



(11)

EP 1 685 914 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.08.2006 Bulletin 2006/31

(51) Int Cl.:
B21D 24/02 (2006.01)

(21) Application number: **06250459.2**

(22) Date of filing: **27.01.2006**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **01.02.2005 JP 2005025413**

(71) Applicant: **FANUC LTD**
Minamitsuru-gun,
Yamanashi 401-0597 (JP)

(72) Inventors:
• **Hishikawa, Tetsuo,**
Room 12-407
Minamitsuru-gun
Yamanashi, 401-0511 (JP)

• **Fujibayashi, Kentaro**
Musashino-shi
Tokyo, 180-0013 (JP)
• **Tsujikawa, Keisuke,**
Fanuc Dai3virakaramatsu
Minamitsuru-gun
Yamanashi, 401-0511 (JP)
• **Hirose, Noboru,**
Fanuc Dai3virakaramatsu
Minamitsuru-gun
Yamanashi, 401-0511 (JP)

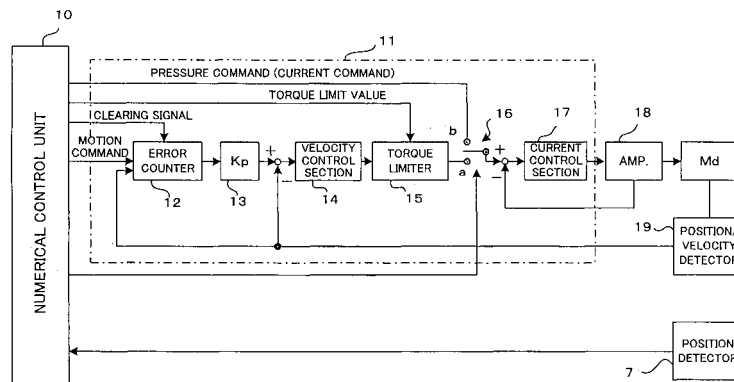
(74) Representative: **Billington, Lawrence Emlyn et al**
Haseltine Lake,
Imperial House,
15-19 Kingsway
London WC2B 6UD (GB)

(54) Die cushion control device

(57) Die cushion control device that implements die cushion control while making a switch between position control and pressure control by using servomotors, and reduces the impact caused by a collision between a press axis and a die cushion axis during position control. Die cushion members (6) are controlled by servomotors Md. The changeover switch (16) is connected to the "a"-side, to thereby control the position (velocity) of the servomotors Md by commands from a numerical controller (10) and control the position of the die cushion members. During position control, the output torque of the servomotors

Md is limited by torque limit means (15). During position control, even if the press axis hits the die cushion members due to erroneous setting, wrong operation or the like, the servomotors Md merely output only a limited torque or less, so that impact force is reduced, which prevents damage to the die cushion members and the press axis. During press operation, when a position detector (7) detects that the press axis moves downward to reach a predetermined position, the changeover switch is connected to the "b"-side, to thereby implement pressure control.

FIG. 2



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a die cushion control device for performing a die cushion control in a press machine.

2. Description of Related Art

[0002] In a press machine, when sheet metal is pressed between a set of dies by relative motion of the set of dies along a press axis, a die cushion control is performed in order to prevent the sheet metal from being applied with abrupt pressure and to moderate a change of pressure applied to the sheet metal.

[0003] A die cushion control device of the press machine conventionally performs hydraulic or pneumatic pressure control. An upper die movably provided by a press axis driving device moves downward to hit the sheet metal, and subsequently, the die cushion control device implements pressure control. In the case of die cushion control using hydraulic or pneumatic pressure, however, there is time lag between provision of a control signal and a response. For this reason, it is difficult to carry out the control in such a way that the sheet metal does not receive surge pressure that is created by impact at the beginning of the press.

[0004] In order to resolve this problem, a die cushion device that has a servomotor for elevating and lowering a die cushion member and is used while switching between the position control of stroke of the cushion member and the pressure control performed by current torque control by means of the servomotor is proposed (see JP 10-202327A).

