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(54) **Apparatus for measuring the bending angle of a workpiece**

(57) An apparatus for measuring the bending angle of a workpiece (1) comprises a housing (7) provided with measuring devices (31) which are disposed on either side of a bending line. Said measuring devices are capable of delivering signals dependent on the movement of the workpiece with respect to a datum plane. The apparatus furthermore comprises a processing unit, which is capable of deriving the overall bending angle of the workpiece from said signals. A first and a second measuring device are disposed on a first side of the bending line, the signals from which measuring devices are de-

pendent on two points of the workpiece located at different distances from the bending line. The processing unit is capable of deriving the sub-angle of bend on the first side of the bending line therefrom. A third measuring device is disposed on the second side of the bending line, which measuring device is capable of delivering a signal dependent on the shifting of a point of the workpiece that is located at a specified distance from the bending line. The processing unit is arranged for determining the sub-angle of bend and the overall bending angle on the basis of the signal from said third measuring device and said specified distance.

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Description

[0001] The invention relates to apparatus for measuring the bending angle of a workpiece, comprising a housing provided with measuring devices which are disposed on either side of a bending line, which measuring devices are capable of delivering signals dependent on the movement of the workpiece with respect to a datum plane, and a processing unit which is capable of deriving the overall bending angle of the workpiece from said signals, wherein a first and a second measuring device are disposed on a first side of the bending line, the signals from which measuring devices are dependent on two points of the workpiece located at different distances from the bending line, from which the processing unit can derive the sub-angle of bend on the first side of the bending line.

[0002] Such an apparatus is known from GB-A-2 072 551. The measuring devices of this prior art apparatus include two feelers, which are arranged one beside another in a direction transversely to the bending line, as a result of which the dimensions of each feeler are only small, on account of the small amount of space that is available. The feelers of the prior art apparatus are comparatively vulnerable. Furthermore it is assumed with this prior art apparatus that the angle that is derived from the difference in movement amounts to half the bending angle. This is only correct, however, when the folding line of the workpiece and the bending line of the punch are in line with the direction of the bending operation, which is not the case under all circumstances. With the prior art apparatus this may lead to measuring errors. GB-A-2 072 551 also discloses an embodiment wherein a feeler is disposed on either side of the bending line, so that the angle can be measured on both sides of the bending line. The angle is thereby derived from the movement of one feeler, which also leads to a less accurate measurement of the bending angle.

[0003] WO-A-9641690 discloses a measuring apparatus that includes two feelers, which are in contact with the workpiece on either side of the bending line, wherein the possible shifting of the folding line of the workpiece with respect to the bending line of the punch can be derived from a movement of said feelers in a direction transversely to the bending line. In this prior art apparatus slots are formed in the housing for the feelers, which slots intersect the bending line, so that said slots need to be narrow. As a result, the feelers are relatively vulnerable.

[0004] International patent application PCT/NL99/00640 of the same applicant discloses an apparatus of the aforesaid kind wherein two measuring devices are disposed on either side of the bending line. The use of four measuring devices makes it possible to determine the bending angle with great accuracy by means of this apparatus.

[0005] The object of the invention is to provide an apparatus of the above kind which has been simplified in

comparison with the apparatus disclosed in the aforesaid international patent application, and by means of which it is nevertheless possible to determine the bending angle with great accuracy.

[0006] In order to accomplish that objective, the apparatus according to the invention is characterized in that a third measuring device is disposed on the second side of the bending line, which measuring device is capable of delivering a signal dependent on the shifting of a point of the workpiece that is located at a specified distance from the bending line, wherein the processing unit is arranged for determining the sub-angle of bend and the overall bending angle on the basis of the signal from said third measuring device and said specified distance.

[0007] In fact the ratio between the sub-angles of bend on either side of the bending line is measured by means of the signal from the third measuring device, by comparing said signal to a signal from a measuring device on the first side of the bending line, as a result of which an apparatus is obtained which is of simpler design and which is capable of determining the overall bending angle with a higher degree of accuracy. Moreover, the apparatus according to the invention has the advantage that only one measuring device is required on one side of the bending line, which measuring device is disposed relatively close to the bending line, as a result of which the dimensions of the freely projecting end of the housing of the apparatus can be reduced. Since said dimensions are usually selected to be identical to the dimensions of the freely projecting part of the punch of the bending apparatus in which the apparatus according to the invention is used, also the free end of the punch can be designed to have relatively small dimensions. This makes it possible to produce workpieces having edges that have been flanged to a U-shape, whose legs may be spaced a small distance apart.

