moved from one needle position to others. This provides greater flexibility to produce a required pattern, as needles containing a particular colour can be shifted laterally to a position where that particular colour is required in the pattern.

Mechanisms for moving the needle bars include hydraulic actuators, pneumatic actuators, and electric servo controlled motors with a rotational to linear conversion device. This latter mechanism is typified by WO 97/15708 and EP 867,553. In these cases, the rotational to linear conversion devices include screw thread and nut arrangements (including those with acme threads and other thread profiles); ball screws; inverted roller screws and similar equivalent devices. Other such devices include rack and pinion assemblies and friction drive mechanisms. These mechanisms provide the necessary motional requirements from a functional view but also limit the speed capability of the tufting machine. This limitation arises due to the force required to obtain the necessary rate of acceleration being beyond the capability of the driving mechanism and slackness or free play in the mechanisms connecting the servo motor with the sliding needle bar affecting the stability of the control loops and the consequent variations in instantaneous inertia.

Further, with these systems, the sliding needle bar drive system, servo motors, or equivalent hydraulic or pneumatic actuators have been mounted on the external end faces of the tufting machine. This has required the provision of holes in the end plates or housing to allow the servo motor output shaft to feed into the sliding needle bar assembly. The servo motor output shaft has been coupled to a ball screw or equivalent device (such as an inverted roller screw or screw and nut assembly). The motion sensor for the servo motor has usually been coupled directly to its rotating shaft so that lost motion in any coupling mechanism between the servo and the sliding needle bar has remained uncompensated.

According to the present invention, there is provided a tufting machine comprising a housing, a needle bar which is reciprocable within the housing and on which a plurality of needles are mounted, whereby, in use, as a web of backing medium is fed through the machine, the needles reciprocate towards and away from the web, and at least one linear motor for moving the needle bar in a lateral direction across the width of the web, the or each linear motor comprising a first part fixed with respect to the housing, a second part electromagnetically coupled with respect to the first part and coupled to drive the needle bar, and a power source for supplying electric power to one of the motor parts to drive the first and second parts relatively to one another in the lateral direction.

As a part of the linear motor is connected with respect to the needle bar, no linkage or other intervening mechanism is required to drive the needle bar laterally. The mechanism is therefore simple and cannot introduce any lost motion.

The tufting machine may have a single needle bar. However, preferably, it comprises one or more further needle bars, the or each further needle bar being either driven conventionally or preferably being provided with at least one linear motor for moving the further needle bar in a lateral direction across the width of the web, the linear motor comprising a first part fixed with respect to the housing and a second part electromagnetically coupled with respect to the first part and fixed with respect to the further needle bar, and a power source for supplying electric power to one of the motor parts to drive the first and second parts relatively to one another in the lateral direction.

The linear motor could be of the kind comprising a tubular arrangement of magnets surrounded by an annular arrangement of coils. However, in this case, a bearing would be required to mount the coil assembly with respect to the housing.

Alternatively, the linear motor may be of an open form in which magnets are provided on one part and the arrangement of coils is provided on the other part. This type of motor experiences considerable attractive force between the magnets and the coils and therefore bearings are required to resist these otherwise unusable forces.

Preferably, however the or each linear motor is of a type which allows relative movement of the first and second parts in the direction of reciprocation of needle. Such a motor is provided when one of the first and second parts is a U-shape channel extending in the lateral direction, and the other of the first and second parts is within the U-shape channel. This represents a particularly efficient way of electromagnetically coupling the first and second parts, as there is a relatively large surface area between the two parts and the U-shape channel ensures that there is no net attractive force between the first and second parts.

The linear motors are preferably provided with permanent magnets and coils to generate the electro-motive forces. However, it is possible to have the permanent magnet system replaced by electrical excitation (as in a DC excited dynamo). Unfortunately, the steady state fields produced by coils subject to electrical excitation are significantly smaller, due to coil heating effects, than those available from rare earth magnets. Consequently, such motors are relatively inefficient and thus not currently practical.

Preferably the or each linear motor has a plurality of coils on the first or second part which are electrically coupled to the power source, and a plurality of corresponding magnets on the other of the first and second part, wherein the coils and magnets form the electromagnetic coupling between the two parts.

From an electromotive point of view, it does not matter whether the coils are provided on the first or the second part of the motor. However, it is preferable for the coils to be mounted on the first part of the linear motor, as this does not move during operation, thereby making for simpler electrical connections to the coil.