[0005] In the case of a die cushion device that carries out the drive of the die cushion member by the servomotor and implements the control while switching between the position control of stroke of the cushion member and the pressure control as in the invention described in JP 10-202327A, the pressure control is performed as the sheet metal is pinched between the die cushion member and upper die driven by the press axis driving device, and in the other periods, the position control is carried out. The position control is performed to drive-control the servomotor so as to follow a commanded position. When the die cushion member is applied with great force, the servomotor produces great torque for the purpose of maintaining the commanded position and acts to maintain the position.

[0006] On this account, during die change or during position control as in adjustment of the press machine and the like, if the upper die driven by the press axis driving device hits the die cushion member, or if the press axis is driven with a foreign matter pinched between the die cushion member and the upper die fixed to the press

axis to apply great force to the die cushion member and the like, great impact force is created, which does a lot of damage to the die cushion member and the die in some cases.

[0007] As a die cushion control device, there is another known device in which the motion of the die cushion member is started at a slower velocity than the motion velocity of the upper die driven by the press axis driving device in the direction drawing away from the upper die before the upper die is brought into contact with the die cushion member, and the die cushion member is so controlled as to hit the upper die during the motion by difference of relative motion velocities, to thereby achieve the reduction of hitting noise made in the event of a collision or the like.

[0008] In case that such control is implemented by the die cushion control device, if the press hits the die cushion for another reason, such as erroneous setting and wrong operation, and position control is carried out while the control is not switched to pressure control, the commanded position of the die cushion and the actual position thereof deviate from each other. The servomotor then generates great torque in order to maintain the commanded position, which causes the problem that there occurs a mechanical damage such as damage to the die cushion member.

SUMMARY OF THE INVENTION

[0009] A die cushion control device of the present invention is provided for a press machine that presses metal between a set of dies relatively movable along a press axis while controlling a pressure exerted on the sheet metal. The die cushion control device comprises: a die cushion member for cushioning the pressure exerted on the sheet metal by the relative motion of the set of dies; a servomotor for moving the die cushion member in a direction of the press axis; and a controller for controlling the servomotor by selectively performing one of a position control and a pressure control of the die cushion member, and having torque limit means for effecting a torque limit on the servomotor during the position control of the die cushion member.

[0010] The torque limit means may apply a torque limit to a torque command for the servomotor to move the die cushion member in a direction that the set of dies press the sheet metal, and does not apply the torque limit to a torque command for the servomotor to move the die cushion member in a direction opposite to the direction that the set of dies press the sheet metal.

[0011] Further, the torque limit means may apply a first torque limit to a torque command for the servomotor to move the die cushion member in a direction that the set of dies press the sheet metal, and apply a second torque limit of a value different from a value of the first torque limit to a torque command for the servomotor to move the die cushion member in a direction opposite to the direction that the set of dies press the sheet metal.

[0012] When the die cushion members are under position control, the servomotor for driving the die cushion members is provided with torque limits, and the servomotor does not output torque of a predetermined value or more. Therefore, even if the upper die hits the die cushion members due to malfunctions or wrong operation, the die cushion members do not generate drag equal to or more than a torque limit value. This prevents damage to the die fixed to the press axis, the die cushion members, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

FIG. 1 is a schematic view of a press machine in which a die cushion control device of a first embodiment of the present invention is applied;

FIG. 2 is a block diagram of the die cushion control device in the first embodiment;

FIG. 3 is a view for explaining a collision between die cushion members and an upper die in a position control state of the first embodiment;

FIG. 4 is a schematic view of a press machine in which a die cushion control device of a second embodiment of the present invention is applied; and

FIG. 5 is a view for explaining a switch from position control to pressure control in the second embodiment.

DETAILED DESCRIPTION

[0014] FIG. 1 is a schematic view of a press machine in which a die cushion control device of a first embodiment of the present invention is applied. A lower die 2 of a set of dies is fixed to a base of the press machine, and an upper die 1 is driven by a press axis driving device (not shown), so as to face the lower die 2. The press axis driving device may be constituted by a crank mechanism, by a hydraulic or pneumatic pressure mechanism, or by a position control mechanism using a servomotor, thereby driving the upper die 1 according to a predetermined pattern and moving the same upward and downward in the figure.

[0015] A plurality of die cushion members 6 are disposed on the lower die 2 side. The die cushion members 6 are configured so that they are driven by respective servomotors Md in the vertical direction in the figure. In the example shown in FIG. 1, the die cushion members 6 and the die cushion servomotors Md are provided in two pairs. However, there may be provided a plurality of pairs, that is, three or four pairs. Alternatively, the plurality of die cushion members 6 may be integrally joined to each other to be driven by one die cushion servomotor Md. This die cushion servomotor Md is drive-controlled by a die cushion controller 5.

