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(54) **Press brake and related workpiece bending procedure**

(57) The present invention relates to a press brake (1) comprising at least:

- a die (3) that extends substantially along a horizontal longitudinal axis (4) of said press brake, said die being integrally connected to a base (2) of said press brake; and
- a punch (5) that extends above said die, substantially along the same horizontal axis as said die, said punch being vertically movable in both directions (50) so as to co-operate with said die to achieve the bending of a workpiece (7); and
- regulating means (10) for adjusting the procedure for bending the workpiece.

In the press brake, according to the invention, the regulating means include first detecting means (11), which comprise:

- light emitting means (12) suitable for emitting a beam of light (13) along the direction in which said die extends, to at least partially illuminate at least a portion of said die and/or of said punch, and/or of the workpiece, and to project the profile, on a predefined plane, of at least a portion of the cross-section of said lower die and/or of said punch, and/or of the workpiece; and
- optical sensing means (14) suitable for acquiring an image of said projection, generated by said beam of light.

In its further aspect, the present invention relates also to an improved and more reliable bending procedure of a workpiece.

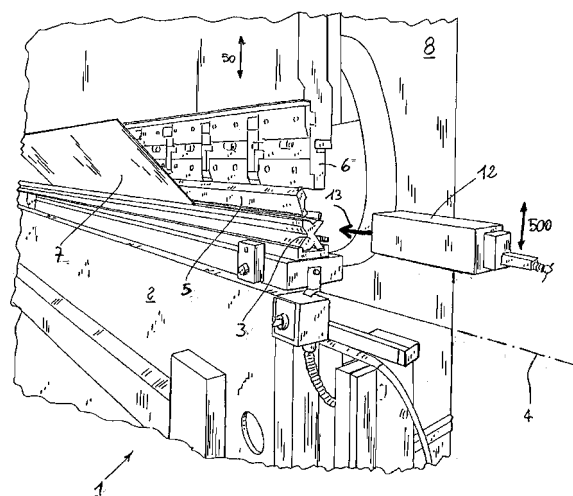


FIG. 2

Description

[0001] The present invention relates to an improved press brake. Moreover, the present invention also refers to an improved bending procedure implemented.

[0002] It is common knowledge that press brakes are used to bend metal parts, particularly sheet metal pieces or strips.

[0003] A press brake generally comprises a pair of machine tools that co-operate with one another to perform the bending operation. The upper tool, or punch, extends horizontally and is vertically movable in both directions. The lower tool, or die, is attached to the body of the machine and also extends horizontally, in the same direction as the punch.

[0004] By comparison with conventional moulding presses, press brakes have the considerable advantage of using far less power to bend a workpiece, to obtain angle bars from a sheet of metal for instance.

[0005] Press brakes often have the drawback, however, of failing to ensure a constant and satisfactory reproducibility of the end product. For instance, the bend angle can generally be strongly influenced by a different thickness or a different spring-back of each workpiece, due for instance to a different prior rolling treatment on the workpiece. As a result, it may be very difficult to obtain the same bend angle when different batches of workpieces are used, as is commonly the case in industrial production.

[0006] There are known press brakes that are equipped with devices that enable this drawback to be overcome by taking action manually on the machine's control system. To achieve said result, however, demands a continuous manual control of the bend angle and consequently has a significant negative fallout on the machining times and costs.

[0007] Alternatively, there are known press brakes that use sensors to enable regulating means to identify the actual bend angle after the spring-back of the workpiece. This enables the punch to be operated several times to achieve the required bend angle, to within the allowable tolerances in each case.

[0008] A drawback of such machines lies in that these sensors constitute an unwanted hindrance in the workspace coming between the tooling. This factor naturally restricts the operativity of the machine.

[0009] In an effort to overcome this problem, some solutions involve integrating the above-mentioned sensors in the body of the punch or die. Practice has demonstrated, however, that such integration entails a considerable increase in the cost of the tooling and consequently in the overall cost of the machine.

[0010] Finally, there are known press brakes that use a television camera to detect an image of the workpiece before it is bent and data processing means for using said image to establish the actual thickness of the workpiece, thus enabling the final theoretical bending point to be calculated. At the end of the bending process, the

television camera can provide a further image showing the actual bend angle. Then the bending of the workpiece is repeated until the actual bend angle coincides with the required bend angle, within the range of the allowable tolerances.

[0011] Although these press brakes represent a considerable improvement over the previously-described solutions, they nonetheless have several drawbacks.

[0012] A first drawback derives from the fact that it is often necessary to correct the focus of the television camera, e.g. to adjust it to suit the image of workpieces of different shape and size. Any such action necessarily entails a machine stoppage and a consequent increase in the overall machining times.

[0013] It has been demonstrated, moreover, that the clarity of the images detected by the television cameras very often varies considerably depending on the ambient lighting conditions in which the machine is operated. In conditions of relatively bright lighting, for instance, the images appear out of focus or include reflections or luminous artefacts that negatively affect their quality. Images of relatively poor quality can lead to calculation errors and ultimately to errors in the bending of the workpiece, with a consequent increase in the number of rejects from the production process.

[0014] Moreover, there is evidence to show that measurement errors can be determined by mechanical strains on the die, the base, the upper cross member and/or the columns of the press brake, due to the load brought to bear by the punch during the bending of the workpiece. In fact, these mechanical strains can induce a deterioration in the detecting of the images of the tooling and workpiece, with a consequent measurement error. There is also the risk of error in the movement of the punch, with a consequent increase in the probability of unsatisfactory end products being obtained.

[0015] The main technical aim of the present invention is therefore to realise a press brake that enables the above-mentioned drawbacks to be overcome.

[0016] Within this aim, an object of the present invention is to realise a press brake that makes the bending process highly and constantly reproducible, even for work pieces from different batches.

[0017] Another object of the present invention is to realise a press brake that is highly reliable and robust in operation, enabling the machining times and the number of rejects to be reduced to a minimum.

[0018] Another object of the present invention is to realise a press brake that enables a reduction in the influence of the mechanical strains induced in the parts of the die side of the press brake by the load brought to bear by the punch during the bending process.

[0019] Another, not necessarily last object of the present invention is to realise a press brake that is relatively straightforward to operate and easy to manufacture at a competitive cost.

[0020] Thus, the present invention provides a press brake according to the claim 1, as stated below.