[0008] The invention will now be explained in more detail with reference to the drawings, which very schematically show an apparatus for bending workpieces, wherein an exemplary embodiment of the apparatus according to the invention is used.

[0009] Fig. 1 is a perspective, schematic view of part of an apparatus for bending workpieces, which is fitted with an embodiment of the apparatus for measuring the bending angle according to the invention.

[0010] Fig. 2 is a sectional view along plane II-II in Fig. 1.

[0011] Fig. 3 is a sectional view along plane III-III in Fig. 1.

[0012] Fig. 4 is a sectional view along plane IV-IV in Fig. 1.

[0013] Fig. 5 is a sectional view corresponding to Fig. 4 of a second embodiment of the apparatus according to the invention, intended for use with a so-called 90° punch.

[0014] Fig. 6 is a sectional view corresponding to Fig. 2 of the apparatus of Fig. 5.

[0015] Fig. 7 shows a part of the apparatus of Fig. 5, wherein a part of a workpiece is schematically indicated.

[0016] Fig. 1 shows in perspective view a part of an apparatus for bending workpieces, in particular for bending plate-shaped workpieces. In the drawing a relatively small plate-shaped workpiece 1 is shown by way of illustration. The bending apparatus comprises a die block 2 including a groove 3 of V-shaped section, which die block 2 is supported on a table 4 of the bending apparatus. The bending apparatus furthermore comprises a punch 5, which is schematically indicated by dashed lines. A measuring apparatus 6 for measuring the bending angle of workpiece 1 is aligned with punch 5. The measuring apparatus comprises a housing 7, the shape of at least the end of which corresponds to the shape of the end of punch 5. It is noted that it is not necessary for the shape of housing 7 to correspond to the shape of punch 5. Housing 7 may have any desired shape, as long as said shape does not conflict with the shape of the workpiece to be bent. Housing 7 is mounted in an upper beam 8 of the bending apparatus in the same manner as punch 5 by means of a clamp 9. Although the measuring apparatus 6 is mounted on one end of the upper beam in Fig. 1, it is also possible to mount the measuring apparatus 6 in the upper beam at another location, if desired. Furthermore it is possible to mount more than one measuring device in the upper beam.

[0017] The bending apparatus furthermore comprises a driving unit (not shown) for moving die block 2 and punch 3 with respect to each other in a bending direction for carrying out a bending operation on workpiece 1. The direction of the bending operation is indicated in a broken line 10 in the drawing. The construction of the bending apparatus does not form part of the present invention and consequently it is not described in more detail herein. The construction may be of a type which is known per se.

[0018] Housing 7, like punch 5, includes an end having sloping flanks 11, 12, which define a bending line 13 that extends in the longitudinal direction of punch 5 and housing 7. Sloping flanks 11, 12 furthermore define a V-shaped cross-section. The shapes of the ends of housing 7 and punch 5 are similar to the extent that the flanks 11, 12 and the bending line 13 of the housing and of the punch are in line. It is noted that the bending angle of workpiece 1 is composed of sub-angles of bend on either side of bending line 13. Although the shape of the entire housing 7 corresponds to that of punch 5 in the illustrated embodiment, this is not a necessary feature. Important is only the fact that the bending line 13 of housing 7 is in line with that of stamp 5.