A particularly advantageous construction is for the coils to be provided on the first part, and for the first part to form the U-shape channel depending downwardly from the fixture of the first part to the housing. In this case, heat produced in the coils may now be removed by conduction through the coil mounting structure and the housing of the tufting machine, or by convection with fins provided on the outer surface of the U-shaped channel. The number of magnets is reduced to approximately half of the number that would be required in the alternative arrangement where the magnets are provided on the U-shape channel. The magnet assembly is connected to the needle bar and is significantly reduced in weight as compared to a U-shape structure connected to the needle bar. This consequential reduction in the mass and inertia of the needle bar assembly allows the required motion to be completed in shorter times for the same electromotive input forces.

Preferably, there is an air gap between the first and second motor parts, so that no motor bearing is required between the two parts. This also means that the needles can reciprocate without requiring a mechanical coupling between motor parts to allow for this. The mechanical construction of the supporting assembly in the sliding needle bar can ensure that the two parts of the motor are positioned so that they do not touch. Additional non-loaded bearings such as are made of plastic may be used between the first and second parts of the motor to ensure that the air gaps are maintained with approximately the same spacing, without the need for close tolerances to be maintained elsewhere in the sliding needle bar assembly.

One of the advantages of the linear motor is that it does not require the linkage associated with a rotary to linear device. However, under certain circumstances, a linkage may be provided if necessary. For example, the linear motor may be mounted on the body of the tufting machine away from the tufting area and be coupled to the needle bar using a translated motion mechanism to transmit linear motion from the motor to the needle bar. In this case, the linkage is simpler than the linkage associated with a rotary to linear convertor and thus provides a lower mass to be moved, and also has less backlash. One particular arrangement of this type has the linear motor mounted on the frame of the tufting machine (not on the needle bar assembly) and coupled to the needle bar assembly through a simple single bar coupling arrangement. The coupling bar is supported at each end on a rotational bearing with one end coupled to the needle bar and the other to the movable part of the linear motor.

The tufting machine also preferably comprises a control system for controlling the motion of the or each linear motor, the control system comprising a sensor for detecting the position of at least one motor on the or each needle bar, and a processor provided with data relating to the pattern for the carpet to be tufted and having means to generate signals to drive the or each motor to locations determined from the sensor readings and the data relating to the pattern.

Under certain circumstances, for example, if the machine speed is too high for the needle bar to have time to move laterally to a position required for a specific pattern, the control system may be provided with means to automatically restrict the speed of reciprocation of the needle bar. This prevents unwanted lateral movement of the needles while the needles are still in the backing material.

According to a second aspect of the present invention, there is provided a method of driving a needle bar in a tufting machine, the method comprising reciprocating the needle bar towards and away from a backing medium; and moving the needle bar laterally across the backing medium using a linear motor.

An example of a tufting machine constructed in accordance with the present invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a front view showing the general arrangement of the tufting machine,

Fig. 2 is a section along line II-II in Fig.1;

Fig. 3 is a perspective view showing two needle bars and their respective linear motors;

Fig. 4 is a perspective view showing the detail of one linear motor;

Fig. 5 is a cross-section through the two linear motors as illustrated in Fig.3; and

Fig. 6 is a cross-section similar to Fig.5 showing an alternative arrangement of linear motor.

In most respects, the machine is a conventional tufting machine, so that a detailed description of the tufting operation will not be included here. The machine has a top housing 1 housing the yarn feed mechanisms 2, and three reciprocating pistons 3 for reciprocating needles 4. A bottom housing 5 is mounted on legs 6 (neither of which are shown in Fig 1) as is the bed plate 7 and is provided with a series of rollers 8 for feeding the backing medium through the machine. As the backing medium is fed through the machine, the needles 4 are vertically reciprocated by the reciprocating pistons 3 and co-operate with a plurality of hooks or loopers beneath the backing medium to produce a tufted carpet by means well known in the art.

The apparatus shown in Figs.3 and 5 comprises a pair of needle bars 9, each of which have needles 4 connected along their length. Three plates 10 are reciprocally vertically movable by means of a respective push rod 11 driven by a respective reciprocating motion piston 3. As shown in Fig.3, the plates 10 are connected by four laterally extending guide bars 12 which are rigidly fixed to the plates 10. Each needle bar 9 is associated with its own pair of laterally spaced linear motors 13 as shown in Fig.1. The detail of one such linear motor for each needle bar 9 is shown in Figs. 3 and 5. In Fig.5, the linear motor for one needle bar 9 is on one side of the centre line Y-Y, while the other linear motor is on the other. Each linear motor comprises a sliding part 14 and a static part 15. Each sliding part 14 comprises a magnet support 14A mounted to a respective needle bar 9 and a mounting part comprising a pair of flanges 14B which are slidable along two of the guide bars 12 on linear bearings 12A so as to move the needle bar 9 laterally.