[0021] The press brake according to the present invention has improved regulating means comprising detecting means capable of acquiring high-quality images of the tooling and workpiece. Said regulating means further enable highly accurate data to be drawn from said images, relating to one or more quantities indicative of the size, shape and/or position of the tooling and workpiece. This makes it possible an accurate assessment of the operating parameters characterising the bending cycle and consequently ensures that the bending process is highly and constantly reproducible, with a reduction in the number of rejects and in the machining times.

[0022] In its further aspect, the present invention relates also to an improved and more reliable bending procedure of a workpiece.

[0023] Additional characteristics and advantages of the present invention will become apparent from the description given below and from the attached figures, provided simply for explanatory and non-limiting purposes, wherein:

- figure 1 shows a flow chart of the regulating means for the press brake according to the invention;
- figure 2 schematically shows a perspective view of a portion of the press brake according to the invention, comprising the light emitting means that form part of the regulating means of said press brake;
- figure 3 shows an image detected by the optical detecting means included in said regulating means;
- figures 4A-4C respectively show three different stages of a bending procedure using the press brake according to the present invention.

[0024] With reference to the above-mentioned figures, the present invention refers to a press brake 1 that comprises a base or lower cross member 2, to which a die 3 is attached that extends horizontally in relation to the base 2, along the horizontal longitudinal axis 4 of the machine 1. Above the die 3, and coinciding with the latter, there is a punch 5, that can be attached to an upper toolholder cross member 6, supported by a pair of columns 8 extending upwards from the base 2. The punch 5 is vertically movable in both directions (arrow 50) along a substantially straight trajectory. The punch 5 is moved by suitable oil hydraulic drive means (not shown). The punch 5 can thus co-operate with the die 3 to bend a workpiece 7, for instance a piece of sheet metal.

[0025] The press brake 1 also comprises regulating means 10 for regulating the bending of the workpiece 7. These regulating means 10 comprise first detecting means 11 comprising light emitting means 12 and optical sensing means 14. The light emitting means 12 are designed to deliver a beam of light 13 in the direction in which the die 3 extends. In particular, the beam of light 13 is preferably directed along the vertical plane containing the bottom line of the V-shaped upper recess 3A in the die 3, running in the direction of the axis 4. The beam of light 13 is advantageously of predefined area 13A (fig-

ure 4A), e.g. circular or rectangular, so that it at least partially illuminates at least a predefined portion of the die 3, the punch 5 and/or the workpiece 7, in the direction in which the die 3 extends. The beam 13 thus projects at least a portion of the cross-section (i.e. of the section along a plane orthogonal to the axis 4) of the die 3, punch 5 and/or workpiece 7, on a predefined plane (not shown) lying substantially perpendicular to the direction in which the die 3 extends. The light emitting means preferably comprise a laser source that emits a beam of light within the visible range. The use of a laser source is extremely advantageous because it produced a strongly directional and polarised beam of light.

[0026] The optical sensing means 14 are suitable for acquiring an image of said projection generated by the beam of light 13. The optical sensing means 14 preferably comprise a television camera or digital camera comprising an optical receiver matrix (not shown) arranged orthogonally to the axis 4 and aligned with the beam of light 13. The receiver plane of the optical receiver matrix advantageously coincides with the plane on which the cone of shadow generated by the cross-section of the die 3, punch 5 and/or workpiece 7 is projected when they are illuminated by the beam of light 13. A back-lit image of the cross-section of the tooling 3 and 5 and/or the workpiece 7 is thus detected. Figure 3 shows an example of an image detected by said optical means 14. In this image, the back-lit profile of the die 3, the punch 5 and the workpiece 7 are clearly distinguishable.

[0027] The light emitting means 12 and the optical sensing means 14 are advantageously aligned with one another in the direction in which the punch 5 extends. They are advantageously positioned in line with a first end and a second end of the punch 5, on the outside of the workspace of the press brake 1, as shown in figure 2 for the light emitting means 12. The light emitting means 12 and the optical means 14 are vertically movable in both directions (arrow 500). They preferably move as a function of the movements of the punch 5, so as to maintain a predefined (and preferably constant) position and alignment with respect to the punch 5. For said purpose, the means 12 and 14 can be integrally connected to the upper cross member 6 by means of a suitable supporting elements (not shown), so as to be displaced directly by said cross member 6.

[0028] The first detecting means 11 preferably also comprise first electronic means 15 suitable for receiving as input and processing the data 16 relating to the image acquired by the optical means 14.

[0029] The first electronic means 15 process the image received from the optical means 14, e.g. removing any streaks of interference or other luminous impurities or artefacts.

[0030] The first electronic means 15 thus enable a relatively good-quality image to be obtained, for subsequent use in deriving certain notable data relating to the die 3, the punch 5 and the workpiece 7.

[0031] The first electronic means 15 are also suitable

for receiving control signals 17A as input, on the basis of which they govern the operation of the light emitting means 12 and/or of the optical means 14, by sending suitable control signals 18A and 18B.

[0032] The regulating means 10 advantageously comprise second electronic means 20, operatively connected to the first electronic means 15 and to the control system 31 for the press brake 1.

[0033] The second electronic means 20 are suitable for obtaining data 20A indicative of one or more relevant quantities relating to the die 3, the punch 5 and/or the workpiece 7. In particular, the data 20A are advantageously derived from the data 19A, received by the first electronic means 15. Said data 19A can optionally also be integrated with data 19B, received by the control system 31 of the press brake 1, and/or with data 19C, received by third electronic means 41.

[0034] The second electronic means 20 advantageously serve as an interface between the first detecting means 11 and the control system 31 of the press brake 1. They calculate several notable quantities relating to the shape, size and position of the tooling 3 and 5, and of the workpiece 7, starting from the images (data 19A) provided by the first detecting means 11. For instance, during the process for bending the workpiece 7, the second electronic means 20 can advantageously calculate the dimensions of the cross-section of the tooling 3 and 5, the relative position of the punch 5, the thickness of the workpiece 7 and/or the bend angle obtained on the workpiece 7.

[0035] The data 20A are obtained using suitable algorithms for processing the images 19A provided by the first detecting means 11. For this purpose, procedures are advantageously used that analyse the mutual luminous interference between the tooling 3 and 5, and the workpiece 7. The second electronic means 20 use the data 20A to generate the control signals 17A and 17B for the control system 31 and for the first detecting means 11, respectively. The control signals 17A and 17B enable the operation of the first detecting means 11 and of the press brake 1 to be adjusted and co-ordinated during the bending of the workpiece 7.