[0019] Measuring apparatus 6 includes three measuring devices, each comprising a respective mechanical feeler 14, 15, 16 in the illustrated embodiment, as well as two measuring units 17 and 18. Feelers 14-16 and measuring units 17, 18 are shown in more detail in the sectional views according to Figs. 2 - 4. It appears therefrom that according to the view of Fig. 1 feelers 14 and

15 are disposed on the right-hand side of the bending line 13 and feeler 16 is disposed on the left-hand side of the bending line 13. Each of the feelers 14-16 is movable in housing 7, preferably in the direction of the bending operation, and projects from the sloping flank 11 or 12 of housing 7, as is shown in the sectional views of Figs. 2 - 4. The manner in which feelers 14-16 are guided is not shown in detail; for a more detailed description reference may be made to PCT/NL99/00640, whose contents are considered to be incorporated herein by reference. It is noted that the housing 7 is shown fully in cut-away view in Fig. 1 for the purpose of showing the various parts of measuring apparatus 6. The projecting ends of the feelers 14-16 are in contact with the workpiece during a bending operation. Said projecting ends exhibit a rounding with a small predetermined radius at the location of the point of contact with the workpiece 1. This rounding can be taken into account upon calculation of the bending angle.

[0020] Disposed in housing 7 is a central guide dam 19, which guides feelers 14-16 during movement thereof. Feelers 14-16 each comprise a respective cross arm 20, 21, 22, which cross arms determine the lowermost position of feelers 14-16 by mating with the upper side of guide dam 19.

[0021] As appears from Fig. 1, the two measuring units 17, 18 are disposed on the same side of the vertical plane in which the bending line lies, and each cross arm 20-22 is connected to a respective guide rod 23, 24, 25, which likewise lies on this side of the vertical plane. The guide rod 23 of feeler 14 provides accurate guidance of feeler 14 in housing 7. One end of cross arm 20 mates with a measuring pin 26 of measuring unit 17, a housing 27 of which is fixed in a coupling plate 28. Said coupling plate 28 is connected to guide rod 24, which is also connected to the cross arm 21 of feeler 15. It will be understood that the distances over which feelers 14 and 15 are moved when workpiece 1 is subjected to a bending operation differ from each other, since the feelers 14, 15 mate with different points on the workpiece 1, which points are spaced from bending line 13 by different distances. The measuring unit 17 delivers a measuring signal which corresponds to the difference in movement between feelers 14 and 15.

[0022] The cross arm 22 of feeler 16 is connected to the guide rod 25, which likewise provides accurate guidance of feeler 16 in housing 7. Guide rods 23 and 25 are not connected to coupling plate 28. Measuring unit 18 has a measuring pin 29, which mates with the end of cross arm 22 remote from feeler 16. A housing 30 of measuring unit 18 is fixed to coupling plate 28, so that measuring unit 18 delivers a signal in dependence on the difference in movement between feelers 15 and 16.

[0023] In the embodiment of the measuring apparatus 6 as described herein the ends of feelers 15 and 16 that are in contact with the workpiece 1 are spaced from the bending line 13 by exactly the same distance during bending, so that feelers 15 and 16 would be moved ex-

actly the same distance if the sub-angles of bend to the left and the right of the bending line 13 were identical. In other words, the ends of feelers 15, 16 each mate with a point on the workpiece located to the right and to the left, respectively, of the bending line 13, which points are spaced from the bending line by the same distance. Since the sub-angle of bend on the right-hand side of bending line 13 is measured accurately from the difference in movement between feelers 14 and 15, the sub-angle of bend on the left-hand side of bending line 13 can be determined with similar accuracy from the difference in movement between feelers 15 and 16. Measuring units 17 and 18 are connected to a processing unit 31 that is schematically indicated in Fig. 1, which processing unit is capable of determining the overall bending angle of the workpiece from the signals received from measuring units 17, 18.

[0024] In the measuring apparatus 6 as described herein, the ratio between the sub-angles of bend on either side of bending line 13 is in fact determined by comparing the movements of feelers 15 and 16 with each other. Since one sub-angle of bend is measured directly from the difference in movement between feelers 14 and 15, the other sub-angle of bend and thus the overall bending angle follows from said ratio. It would also be possible to dispose another feeler on the side of feelers 14, 15 for measuring the ratio between the two sub-angles of bend.