[0016] There is provided a position detector 7 for detecting the position of the upper die 1, i.e. that of the press

axis. Output of the position detector 7 is inputted to the die cushion controller 5. Although the embodiment illustrated in FIG. 1 shows an example of the rectilinear position detector 7, detection may be carried out with a rotary position detector fixed to a motor shaft, a rotary shaft or the like for driving the press axis.

[0017] Sheet metal (workpiece) 3 to be pressed is placed on the die cushion members 6 and is disposed on the lower die 2.

[0018] FIG. 2 is a block diagram of the die cushion controller 5 in the first embodiment.

[0019] The die cushion controller 5 comprises a numerical control unit 10 including a numerical controller and the like and a servo control unit 11. The servo control unit 11 comprises an error counter 12 and a term of a position loop gain Kp 13 which constitute a position control section, a velocity control section 14, a torque limiter 15, a changeover switch 16, and a current control section 17, and performs a software servo control by a processor. In comparison with the configuration of a common servo controller for controlling a conventional servomotor, there is a difference in that the torque limiter 15 and the changeover switch 16 are provided. In case that a torque command (current command) outputted from the velocity control section 14 exceeds a set torque limit value (in plus direction or in minus direction), the torque limiter 15 limits the torque command to the set torque limit value (an upper limit or a lower limit) and outputs the torque command to the current control section 17. The torque limit value of the torque limiter may be set by a command from the numerical control unit 10 or may be set to predetermined fixed values.

[0020] The changeover switch 16 is arranged between the torque limiter 15 and the current control section 17. By the changeover switch 16, selection is made as to whether the input of the current control section 17 is a torque command obtained by performing the position and the velocity control and subjected to the torque limit or a pressure command (current command) outputted from the numerical control unit 10. The output of the current control section 17 is inputted through an amplifier 18 to the die cushion servomotors Md, to thereby drivingly control the servomotors Md. The position and the velocity are fed back from a position/velocity detector 19 provided to the servomotors Md, thereby performing feedback control of the position and velocity.

[0021] The changeover switch 16 is generally switched to an "a"-side, and the die cushion members 6 and the die cushion servomotors Md are under the position and velocity control in a state where the output of the velocity control section 14 is inputted through the torque limiter 15 to the current control section 17. When a motion command to a predetermined position where the sheet metal (workpiece) 3 is placed on the die cushion members 6 is outputted from the numerical control unit 10 to the servo controller 11, the error counter 12 adds this motion command and subtracts a position feedback amount from the position/velocity detector 19 to obtain a position deviation

amount. The error counter 12 then multiplies the position deviation amount by the position loop gain K_p to obtain a velocity command and subtracts the velocity command and a velocity feedback amount from the position/velocity detector 19 to obtain a velocity deviation. In the velocity control section 14, a torque command (current command) is obtained by performing velocity loop control such as PI control with respect to the velocity deviation.

[0022] If the torque command (current command) does not exceed the set torque limit value (in the plus direction or the minus direction), the torque limiter 15 directly outputs the torque command outputted from the velocity control section 14. If the torque command exceeds the set torque limit value, however, the torque limiter 15 outputs the set torque limit value. For a brief explanation, a torque direction in which the die cushion members 6 are moved upward (direction toward the upper die side) in FIG. 1 is referred to as plus, and a torque direction in which the die cushion members 6 are moved downward is referred to as minus.

[0023] The torque command outputted from the torque limiter 15 is issued through the changeover switch 16 switched to the "a"-side to the current control section 17. A deviation between the torque command and a current feedback signal from a current detector disposed in the amplifier 18 is obtained. Based on this current deviation, current loop control is performed, and the die cushion servomotor Md is drivingly controlled through the amplifier 18. Subsequently, the position control is performed to maintain the die cushion members 6 in the predetermined position that is commanded. The die cushion members 6 are normally maintained in this standby position.