[0036] In a preferred embodiment of the invention, the regulating means 10 also detect and process data relating to first mechanical strains coming to bear on the die 3, the base 2 and/or the upper cross member 6, and/or second mechanical strains coming to bear on the columns 8 of the press brake 1. The above-mentioned mechanical strains typically develop during the bending procedure and, as mentioned earlier, are determined by the load brought to bear by the punch 5. They are generally directed in a parallel vertical plane and in a plane orthogonal to the longitudinal axis 4, respectively, and both in a direction substantially perpendicular to the plane on which the press brake 1 stands.

[0037] Thus, the regulating means 10 advantageously comprise second detecting means 43 for detecting data indicative of said first and/or second mechanical strains.

[0038] The second detecting means 43 comprise one or more sensors 40, for instance, positioned in line with the base 2, the upper cross member 6 and/or the columns 8 of the machine 1.

[0039] The second detecting means 43 comprises also third electronic means 41, which process the fourth set of data 40A provided by the sensors 40 and preferably also send the resulting data 19C to the second electronic means 20.

[0040] Based on these processed data, the third electronic means 41 generate as output the control signals 41A for actuator means 42, preferably associated operatively with the base 2.

[0041] Based on the control signals 41A, the actuator means 42 bring a force to bear to compensate for the effect of said first and/or second mechanical strains. For instance, the actuator means 42 exert a force on the die 3 sufficient to counter the bending strain along the longitudinal axis 4. The die 3 thus becomes substantially undeformable during the bending of the workpiece 7.

[0042] This enables measurement errors in the thicknesses and bend angles of the workpieces 7 to be avoided.

[0043] To better understand the operative advantages that the present invention affords, a preferred bending procedure achieved with the press brake 1 is described in detail below.

[0044] To facilitate the reading of the operative stages described, it is important to bear in mind that, during the bending cycle, the vertical trajectory of the punch 5 conventionally develops along the following succession of notable points:

rest point: this term is conventionally used to mean the point on the trajectory where the punch 5 is positioned when the press brake 1 is started up;

top dead centre: this term is conventionally used to mean the point on the trajectory covered during the bending process with the maximum distance between the bending edge 5A of the punch 5 and the lower edge 3C of the die 3;

speed change point: this term is conventionally used to mean the point on the trajectory covered during the bending process where the speed of displacement of the punch 5 changes considerably; for instance, as it descends towards the die 3, the punch 5 considerably reduces the speed of its downward stroke at the speed change point;

punch/sheet contact point: this term is conventionally used to mean the point on the trajectory covered during the bending procedure where the punch 5 comes into contact with the surface of the workpiece 7; Figure 4A advantageously shows the punch 5 at the punch/sheet contact point;

bottom dead centre: this term is conventionally used to mean the point on a trajectory covered during the bending procedure with the minimum distance between the bending edge 5A of the punch 5 and the

bottom edge 3C of the die 3; Figure 4B advantageously shows the punch 5 at the bottom dead centre;

floating point: this term is conventionally used to mean a point on the (return) trajectory where, after taking the spring-back of the workpiece 7 into account, the workpiece 7 is still held between the die 3 and the punch 5; Figure 4C advantageously shows the punch 5 in line with the floating point, which necessarily comes within the stretch of return trajectory between the bottom dead centre and the punch/sheet contact point.

[0045] Said preferred bending procedure also comprises various stages in which at least one image is detected of at least a portion of the cross-section of the die 3, the punch 5 and/or the workpiece 7, and data relating to the shape and/or size, and/or position of the die 3, the punch 5 and/or the workpiece 7 are processed. Said image is detected as a result of instructions 18A and 18B being sent by first electronic means 15 to the light emitting means 12 and/or the optical means 14. Said control signals are sent after the first electronic means 15 have received corresponding control signals 17A from the second electronic means 20. The data 16 relating to the image detected by the optical means 14 are sent to the first electronic means 15, which perform a first processing of said image. The data 19A relating to the image processed by the first electronic means 15 are then sent to the second electronic means 20 to obtain the data 20A relating to the physical quantities of interest. The above-described operative sequence is preferably repeated for each of said stages of the bending procedure.

[0046] Moreover, as explained later on, other stages of said preferred bending procedure involve calculating several notable points on the trajectory of the punch 5 and operating the press brake 1 to transfer said punch 5 to said notable points. For each of said stages, a vertical movement 50 of the punch 5 coincides with a vertical movement 500 of the light emitting means 12 and the optical means 14, so the light emitting means 12 and the optical means 14 remain in a pre-set (and preferably constant) position and alignment relative to the punch 5.

[0047] Said notable points are preferably calculated by the second electronic means 20 on the strength of the processed data 20A, the shape and size of the tooling 3 and 5, and/or additional data 19B and/or 19C received as input respectively from the control system 31 and the second detecting means.

[0048] The subsequent operations of the press brake 1 are governed by the control system 31, based on the control signals 17B, received from the second electronic means 20.

[0049] Said preferred bending procedure advantageously comprises a stage (a) of placing the work piece 7 in line with the bending edge 3B of the die 3. The workpiece 7 can be placed in position manually or by means of a service robot. In said stage (a), the punch 5 is at the

rest point when the machine is used for the first time, or at the top dead centre of the trajectory if it has returned to start a new machining cycle.

[0050] With the punch 5 in line with said rest point or top dead centre, the procedure according to the invention comprises a subsequent stage (b) of detecting at least one image relating to at least a portion of the cross-section of the punch 5 and processing data relating to the shape and/or size, and/or position of the punch 5. In particular, the processed data 20A refer to the relative position of the lower edge 5A of the punch 5.

[0051] The procedure according to the invention then comprises a stage (c) of calculating the speed change point on the trajectory of the punch 5 and operating the press brake 1 to bring the bending edge 5A of the punch 5 into line with said speed change point.

[0052] Then comes the stage (d) of calculating the punch/sheet contact point on the trajectory of the punch 5 and operating the press brake 1 to bring the bending edge 5A of the punch 5 into said punch/sheet contact point (figure 4A).