[0025] It is noted that the same measuring principle, with two measuring devices on one side of the bending line 13 and one measuring device on the other side, can be used with other types of measuring devices and/or with different distances between the measuring devices and the bending line. To those skilled in the art it will be apparent that the sub-angles of bend to the left and to the right of the bending line 13 can be determined, by means of simple goniometric calculations, from the difference in movement between feelers 15, 16, also when different distances between feelers 15 and 16 and bending line 13 are used. Instead of using mechanical feelers 14-16 and measuring units 17, 18, it is also possible to use other types of measuring devices as the measuring means, by means of which the extent to which a point of the workpiece located at a specified distance from the bending line 13 has shifted can be measured, for example by using light beams or acoustic signals. Suitable measuring devices are for example telemeters that operate with laser diodes, as for example disclosed in the present applicant's Dutch patent no. 1007290.

[0026] Furthermore it is noted that the term measuring device as used within the framework of the description and the claims relates to any device whereof a parameter undergoes a change dependent on the bending angle of the workpiece, which change is called a signal in the claims. In the case of mechanical feelers this signal is the movement. In the case of optical or acoustic measuring devices the optical or acoustic measuring signal will undergo a change, which change is usually present-

ed for processing in the form of an electrical output signal.

[0027] The apparatus described herein has the advantage that the manufacturing costs of the measuring apparatus can be reduced by using only three measuring devices, whilst in addition it is possible to use smaller dimensions for the housing 7 than in the situation wherein two measuring devices are used on either side of the bending line. This makes it possible to use relatively small dimensions for the free end 32 of housing 7 with the central guide dam 19.

[0028] A punch that has an end of small dimensions makes it possible to bend workpieces having complicated shapes, in particular when a so-called 90° punch is used, an exemplary embodiment of which is shown in Figs. 5 and 6. Parts that correspond to parts used in the embodiment according to Figs. 1 - 4 are indicated by the same numerals. Fig. 5 is a cross-sectional view corresponding to Fig. 4, wherein the feeler 16 is shown. Fig. 6 shows feeler 14.

[0029] Fig. 7 shows the free end 32 of housing 7, wherein workpiece 1 is shown to have an edge 33 that is bent to a U-shape, as illustrated by means of a relatively thick line, which edge engages round the free edge 32. As appears from Fig. 7, the free end 32 can extend into the U-shaped edge 33, since only one feeler 16 needs to be present on one side of bending line 13. If two feelers were used, the dimension d in Fig. 7 would be significantly larger. Feelers 14 and 15 are schematically indicated in broken lines in Fig. 7.

[0030] The dimension d in Fig. 7 is further reduced in that a recess 34 for cross arm 22 is formed in guide dam 19. The provision of said recess 34 is possible because the vertical distance over which feeler 16 must be movable is smaller than the vertical distance over which feeler 14 must be movable.

[0031] Fig. 1 shows a pressure sensor 35, a feeler 36 of which is in contact with the workpiece 1 during bending. Said pressure sensor is used in the measurement and compensation of the spring back of workpiece 1, as is described in more detail in a Dutch patent application no. 1013517 of the present applicant, to which the reference may be made for a more detailed explanation.

[0032] The invention is not restricted to the above-described embodiments, which can be varied in several ways without departing from the scope of the claims.

Claims

1. Apparatus for measuring the bending angle of a workpiece, comprising a housing provided with measuring devices which are disposed on either side of a bending line, which measuring devices are capable of delivering signals dependent on the movement of the workpiece with respect to a datum plane, and a processing unit which is capable of deriving the overall bending angle of the workpiece

from said signals, wherein a first and a second measuring device are disposed on a first side of the bending line, the signals from which measuring devices are dependent on two points of the workpiece located at different distances from the bending line, from which the processing unit can derive the sub-angle of bend on the first side of the bending line, characterized in that a third measuring device is disposed on the second side of the bending line, which measuring device is capable of delivering a signal dependent on the shifting of a point of the workpiece that is located at a specified distance from the bending line, wherein the processing unit is arranged for determining the sub-angle of bend and the overall bending angle on the basis of the signal from said third measuring device and said specified distance.

arm of said third feeler.