[0024] Once the sheet metal (workpiece) 3 is placed on the die cushion members 6 maintained in the predetermined position, and a press command is issued, the upper die 1 is lowered. The position of the upper die 1 is detected by the position detector 7 and is outputted to the numerical control unit 10 of the die cushion controller 5. When the numerical control unit 10 of the die cushion controller 5 detects from a signal from the position detector 7 that the upper die 1 reaches a preset position (position in which the upper die 1 is brought into contact to the sheet metal 3) in a state where the press axis is down, the numerical control unit 10 switches the changeover switch 16 to a "b"-side and outputs a pressure command (current command) through the changeover switch 16 to the current control section 17. The current control section 17 performs the current loop control based on a deviation between the pressure command and the current feedback, thereby implementing pressure control.

[0025] In other words, after the upper die 1 is lowered by the drive of the press axis and is brought into contact to the sheet metal (workpiece) 3, the sheet metal (workpiece) 3 and the die cushion members 6 are pressed, and this press force is added to the die cushion servomotors Md as load. As described above, after the upper die 1 starts to press the sheet metal (workpiece) 3, the

command to the current control section 17 is switched to the pressure command outputted from the numerical control unit 10, so that the die cushion servomotors Md are applied with pressure feedback control so that the output torque corresponds with the command pressure. The die cushion members 6 descend with the upper die 1 while maintaining the command pressure, and the sheet metal (workpiece) 3 is pinched between the upper die 1 and the lower die 2, to thereby perform press machining.

[0026] Thereafter, the press axis starts to move upward. When the numerical control unit 10 detects from a signal from the position detector 7 that the press axis moves upward to reach a predetermined position that is preset, the error counter 12 is first cleared. That is to say, during pressure control, the die cushion servomotors Md move along with the motion of the die cushion members 6, and a motion amount thereof remains in the error counter 12. Therefore, a command to delete the position deviation of the error counter 12 is outputted, to thereby clear the contents of the error counter and make the error counter correspond to a current position. Subsequently, a command to switch the changeover switch 16 to the "a"-side is outputted. Furthermore, the numerical control unit 10 outputs a motion command to a predetermined ascending position in which the sheet metal (workpiece) 3 is placed.

[0027] By so doing, since the changeover switch 16 is switched to the "a"-side, the position control is carried out according to the motion command. Specifically, position loop control (12 and 23) and velocity loop control (14) are performed, and a torque command is outputted through the torque limiter 15 to the current loop control. The current loop control is then implemented to drive the die cushion servomotors Md through the amplifier 18. The die cushion members 6 are moved to the predetermined position and maintained in the position.

[0028] Thereafter, the above-described operation is repeated, to thereby subject the sheet metal (workpiece) 3 to press machining while carrying out the die cushion control.

[0029] The die cushion controller 5 usually maintains the die cushion members 6 in the predetermined position by carrying out the position control. A switch to the pressure control is made in a period between the point when the upper die 1 moves downward to reach the predetermined position to pinch the sheet metal to the point when the machining is finished, and the upper die 1 starts to move upward to reach a predetermined position. The position control is performed when the press machine is on standby, in a preparatory stage, in a die change stage, during adjustment, and the like. For this reason, in the position control state where a switch to the pressure control is not made, if the press axis is accidentally driven during adjustment of a changeover position to the pressure control according to the thickness of the sheet metal, or in a state where sheet metal having an unscripted thickness or a foreign matter is pinched between the die

cushion members 6 and the upper die 1, the upper die 1 and the die cushion members 6 receive great force.

[0030] In the embodiment, however, the torque limiter 15 is provided in order to deal with such circumstances. FIG. 3 is a view showing relationship of a position of the press axis (position of the upper die 1) when the press axis is operated for some reason to lower the upper die 1 and the output torque of the servomotors Md that drive the die cushion members 6 in the middle of the position control.

[0031] The die cushion members 6 are maintained in the predetermined position. The upper die 1 moves downward, and the die cushion members 6 are pressed to descend. The servomotors Md increase the output torque for the purpose of maintaining the die cushion members 6 in the predetermined position that is commanded. To be concrete, due to the descent of the die cushion members, a command position to the servomotors and an actual position deviate from each other. As a result, the position deviation accumulated in the error counter 12 is increased. This increases a velocity command, and the torque command is also increased to return the die cushion members 6 to the command position. As shown in FIG. 3, however, a torque command equal to or more than the torque limit value that are set by the torque limiter 15 are not outputted to the servomotors Md, so that the servomotors Md output only torque equal to or less than the torque limit value. Accordingly, even if the press axis moves downward, and the upper die 1 presses the die cushion members 6, the servomotors Md do not output torque equal to or more than the torque limit value. Therefore, the die cushion members 6 descend with the upper die 1, and force equal to or more than a predetermined value (force corresponding to the torque limit value that is set by the torque limiter) does not act upon the die cushion members 6 and the upper die 1. Consequently, there occurs no such a damage as to break the die cushion members 6 and the upper die 1.