[0053] Before or after said stage (d), the procedure according to the invention comprises a stage (e) of detecting at least one image relating to a portion of the cross-section of the workpiece 7 and processing data relating to the thickness of the workpiece 7. The processed data 20A refer, in particular, to the thickness of the workpiece 7.

[0054] At this point, there is a stage (f) of calculating the theoretical bend angle as a function of the thickness detected for the workpiece 7 and, where applicable, as a function of the shape and size of the punch 5. The bottom dead centre is also calculated as a function of the theoretical bend angle required for the workpiece 7. In this stage (f), the press brake 1 is operated to bring the bending edge 5A of the punch 5 to said bottom dead centre, thereby inducing the bending of the workpiece 7 (figure 4B).

[0055] After said stage (f), the procedure according to the invention comprises a stage (g) of calculating the floating point on the return trajectory of the punch 5 and operating the press brake 1 to make the bending edge 5A of the punch 5 return to said floating point.

[0056] The floating point can also be calculated by measuring the spring-back of the workpiece 7 as the punch 5 returns from the bottom dead centre.

[0057] For this purpose, the above-mentioned stage (g) preferably also involves an operative step of determining a succession of sampling points along the stretch of the return trajectory of the punch 5 coming between the bottom dead centre and the punch/sheet contact point.

[0058] Said operative step can also be performed by the second electronic means 20. The operative step involves acquiring at least one image relating to at least a portion of the cross-section of the die 3, the punch 5 and/or the workpiece 7 for each of the selected sampling points, and processing data relating to the spring-back

of the workpiece 7.

[0059] The data thus processed are integrated by means of another operative step involving the acquisition by the second detecting means 43 and, where necessary, by one or more additional sensors (not shown), of data relating to said first and/or second mechanical strains in line with one or more of said sampling points.

[0060] As an alternative, the floating point can be calculated on the base of additional properly placed sensing means (not shown).

[0061] The procedure according to the invention then involves a stage (h) of acquiring at least one image relating to at least a portion of the cross-section of the workpiece 7 and processing data relating to the actual bend angle of the workpiece 7, after the spring-back has occurred.

[0062] The procedure according to the invention then comprises a stage (i) of comparing the data relating to the actual bend angle detected at said stage (h) with the data relating to the theoretical bend angle calculated at the previously-mentioned stage (f).

[0063] If the difference between the actual bend angle and the theoretical bend angle comes within the established tolerances, the bending procedure can be completed.

[0064] This involves the stages (j) of operating the press brake 1 to make the bending edge 5A of the punch 5 withdraw to the top dead centre, and the stage (k) of removing the workpiece 7 from the table of the press brake 1.

[0065] If the difference between the actual bend angle and the theoretical bend angle is outside the established tolerances, the bending action on the workpiece can be repeated as often as necessary.

[0066] In this case, the procedure includes a stage (1) of calculating a new theoretical bend angle and a new bottom dead centre for the trajectory of the punch 5, and a stage (m) of repeating the previous stages (g), (h), and (i), using the newly-calculated bottom dead centre and theoretical bend angle.

[0067] In a preferred embodiment of the invention, the above-described bending procedure also includes an adjustment to achieve a dynamic attenuation of the effects deriving from the onset of the above-mentioned mechanical strains, particularly the strains affecting the die 3 and the upper cross member 6. The bending procedure preferably includes performing a procedure, in parallel with the previously-described stages, and stages (c)-(g) in particular, to compensate for said mechanical strains. Said compensation method advantageously includes the following operative steps:

- acquiring and processing data relating to said first mechanical strains using the second detecting means 43, when the punch 5 is in line with a point on the trajectory located above the top dead centre;
- acquiring and processing data relating to the above-mentioned first mechanical strains, again using the

second detecting means 43, when the punch 5 is in line with the top dead centre;

- comparing the data acquired at the previous steps in order to be able to calibrate the data acquired;
- using said second detecting means 43 to acquire and process data relating to said first mechanical strains in line with a succession of sampling points on the stretch of the trajectory of the punch 5 coming between the speed change point and the bottom dead centre;
- based on the data acquired in the succession of sampling points, bring a sufficient force to bear on the die 3 or, more in general, on the base 2 to at least partially compensate for said first mechanical strains.

[0068] Said compensatory force is exerted by the actuator means 42, which can comprise, for instance, a series of oil hydraulic actuators associated with the base 2. The actuator means 42 take effect on the strength of control signals 41A sent by the third electronic means 41, which acquire the data 40A from the sensors 40 and perform software algorithms to filter and process the signals they receive. The sensors 40 advantageously comprise one or more analog pressure sensors placed along the entire length of the base 2 to provide one or more detecting points.

[0069] In another preferred embodiment of the invention, the bending procedure also includes a detecting method to integrate the calculation of notable points on the trajectory of the punch 5, and particularly of the speed change point, the punch/sheet contact point, the bottom dead centre and/or the floating point, taking into account the effects of said first and/or second mechanical strains on the body of the press brake. The detecting method comprises the following steps:

- using the second detecting means 43 to acquire and process data relating to said first and/or second mechanical strains when the punch 5 is in line with a point on the trajectory located above the top dead centre;
- using the second detecting means 43 to acquire and process data relating to said first and/or second mechanical strains when the punch 5 is in line with the top dead centre;
- comparing the data acquired at the previous steps to enable the calibration of the data acquired;
- using the second detecting means 43 to acquire and process data relating to said first and/or second mechanical strains in line with a succession of sampling points on the stretch of trajectory of the punch 5 coming between the speed change point and the bottom dead centre;
- based on the data acquired from said succession of sampling points, correcting the calculation of the speed change point and/or of the punch/sheet contact point, and/or of the bottom dead centre, and/or

of the floating point on the trajectory of said punch.

[0070] As in the previous compensation method, the data relating to the mechanical strains are collected by the sensors 40, which in this case can advantageously also comprise several sensors placed in line with the columns 8 of the press brake 1. The data detected are processed by the third electronic means 41, using suitable filtering algorithms. The third electronic means 41 send the data 19C to the second electronic means 20 and, where necessary, to the control system 31, for the calculation of the notable points on the trajectory.