The construction of the linear motor is shown in greater detail in Fig. 4. The sliding part 14 has a generally U-shape channel extending laterally. The sliding part 14 is made from non-magnetic material such as aluminium, and has a series of magnets 16 fitted to the inside of the U-shape channel in such a way as to provide an alternating magnetic field along the length of the channel. The magnets are arranged as shown Fig.4 with their poles alternating both along the channel, and across the channel. The poles shown in Fig.4 are those which face towards the centre of the channel. The outer sides of the magnets have the opposite magnetic sense to those parts facing the inner side of the U-shape channel as shown. In normal construction, there is an air gap or other non-magnetic part positioned between each magnet in order to provide separation between said magnets.

The fixed part 15 is provided with a plurality of coils 15A fixed to the housing by a bracket 15B. These coils 15A are elongate in the vertical direction and are of approximately the same pitch as the magnetic sequence. The coils are not, however, the same pitch as the magnetic sequence to prevent the cogging effect of identical pitch as shown in U.S. 5,642,013.

Referring to Fig.3, it should be noted that all of the parts illustrated in this figure, with the exception of the fixed parts 15 will reciprocate vertically with the needles 4. Reciprocating vertical motion is thus provided to the needles 4 from the reciprocating pistons 3, via push rods 11, plates 10, guide bars 12 sliding parts 14 and needle bars 9. The effect of this will be to cause the moving part 14 to reciprocate vertically with respect to the fixed part 15. An air gap (not shown in Fig.5) between the two parts ensures that this motion can be accommodated without requiring any bearings between the two.

The application of electrical power to the coils 15A will cause a corresponding lateral movement of the sliding part 14 along guide bars 12, causing the attached needle bar 9 and needles 4 to be moved laterally.

As the sliding part 14 is moved downwardly during reciprocation, the electromotive force will be diminished, as the coils 15A on the fixed part 15 will be partially or completely moved out of the magnetic way provided in the U-shape channel. Lateral movement of the needles will only be made when they are substantially at their uppermost position (within ± 25-30° of TDC) in which they are out of engagement with the backing medium, and in which the coils 15A are deepest within the U-shape channel. In this condition, the motor exerts nearly or exactly its full force capability and provides the greatest lateral acceleration.

While lateral needle motion with the needles in the backing medium is generally undesirable, as it leads to needle breakage and unwanted patterning effects, there is one type of patterning where this type movement may be required. This patterning is known as DSP which is essentially caused by the yarn fibre rotating whilst in the backing material. This is achieved by moving the needles only by a fraction of a gage jump while the needles are still engaged in the backing material. If desired, such motion can be provided by the linear motors described above.

The linear motor is servo-driven and hence requires the means to commutate the coils to provide a reaction force. For this purpose, there is a Hall-effect (magnetic) sensor (not shown) or equivalent embedded in the coil assembly which provides feedback of the location of the coil assembly in relation to the magnetic field formed in the U-shape channel.

A further requirement of the servo controlled motor is that there be means to measure the location of the motor relatively to the rest of the machine. This takes the form of positional sensors, which may be optical or magnetic, external to the motor assembly. The measuring system must be insensitive to the vertical reciprocating motion of the needles, while providing precise transverse location data. As an alternative to a separate location measurement sensor, the Hall-effect sensor or equivalent used for commutation may also be used to provide location data for the position feedback function.

When in the raised position, with the coil assembly fully inserted in to the U-shape channel, the needle bar is subject to rapid movement using the linear motor. This changes the position of the needle bar, if required by the pattern commands, usually by an integer number of gauge jumps (that is an integer number times the distance between each needle). Some patterns require needle bar shifts by other non-integer distances such as in DSP as will be recognised by those skilled in the art of tufted carpet design. The motive force available from the motor is at a maximum in this raised condition. The motion of the linear motor is controlled by a servo amplifier and position control system offering the features of velocity and acceleration feed-forward. These last two characteristics ensure that the motion of the needle bar 9 has little position over shoot. This optimum combination of these control settings minimises the overall duration of the needle bar motion. The tightly coupled nature of the structure ensures that the position measurement of the servo control system accurately reflects that of the sliding needle bar with no lost motion or slack as in previous machines.