[0032] FIG. 4 is a schematic view of a press machine in which a die cushion control device of a second embodiment of the present invention is applied. A configuration of the second embodiment is virtually the same as the first. However, the standby position of the die cushion members 6 protrudes above an upper surface of the lower die 2, so that when the sheet metal 3 is placed on the die cushion members 6, a space is created between the sheet metal 3 and the lower die 2. When the press is started, before the die cushion members 6 contact the upper die 1 with the sheet metal 3 interposed therebetween, the die cushion members 6 start to move in a drawing-away direction (descending direction). During the motion, the upper die 1 is brought into contact to the sheet metal 3, to thereby reduce a hitting noise produced at the time of the contact.

[0033] The configuration of the die cushion controller 5 in the second embodiment is identical to that shown in FIG. 2. A difference from the first embodiment lies in the control of the servomotors that drive the die cushion

members 6 when the descent of the press axis moves the lower die 2 to start the press.

[0034] FIG. 5 is a view for explaining relationship of the motion of the press axis (upper die), the motion of the die cushion members 6 (operation of the servomotors Md), and the output torque of the servomotors Md.

[0035] The numerical control unit 10 connects the changeover switch 16 to the "a"-side, and outputs a motion command to the die cushion members 6 to move to the standby position in which the sheet metal 3 is placed. As described, the numerical control unit 10 implements the position, velocity, and current loop controls, and drives the servomotors Md to position the die cushion members 6 in the standby position protruding above the upper surface of the lower die 2 by a predetermined amount, to thereby maintain the position. Once the sheet metal 3 is placed on the die cushion members 6, and the press axis is driven to lower the upper die 1, the position of the press axis (upper die 1) is detected by the position detector 7. When it is detected that the press axis reaches the preset position, the numerical control unit 10 outputs a predetermined amount of a downward motion command at a preset velocity. Based on this motion command, the position, velocity, and current loop controls are implemented. The servomotors Md are driven, and the die cushion members 6 start to move downward. As shown in FIG. 5, when the output torque of the servomotors Md reaches target velocity that generates great torque acting in the downward direction (minus direction) at first in order to accelerate die cushion, acceleration is stopped, which reduces the output torque.

[0036] The descending velocity of the die cushion members 6 is set at a lower velocity than that of the press axis (upper die 1), so that the upper die 1 is brought into contact to the sheet metal 3 to press down the die cushion members 6. Although the servomotors Md operate to maintain the commanded velocity and position, since the descending velocity of the press axis (upper die 1) is higher than the velocity and position commanded to the servomotors Md, the servomotors Md rotate at a higher velocity than the target velocity, which increase the position deviation accumulated in the error counter 12. The position deviation is one caused by a follow-up delay with respect to the commanded position, and is also one generated in a direction moving the die cushion members 6 upward. As a result, the upward velocity command is also increased, the torque command to drive the die cushion members 6 upward is expanded. In this embodiment, too, however, since there is provided the torque limiter 15, the torque command is limited up to the set torque limit value by means of the torque limiter 15. For this reason, as shown in FIG. 5, the output torque of the servomotors Md is maintained to be the torque limit value, and does not exceed the torque limit value.

[0037] When the position detector 7 detects that the press axis (upper die 1) further moves downward and reaches the position in which the descending position thereof is set, the numerical control unit 10 switches the

changeover switch 16 to the "b"-side and outputs the pressure command (current command) through the changeover switch 16 to the current control section 17. The current control section 17 implements current loop control based on difference between the pressure command and current feedback and carries out the pressure control. Thereafter, the same processing operation as that described in the first embodiment is carried out. The die cushion servomotors Md are applied with the feedback control of pressure so that the output torque corresponds to the command pressure, and the sheet metal 3 is machined while the pressure control is carried out. When it is detected from a signal from the position detector 7 that the press axis (upper die 1) starts to move upward and reaches the predetermined position that is preset, the error counter 12 is cleared in the first place, and a command to switch the changeover switch 16 to the "a"-side is outputted. Furthermore, the numerical control unit 10 outputs a motion command to the predetermined ascending position in which the sheet metal (workpiece) 3 is placed.