[0071] There may be variants, modifications or improvement to the practical embodiment of the press brake 1 according to the invention, all coming within the same inventive concept. For instance, the second and third electronic means 20 and 41 may be integrated in a single microprocessor-controlled circuit, preferably incorporated in the control system 31. Moreover, different types of signal from those described above may also be exchanged between the different components of the regulating means 10, and between said components and the control system 31, to guarantee an optimal and efficient functional operation of the press brake 1.

[0072] Experience has shown that the press brake according to the present invention enables the previously-stated objects to be achieved.

[0073] The press brake according to the invention enables a high and constant reproducibility of the bending process to be achieved. Thanks to the accuracy of the optical measurements obtained by the first detecting means 11, even minimal variations in the thickness of the different workpieces being bent can be allowed for during the operating cycle of the machine. Moreover, the first detecting means 11 enable an extremely precise assessment of the level of wear and tear on the tooling, i.e. on the die 3 and the punch 5. For instance, images detected at different times during the working cycle of the tooling can be compared and the corresponding levels of wear can be analysed. At each test, the data relating to the tooling can be brought up to date and a greater accuracy of the data processing performed during subsequent processing cycles can thus be guaranteed.

[0074] The press brake according to the invention is particularly sturdy in operation, given the ambient conditions in which it is used. The first detecting means 11 provide a strongly directional lighting of the tooling 3 and 5, and of the workpiece 7, by means of a dedicated light source, preferably a laser light source. This enables a marked reduction in the negative interference of conditions of lighting that is too strong or directed crosswise to the workspace for the machine. In addition, the lighting system enables an optimal and constant focusing of the image to be achieved by the optical sensing means 14. This enables relatively clear images to be acquired and a consequently more precise processing of the quantities and/or positions of interest. In a word, the working cycle of the machine can be adjusted very precisely. An addi-

tional adjustment accuracy derives from the second detecting means 43, which enable the effects of the mechanical strain on the machine body during the working cycle to be compensated and/or taken into account. Thanks to the second electronic means 20, used as an intelligent interface between the first detecting means 11 and the control system 31, the regulating means 10 also enable a marked automation of the different stages of the bending cycle, reducing or even eliminating the need for any action by the operator. The strong degree of automation in the machine's operation makes it considerably easier to use, while also affording a better performance than with the known state of the art.

[0075] Clearly, all the above give rise to a considerable reduction in the manufacturing times and an appreciable improvement in the quality of the end product.

[0076] Despite its innovative functionalities, the press brake according to the invention is a of relatively straightforward design and can consequently be manufactured industrially at highly competitive costs.

Claims

1. A press brake (1) comprising at least:

- a die (3) that extends substantially along a horizontal longitudinal axis (4) of said press brake, said die being integrally connected to a base (2) of said press brake;
- a punch (5) that extends above said die, substantially along the same horizontal axis as said die, said punch being vertically movable in both directions (50) so as to co-operate with said die to achieve the bending of a workpiece (7);
- regulating means (10) for adjusting the procedure for bending the workpiece;

characterised in that said regulating means include first detecting means (11) comprising:

- light emitting means (12) suitable for emitting a beam of light (13) along the direction in which said die extends, to at least partially illuminate at least a portion of said die and/or of said punch, and/or of the workpiece, and to project the profile, on a predefined plane, of at least a portion of the cross-section of said lower die and/or of said punch, and/or of the workpiece;
- optical sensing means (14) suitable for acquiring an image of said projection, generated by said beam of light.

2. A press brake according to claim 1, **characterised in that** said first detecting means comprise first electronic means (15) suitable for receiving as input and processing data (16) relating to the image acquired by said optical detection means.

3. A press brake according to claim 2, **characterised in that** said first electronic means are suitable for receiving control signals (17A) as input and adjusting the operation of said light emitting means and/or of said optical sensing means on the strength of said control signals.
4. A press brake according to one or more of the previous claims, **characterised in that** said regulating means comprise second electronic means (20) operatively connected to said first electronic means and to a control system (31) of said press brake, said second electronic means being suitable for obtaining data (20A) indicative of one or more notable quantities relating to said lower die and/or said punch and/or the workpiece.
5. A press brake according to claim 4, **characterised in that** said second electronic means generate control signals (17A, 17B) to send to said first electronic means and/or to the system for controlling said press brake.
6. A press brake according to one or more of the previous claims, **characterised in that** said regulating means comprise second detecting means (43) for detecting data (40A) indicative of first mechanical strains coming to bear on said die and/or on said base, and/or on an upper cross member (6) of said press brake during the bending procedure and/or indicative of second mechanical strains coming to bear on columns (8) of said press brake, during the bending procedure.
7. A press brake according to claim 6, **characterised in that** said second detecting means comprise:
- one or more sensors (40) associated with one or more portions of the body of said press brake;
 - third electronic means (41) operatively connected to said sensors for processing the data detected by said sensors.
8. A press brake according to claim 7, **characterised in that** said third electronic means are suitable for:
- sending control signals (41A) to actuator means (42) suitable for bringing a force to bear to counter said first and/or second mechanical strains; and/or
 - sending data (19C) indicative of said first and/or second mechanical strains to said second electronic means and/or to said control system.
9. A press brake according to one or more of the previous claims, **characterised in that** said light emitting means and said optical detection means are ver-
- tically movable in both directions (500) so as to maintain a predefined position and alignment relative to said punch.
10. A press brake according to claim 9, **characterised in that** said light emitting means and said optical detection means are aligned with one another in the direction in which said punch extends, and they are positioned respectively in line with a first end and a second end of said punch, on the outside of the table of said press brake.
11. A procedure for bending a workpiece using a press brake according to one or more of the previous claims, **characterised in that** it comprises one or more of the following operative stages:
- a) placing the workpiece in line with the bending edge of said lower die;
 - b) acquiring at least one image relating to least a portion of the cross-section of said punch and processing data relating to the shape and/or size, and/or position of said punch in line with a point coming between the rest point and the top dead centre on the trajectory of said punch;
 - c) calculating a speed change point on the trajectory of said punch and operating said press brake to bring the bending edge of said punch into line with said speed change point;
 - d) calculating a punch/sheet contact point on the trajectory of said punch and operating said press brake to bring the bending edge of said punch into line with said punch/sheet contact point;
 - e) acquiring at least one image relating to at least a portion of the cross-section of said punch and/or of said lower die, and/or of the workpiece, and processing data relating to the thickness of the workpiece in line with said speed change point and/or said punch/sheet contact point;
 - f) calculating a bottom dead centre on the trajectory of said punch and the theoretical bend angle, and operating said press brake to bring the bending edge of said punch down to said bottom dead centre;
 - g) calculating a floating point on the trajectory of said punch and operating said press brake to make the bending edge of said punch withdraw to said floating point;
 - h) acquiring at least one image relating to at least a portion of the cross-section of said punch and/or of said lower die, and/or of said workpiece, and processing data relating to the actual bend angle of said workpiece in line with said floating point;
 - i) comparing the data relating to the actual bend angle with the data relating to said theoretical bend angle.