An alternative arrangement of linear motor is shown in Fig.6. In many respects, this example is similar that shown in the other figures and the same reference numerals have been used, where appropriate, to designate the same components.

The difference between this example and that previously described is essentially that the part with the coils which is fixed to the housing 1 is now the U-shape channel while the magnets are within this U-shape channel.

More particularly, the fixed part 115 of the linear motor has a plurality of coils 115A fixed to the inside of a downwardly opening U-shape channel 115B which is fixed at its top end to housing 1. The sliding part 114 comprising a mounting part 114A arranged to slide on two of the guide bars 12 and to which a needle bar 9 is mounted. A set of magnets 114B project upwardly from the mounting part 114A into the U-shape channel 115B between the coil assemblies 115A. An air gap (not shown in Fig.6) is provided between the magnets and coils. The set of magnets

114B has the same alternating configuration as that shown in Fig.4, and co-operates with the coils 115A which are correspondingly arranged in order to drive the needle bar 9 laterally.

CLAIMS:

1. A tufting machine comprising a housing, a needle bar which is reciprocable within the housing and on which a plurality of needles are mounted, whereby, in use, as a web of backing medium is fed through the machine, the needles reciprocate towards and away from the web, and at least one linear motor for moving the needle bar in a lateral direction across the width of the web, the or each linear motor comprising a first part fixed with respect to the housing, a second part electromagnetically coupled with respect to the first part and coupled to drive to the needle bar, and a power source for supplying electric power to one of the motor parts to drive the first and second parts relatively to one another in the lateral direction.

2. A tufting machine according to claim 1 comprising one or more further needle bars, the or each further needle bar being provided with at least one linear motor for moving the further needle bar in a lateral direction across the width of the web, the or each linear motor comprising a first part fixed with respect to the housing and a second part electromagnetically coupled with respect to the first part and fixed with respect to the further needle bar, and a power source for supplying electric power to one of the motor parts to drive the first and second parts relatively to one another in the lateral direction.

3. A tufting machine according to claim 1 or claim 2, wherein the or each linear motor allows relative movement between the first and second parts in the direction of reciprocation of the needles.

4. A tufting machine according to claim 3, wherein one of the first and second parts is a U-shape channel

extending in the lateral direction, and the other of the first and second parts is within the U-shape channel.

5. A tufting machine according to any one of the preceding claims, wherein the or each linear motor has a plurality of coils on the first or second part which are electrically coupled to the power source, and a plurality of corresponding magnets on the other of the first and second part, wherein the coils and magnets form the electromagnetic coupling between the two parts.

6. A tufting machine according to claim 4, wherein the coils are mounted on the first part and magnets are mounted on the second part.

7. A tufting machine according to any one of the preceding claims, wherein there is an air gap between the first and second parts.

8. A tufting machine according to any one of the preceding claims, wherein the linear motor is mounted on the body of the tufting machine away from the tufting area and coupled to the needle bar using a translated motion mechanism to transmit linear motion from the motor to the needle bar.

9. A tufting machine according to any one of the preceding claims, further comprising a control system for controlling the motion of the or each linear motor, the control system comprising a sensor for detecting the position of at least one motor on the or each needle bar, and a processor provided with data relating to the pattern for the carpet to be tufted and having means to generate signals to drive the or each motor to locations determined from the sensor

readings and the data relating to the pattern.

10. A tufting machine according to claim 9, wherein the control means further comprises means to automatically restrict the speed of reciprocation of the needle bar.

11. A method of driving a needle bar in a tufting machine, the method comprising reciprocating the needle bar towards and away from a backing medium; and

moving the needle bar laterally across the backing medium using a linear motor.