[0038] Since the changeover switch 16 is switched to the "a"-side, the position loop control (12 and 23) and the velocity loop control (14) are performed, and the torque command is outputted through the torque limiter 15 to the current loop control. Subsequently, the current loop control is carried out to drive the die cushion servomotors Md through the servo amplifier 18. The die cushion members 6 are then driven to the standby position to be maintained in the position.

[0039] In the second embodiment, too, when the press axis is down, and the pressure control is not carried out as in the standby state of the press machine, the changeover switch 16 is connected to the "a"-side, and the position and velocity control is performed to control the position of the die cushion members 6. During the position control, the output torque of the servomotors Md is always limited by the torque limiter 15. Therefore, even if the press axis and the die cushion members 6 hit each other for some reason as in the first embodiment, there generates no impact of great force.

[0040] In the second embodiment, the position control is continued after the upper die 1 is brought into contact to the die cushion members 6 through the sheet metal 3, and is afterward switched to the pressure control. Consequently, if the velocity of the press axis is high for some reason, such as erroneous setting and wrong operation, and the upper die 1 hits against the die cushion members 6 at an unscripted high velocity, there is the possibility of generation of great impact force. However, even in the period of the position control before the changeover switch 16 is switched to the "b"-side, since the output torque of the servomotors is limited by the torque limiter 15, torque equal to or more than that is not produced, and the die cushion members 6 move downward with the upper die 1. Accordingly, there generates no great impact force in the die cushion members 6, the upper die 1 and the like, so that the upper die 1 and the die cushion mem-

bers 6 are protected.

[0041] In each of the foregoing embodiments, the torque limit value of a torque command in the torque limiter 15 may be set to either the same or different values with respect to plus and minus. Moreover, it is a chief aim to prevent the upper die 1 fixed to the press axis from hitting the die cushion members 6 and the like and being damaged. Therefore, a limitation (torque limit) may be imposed only on the torque command in the direction pinching the sheet metal by means of the die cushion members 6 (upward direction in FIGS. 1 and 4).

[0042] In each of the foregoing embodiments, as to the timing of a switch from the position control to the pressure control and from the pressure control to the position control, the switch is made according to the position detected by the position detector for detecting the position of the press axis. However, the switch may be made by another method, such as a switch made by using a limit switch, a switch with the timing when the output torque (current command) of the die cushion servomotors Md or the position deviation exceeds a fixed value and lasts for a predetermined time period, and a switch with the timing when the output torque (current command) of the motors that drive the press axis exceeds a predetermined value.

Claims

1. A die cushion control device for a press machine that presses sheet metal between a set of dies relatively movable along a press axis while controlling a pressure exerted on the sheet metal, comprising:

a die cushion member for cushioning the pressure exerted on the sheet metal by the relative motion of the set of dies;

a servomotor for moving said die cushion member in a direction of the press axis; and

a controller for controlling said servomotor by selectively performing one of a position control and a pressure control of said die cushion member, and having torque limit means for effecting a torque limit on the servomotor during the position control of said die cushion member.

2. A die cushion control device according to claim 1, wherein said torque limit means applies a torque limit to a torque command for said servomotor to move said die cushion member in a direction that the set of dies press the sheet metal, and does not apply the torque limit to a torque command for said servomotor to move said die cushion member in a direction opposite to the direction that the set of dies press the sheet metal.

3. A die cushion control device according to claim 1, wherein said torque limit means applies a first torque limit to a torque command for said servomotor to

move said die cushion member in a direction that the set of dies press the sheet metal, and applies a second torque limit of a value different from a value of the first torque limit to a torque command for said servomotor to move said die cushion member in a direction opposite to the direction that the set of dies press the sheet metal.