2. Apparatus according to claim 1, wherein the third measuring device measures the shifting of a point that is spaced from the bending line by the same distance as the point closest to the bending line that is measured on the first side of the bending line.
3. Apparatus according to claim 1 or 2, wherein said measuring devices comprise mechanical feelers and two measuring units, wherein the first measuring unit measures the difference in movement between a first and a second mechanical feeler on the first side of the bending line, and wherein the second measuring unit measures the difference in movement between the third mechanical feeler on the second side of the bending line and one of the mechanical feelers, preferably the second mechanical on the first side of the bending line that is disposed closest to the bending line.
4. Apparatus according to claim 3, wherein the two measuring units lie on the same side of the vertical plane as the bending line, wherein each feeler includes a cross arm, which mates with a guide rod, which is guided in the housing on the same side of said vertical plane, wherein the guide rod of the second feeler is connected to a coupling plate, which also functions as carrier of the measuring units, which measuring units each comprise a measuring pin, which is movable with respect to the part that is connected to the coupling place and which mates with the cross arms of said first and said second feeler.
5. Apparatus according to claim 4, wherein said feeler is positioned between said first and said third feeler, and wherein said feeler is connected to said coupling plate via its guide rod.
6. Apparatus according to claim 4 or 5, wherein the feelers are guided in the housing by a central dam, wherein a recess is formed in the dam for the cross