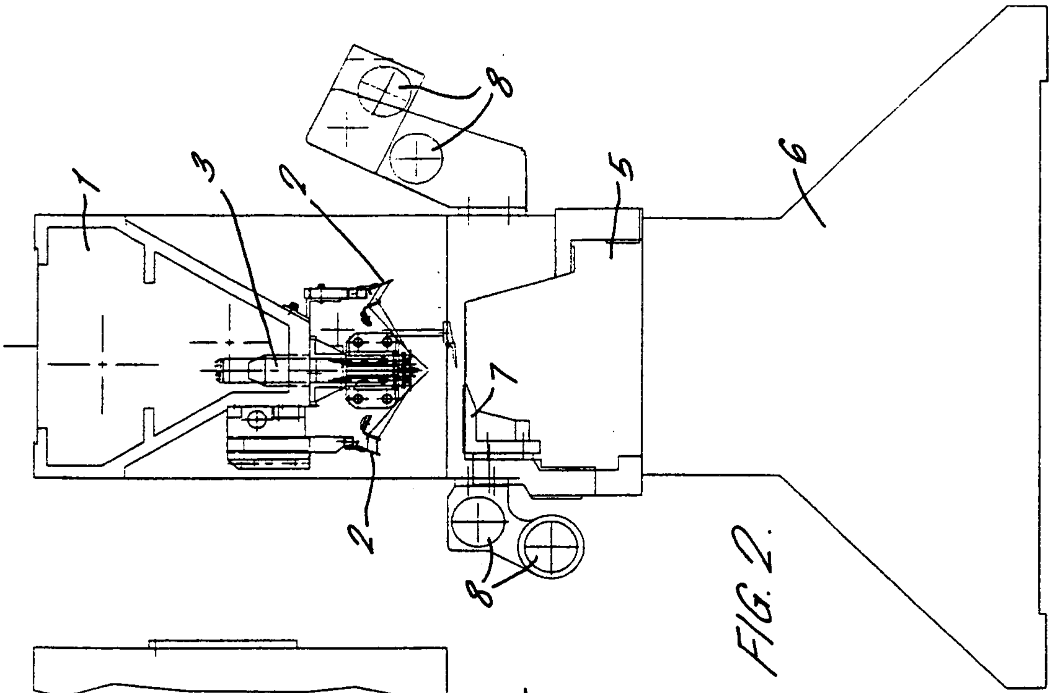

FIG. 2.

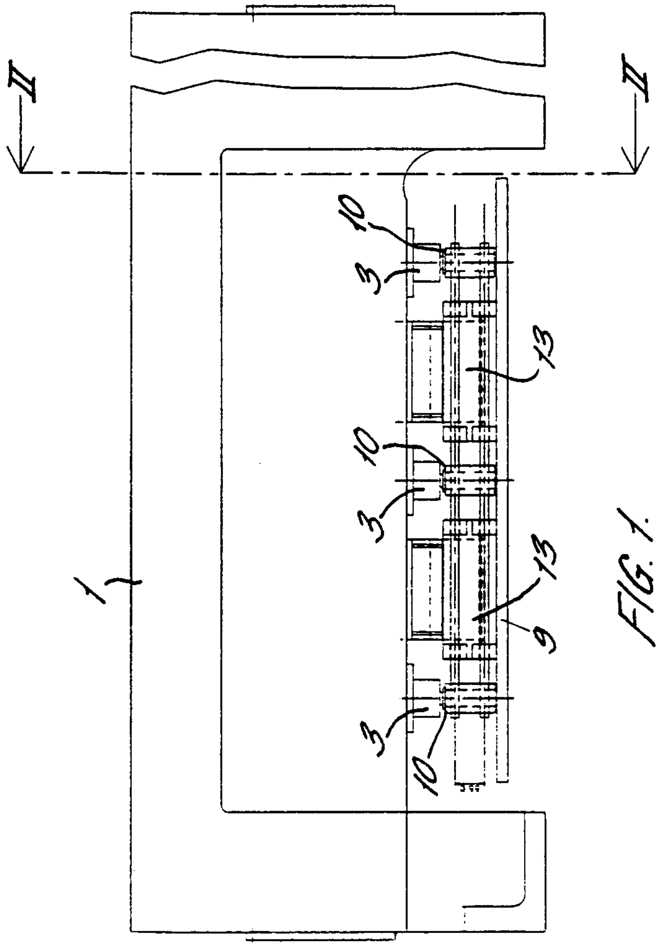

FIG. 1.

FIG. 3.