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FIG. 1

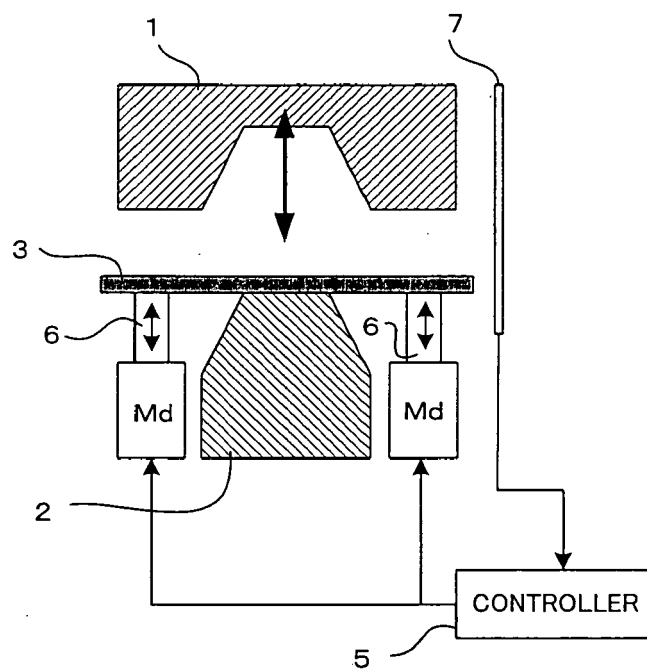


FIG. 4