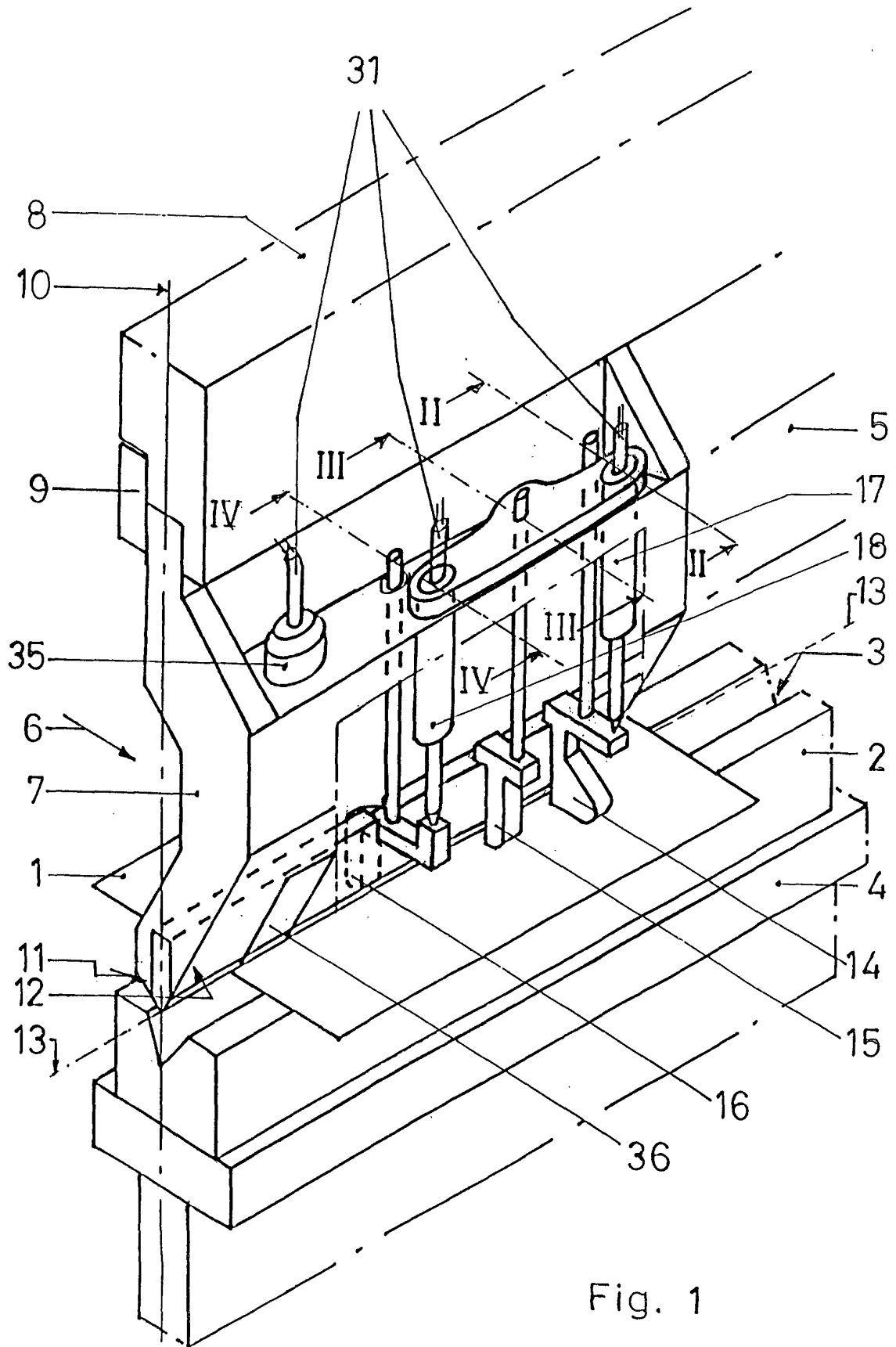


Fig. 1

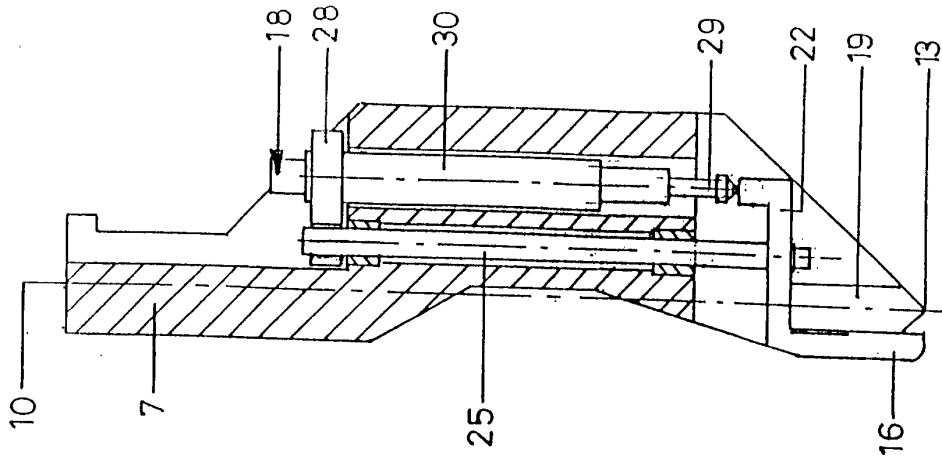


Fig. 2

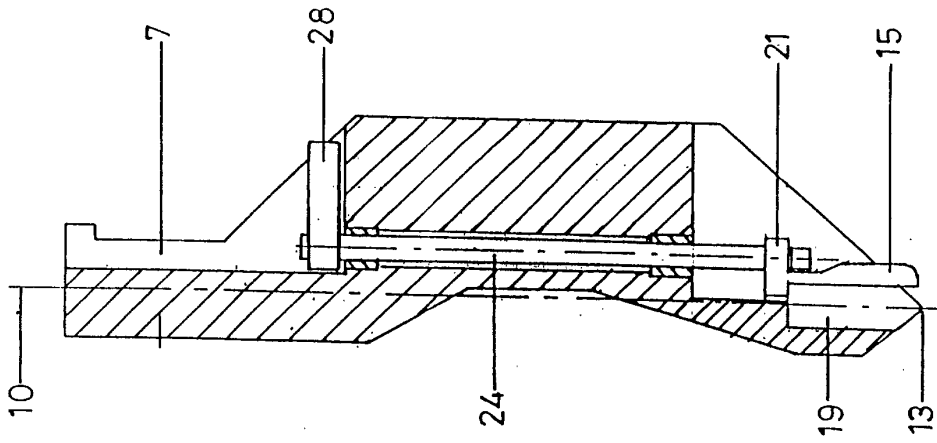


Fig. 3

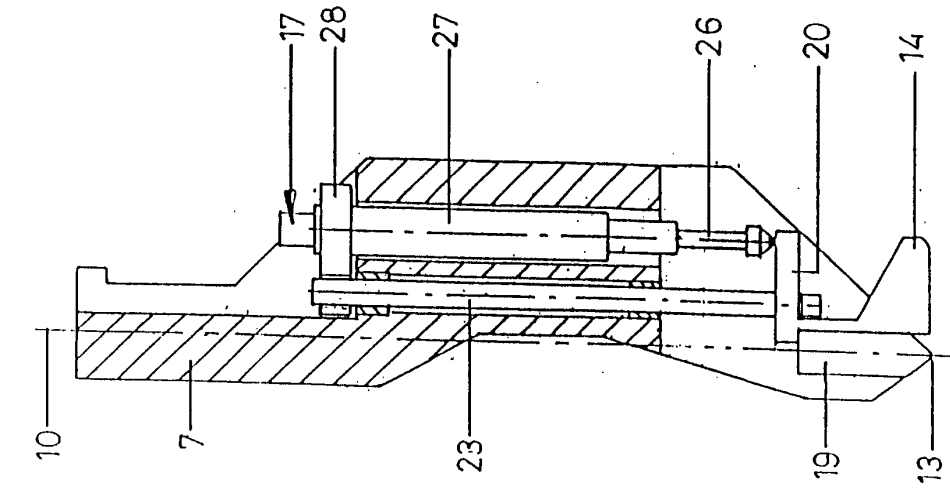


Fig. 4

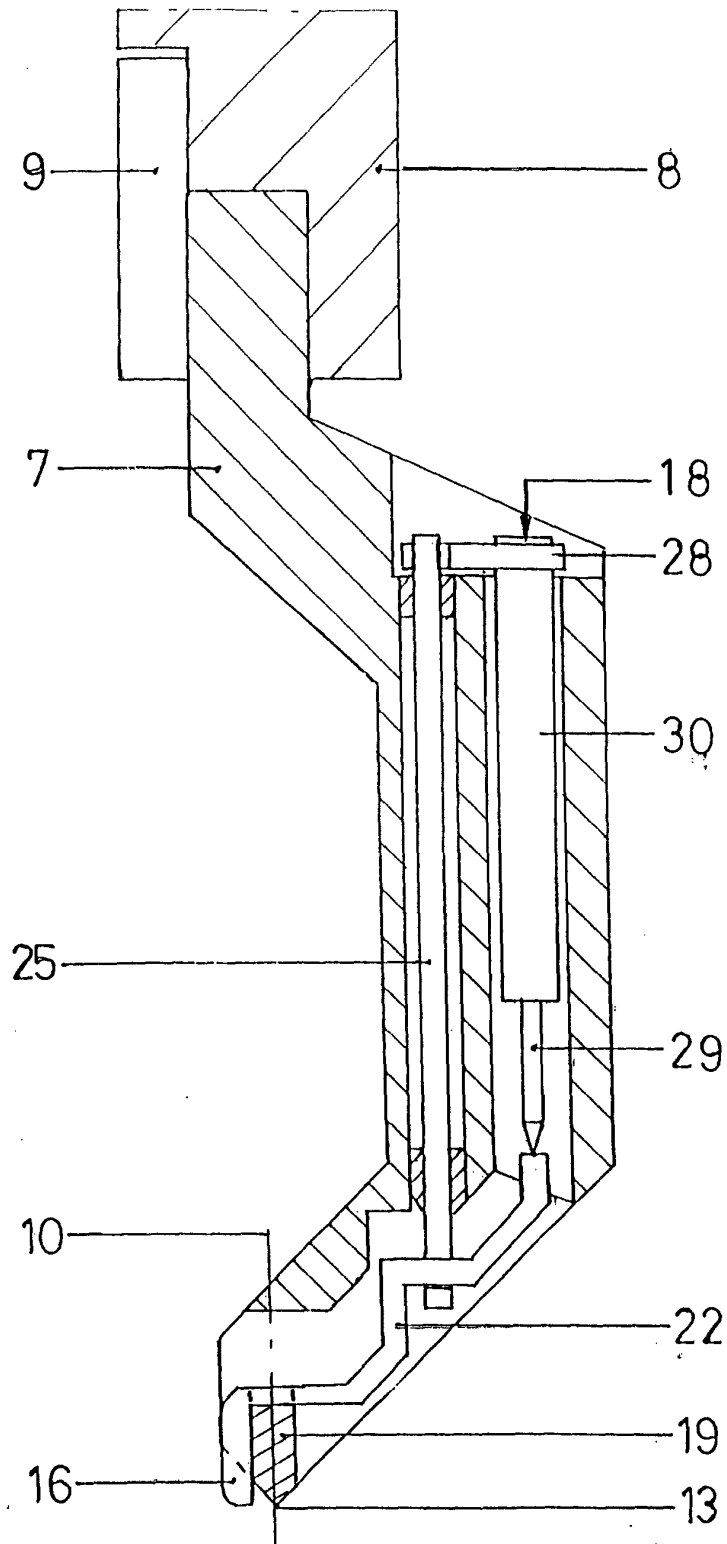