12. A bending procedure according to claim 11, **characterised in that**, after said stage (i), it comprises the following steps:

j) operating said press brake to make the bending edge of said punch withdraw to said top dead centre; 5
k) removing the workpiece.

13. A bending procedure according to claim 11, **characterised in that**, after said stage (i), it comprises the following steps: 10

1) calculating a new bottom dead centre on the trajectory of said punch and a new theoretical bend angle; 15
m) repeating said stages (g), (h), and (i) in the light of the new bottom dead centre and the new theoretical bend angle calculated in said stage (1). 20

14. A bending procedure according to one or more of the claims from 11 to 13, **characterised in that** said stage (g) comprises one or more of the following operative steps: 25

- determining a succession of sampling points in the stretch of return trajectory of said punch coming between said bottom dead centre and said punch/sheet contact point; 30
- acquiring, in line with one or more of said sampling points, at least one image relating to at least a portion of the cross-section of said punch and/or of said lower die, and/or of the workpiece, and processing data relating to the spring-back of the workpiece; 35
- acquiring data relating to said first and/or second mechanical strains in line with one or more of said sampling points;
- calculating said floating point as a function of the data acquired in the previous steps. 40

15. A bending procedure according to one or more of the claims from 11 to 14, **characterised in that** it also includes a method for compensating for said first mechanical strains comprising the following steps: 45

- acquiring and processing data relating to said first mechanical strains in line with a point located above the top dead centre on the trajectory of said punch; 50
- acquiring and processing data relating to said first mechanical strains in line with said top dead centre; 55
- comparing the data acquired in the previous steps;
- acquiring and processing data relating to said

first mechanical strains in line with a succession of sampling points on the stretch of trajectory of said punch coming between said speed change point and said bottom dead centre;

- based on the data acquired from said succession of sampling points, bringing a force to bear on said die and/or on said base sufficient to at least partially compensate for said first mechanical strains.

16. A bending procedure according to claim 15, **characterised in that** it includes a detecting method for integrating the calculation of one or more notable points on the trajectory of said punch, that comprises the following steps:

- acquiring and processing data relating to said first and/or second mechanical strains in line with a point located above a top dead centre on the trajectory of said punch;
- acquiring and processing data relating to said first and/or second mechanical strains in line with said top dead centre;
- comparing the data acquired in the previous steps;
- acquiring and processing data relating to said first and/or second mechanical strains in line with a succession of sampling points on the stretch of the trajectory of said punch coming between said speed change point and said bottom dead centre;
- integrating/correcting the calculation of one or more of notable points on the trajectory of said punch on the strength of the data acquired from said succession of sampling points.