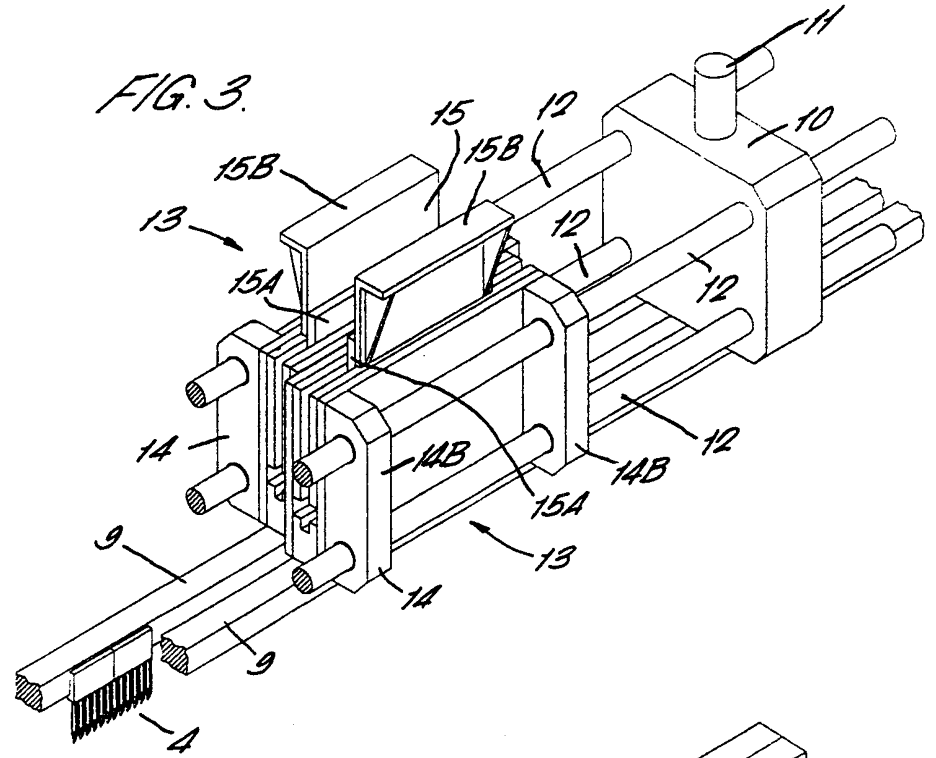
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FIG. 4.

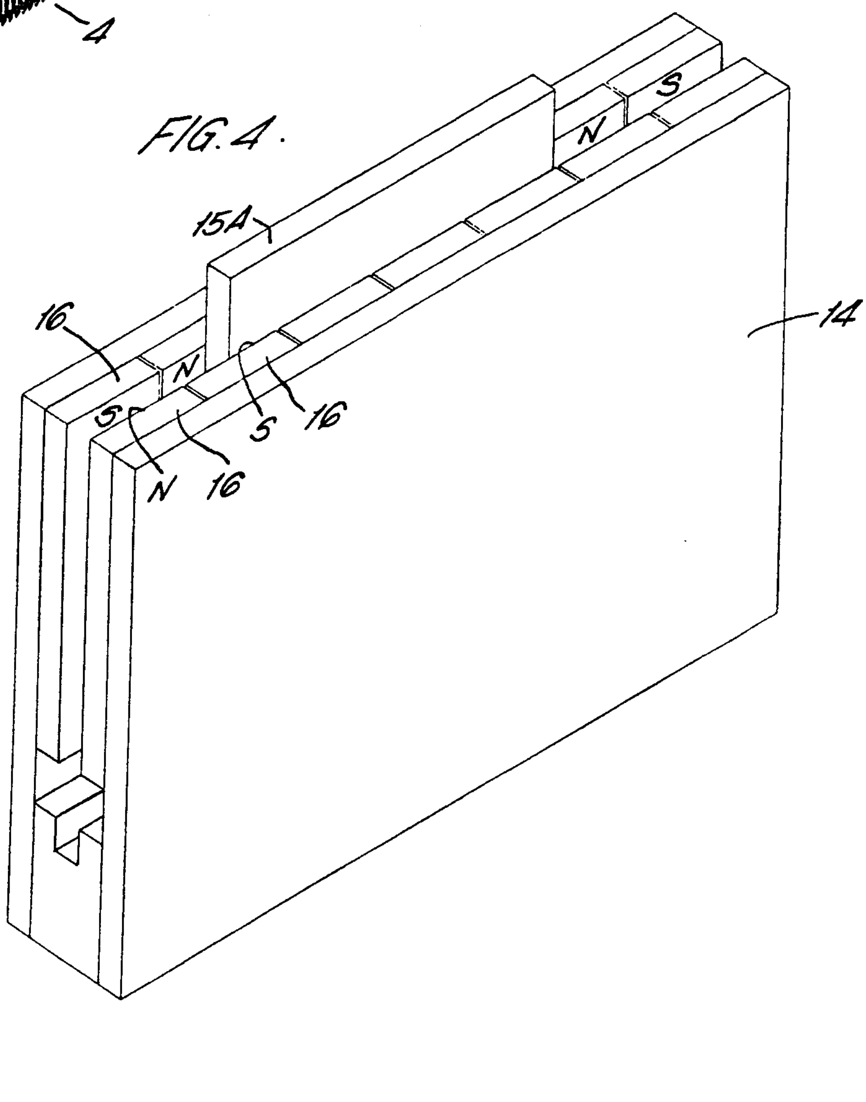
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FIG. 5.