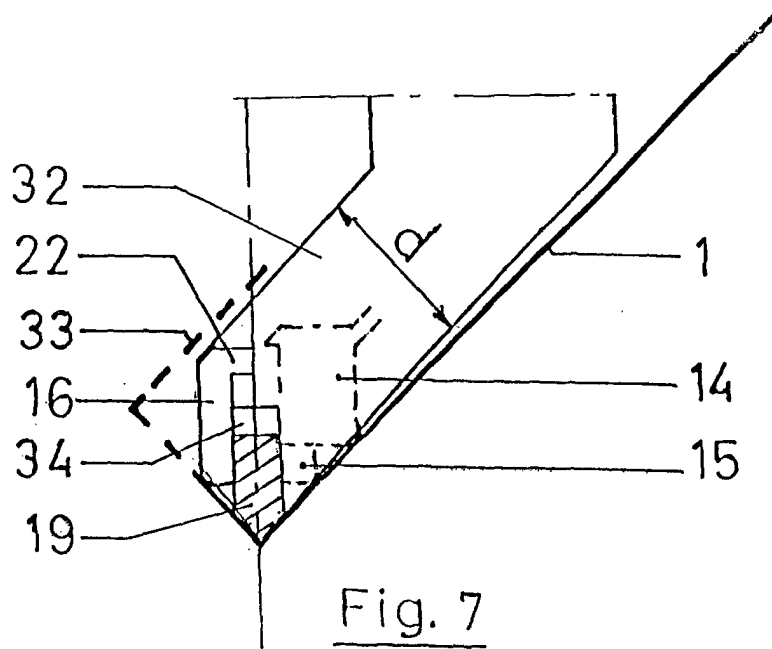
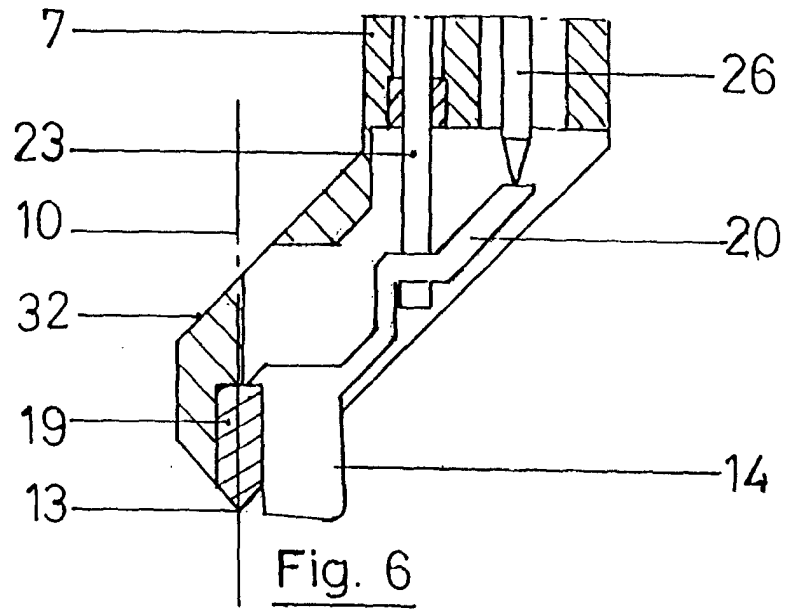


Fig. 5





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EUROPEAN SEARCH REPORT

Application Number
EP 01 20 0091

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Place of search	Date of completion of the search	Examiner	
THE HAGUE	15 March 2001	Peeters, L	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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