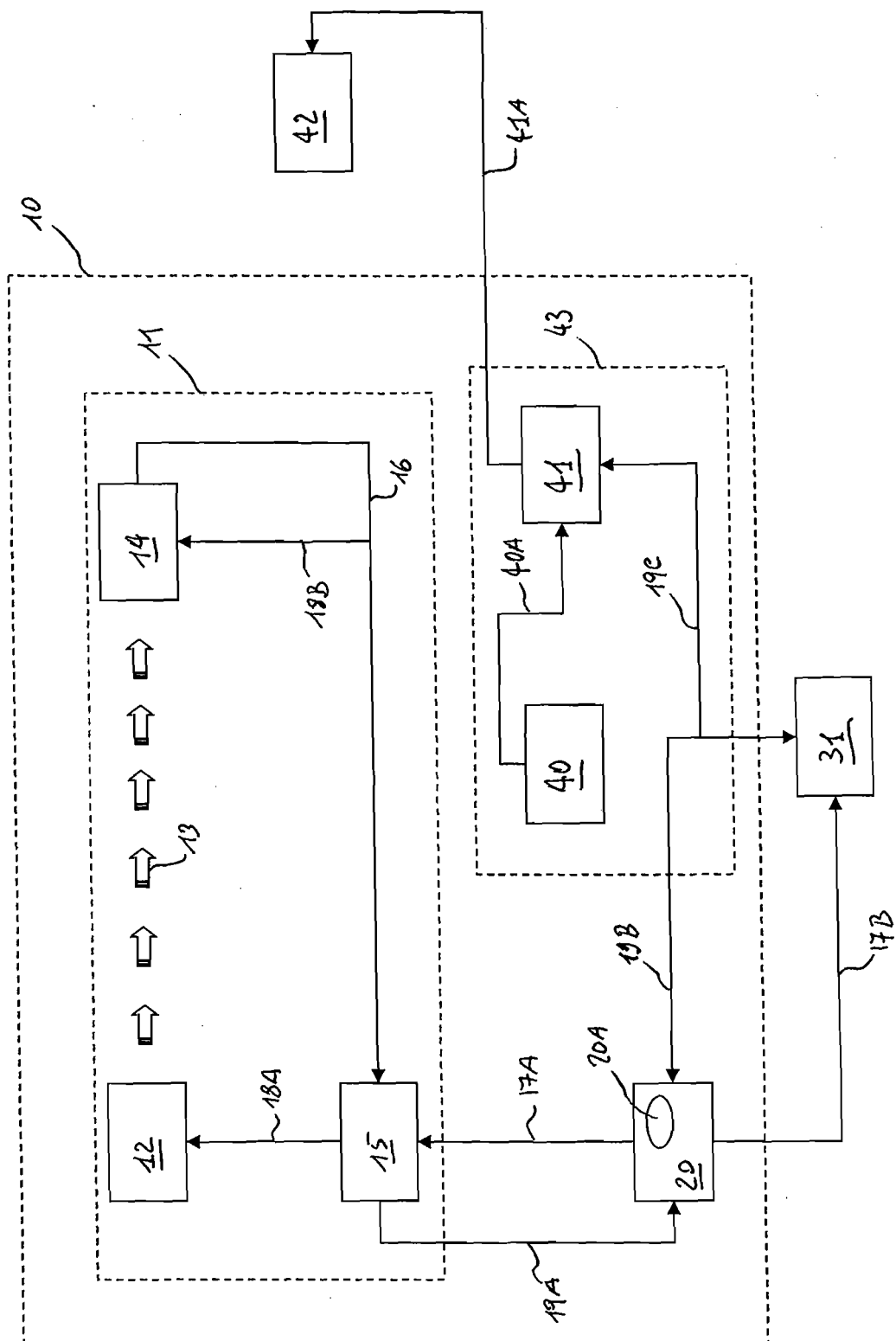


FIG. 1

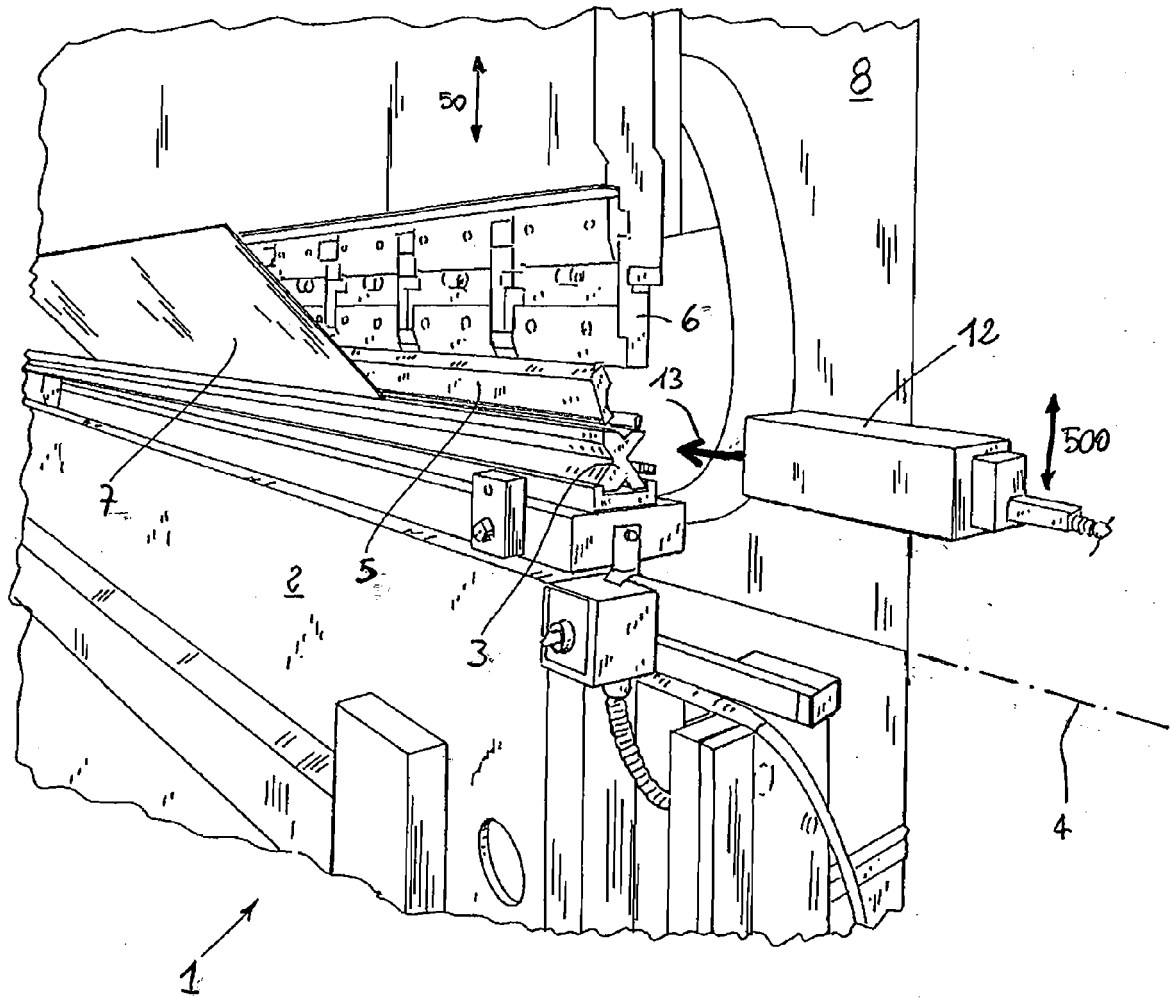


FIG. 2

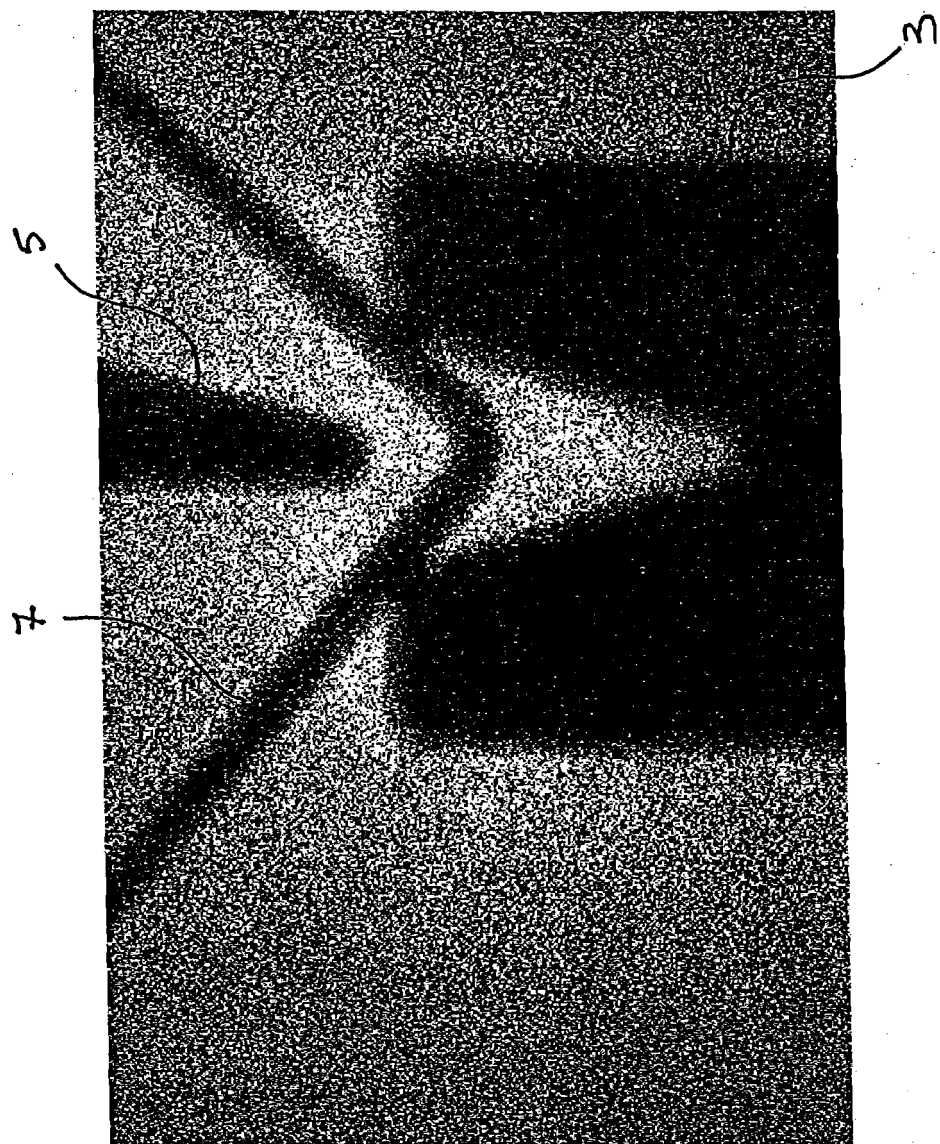


FIG. 3

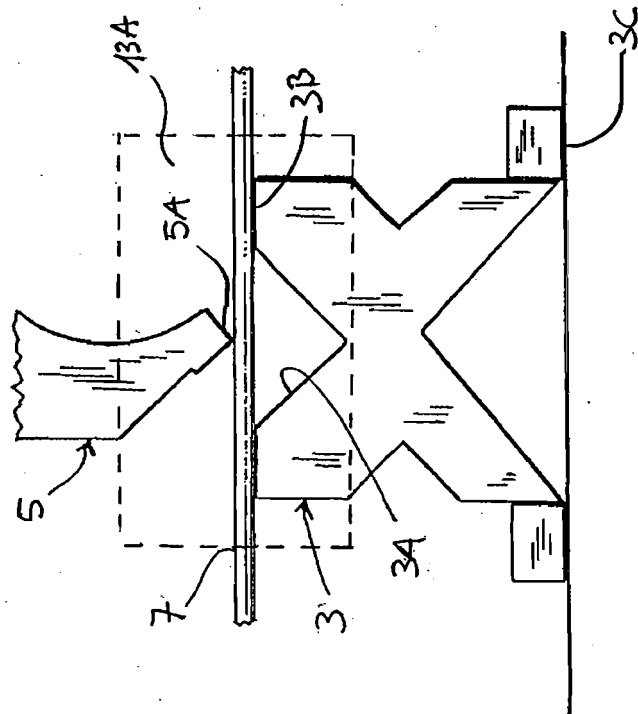


FIG. 4A

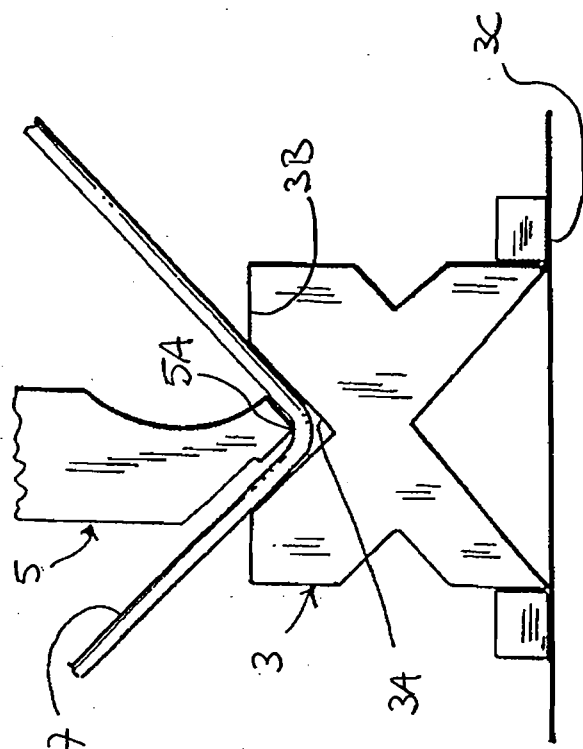


FIG. 4B

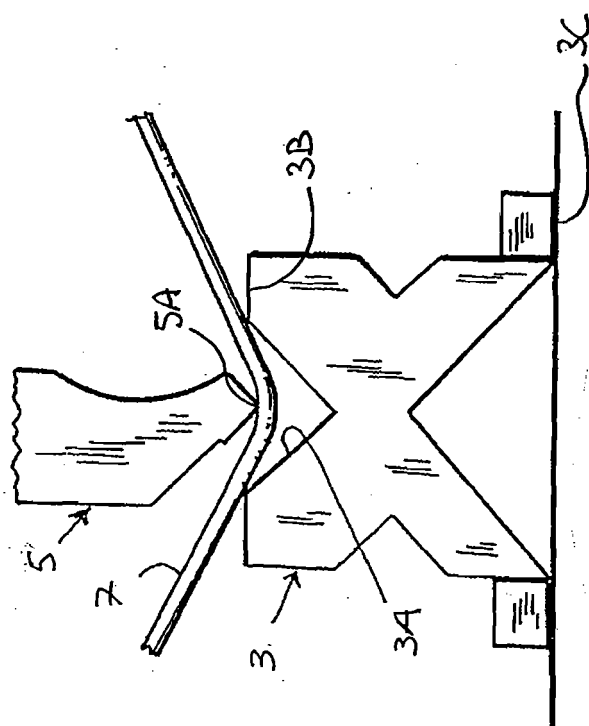


FIG. 4C



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 07 11 8338

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Place of search The Hague		Date of completion of the search 5 February 2008	Examiner Pothmann, Johannes
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