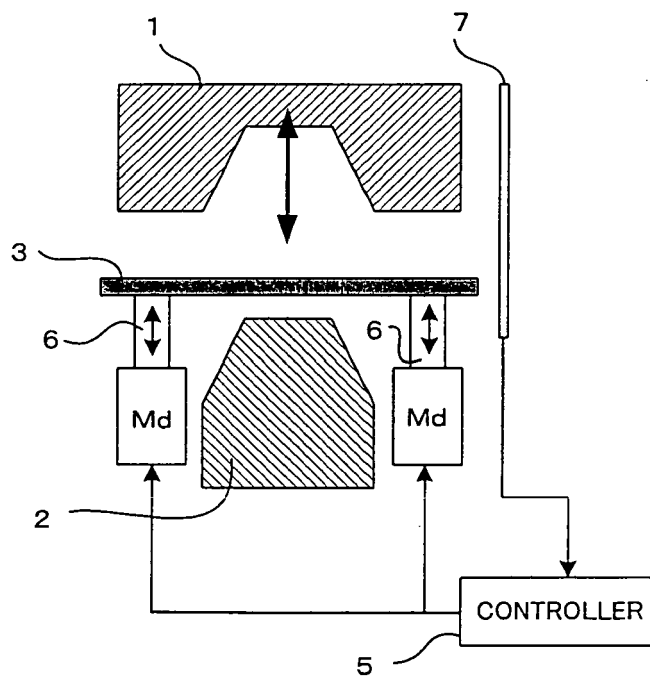


FIG. 2

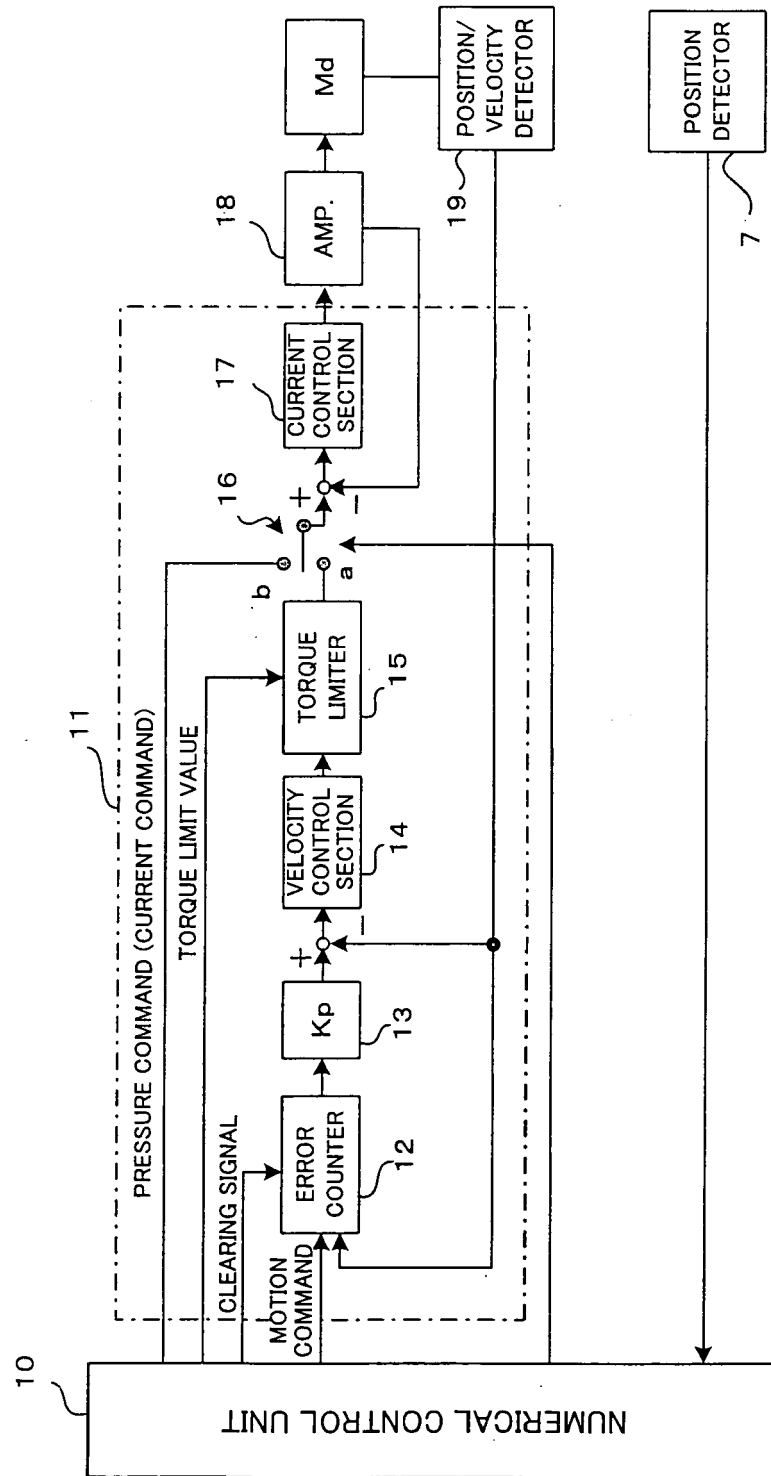


FIG. 5

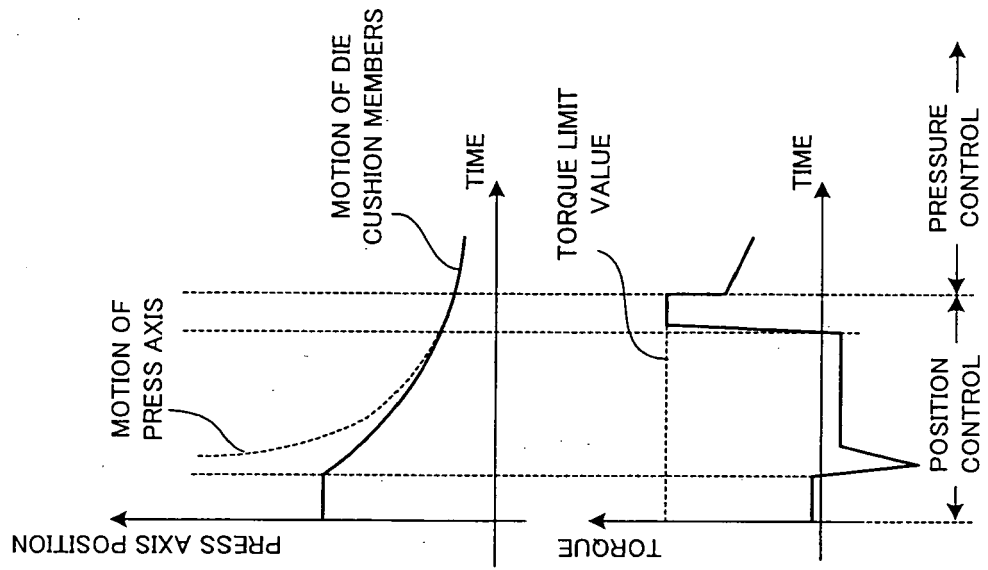


FIG. 3