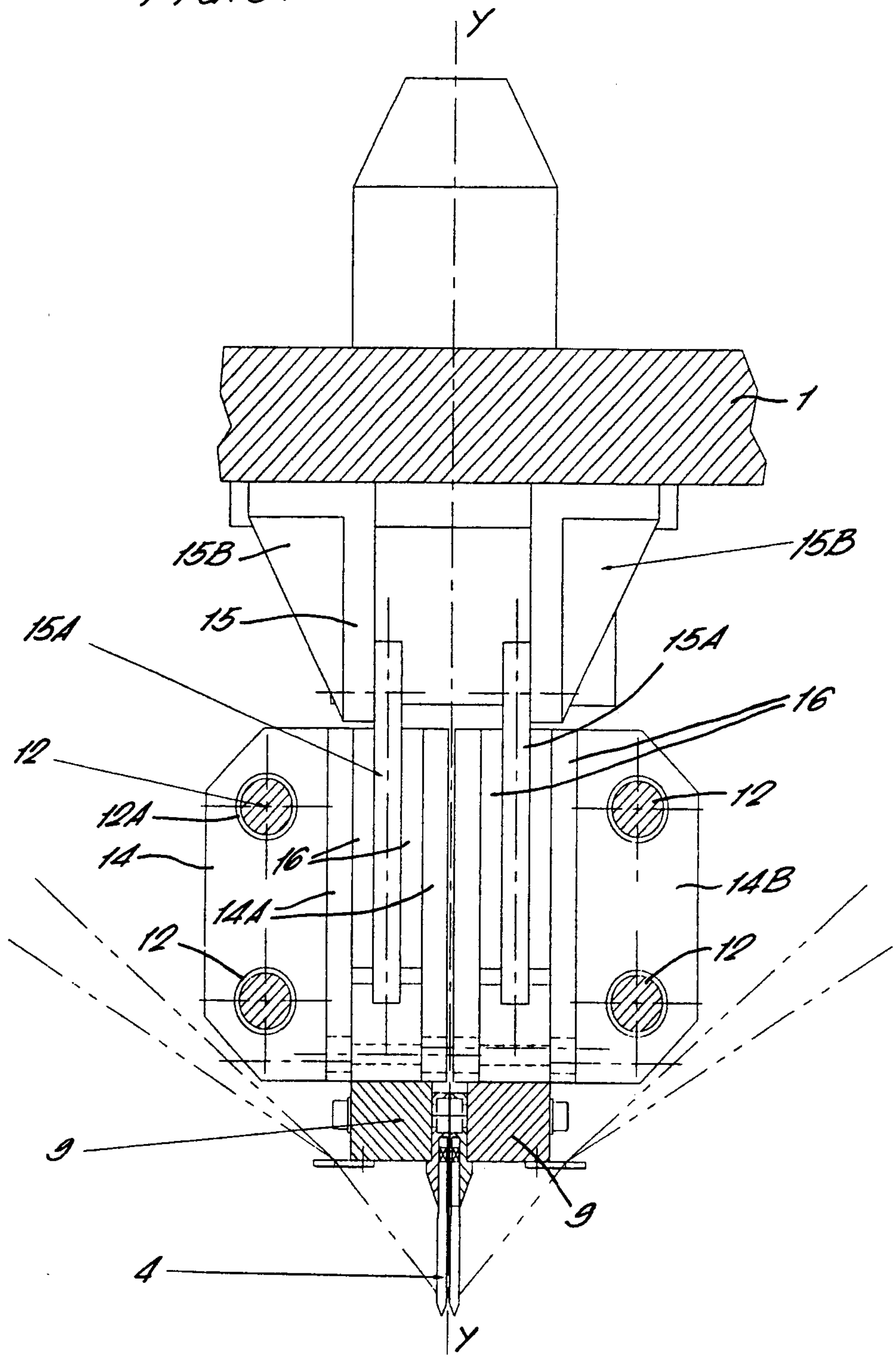
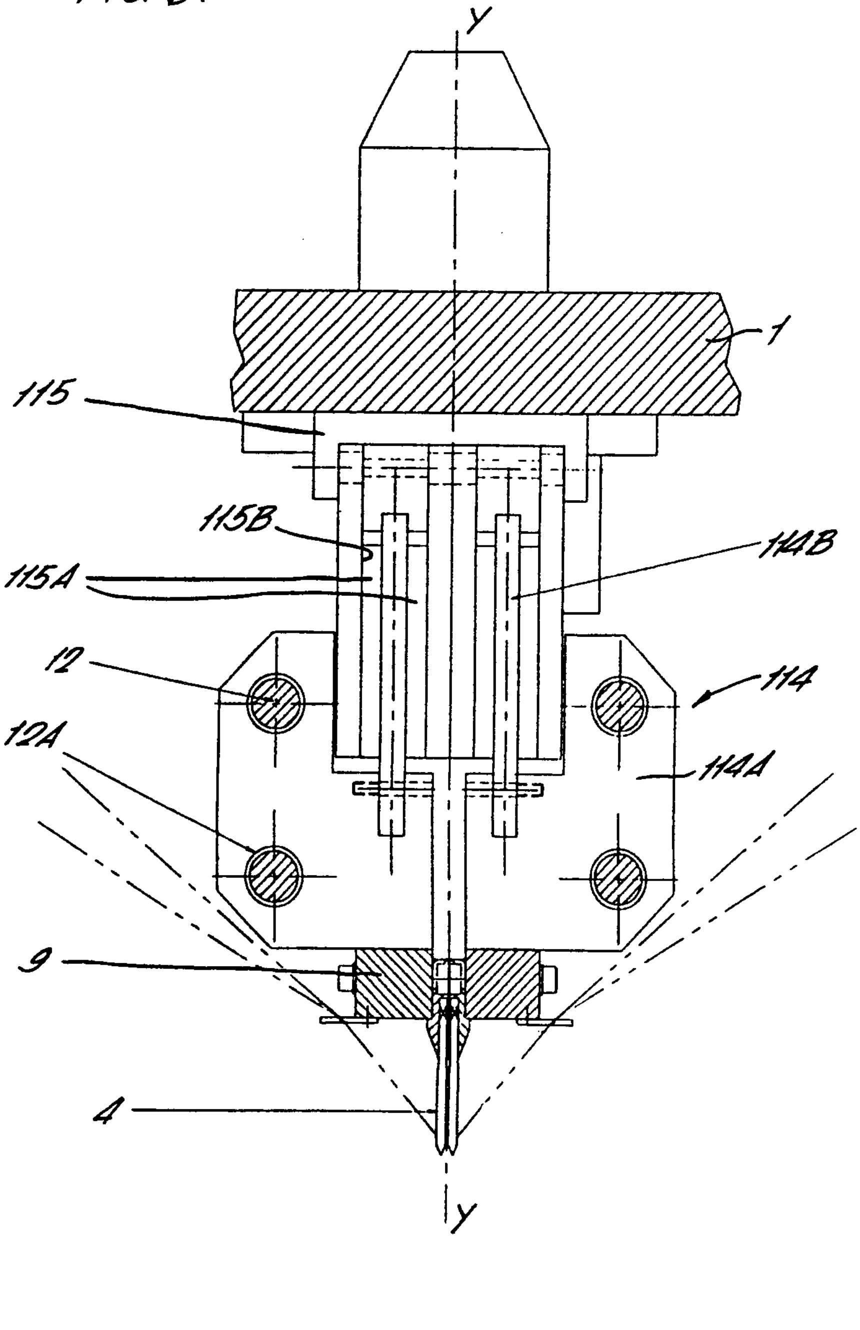


FIG. 6.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01906

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 D05C15/30 D05C15/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D05C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 05, 30 April 1998 (1998-04-30) & JP 10 005464 A (BROTHER IND LTD), 13 January 1998 (1998-01-13) abstract; figures	11
X	US 5 832 849 A (KAETTERHENRY JEFF ET AL) 10 November 1998 (1998-11-10) abstract; figures	11
A	EP 0 867 553 A (CARD MONROE CORP) 30 September 1998 (1998-09-30) cited in the application the whole document	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2000	12/09/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Intern   ial Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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