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(54) Titre : DISPOSITIF DE FORMATION DE PRESSE, PROCEDE DE FORMATION DE PRESSE, PROGRAMME INFORMATIQUE, ET SUPPORT D'ENREGISTREMENT

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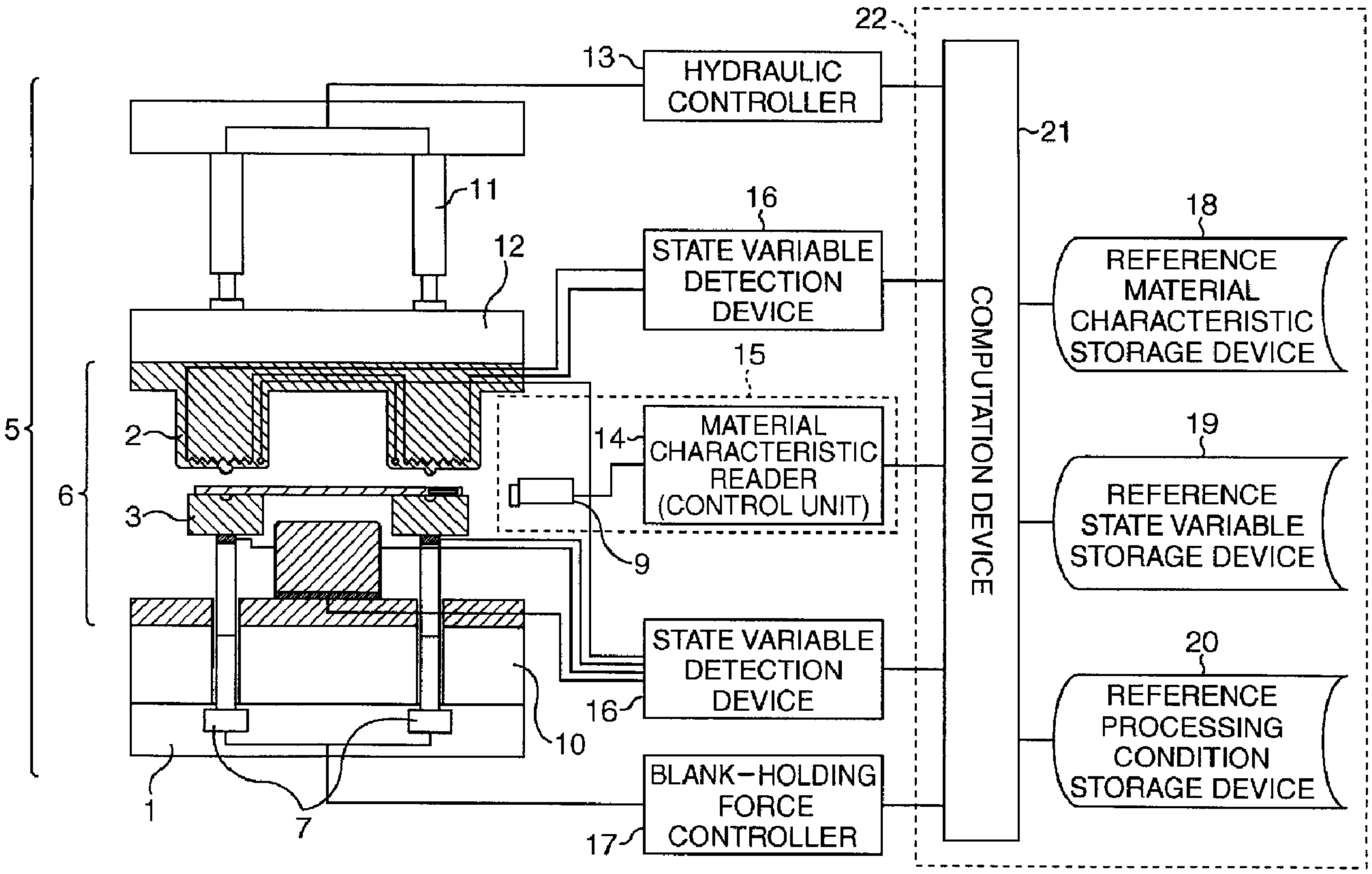

(57) Abrégé/Abstract:
A press-forming device includes: material characteristic input means inputting at least one of the material characteristics out of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation,

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(57) **Abrégé(suite)/Abstract(continued)**:
hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material; state variable detector measuring at least one state variable out of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, and work piece temperature during forming; processing condition computing means computing at least one processing condition out of forming speed, blank holding force, or metal mold temperature from the material characteristic inputted by the material characteristic inputting means and the state variable during forming measured by the state variable detector; and processing condition controller controlling at least one of the punch or die movement speed, temperature, or blank holding force according to the processing condition computed by the processing condition computing means.

ABSTRACT

A press-forming device includes: material characteristic input means inputting at least one of the material characteristics out of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material; state variable detector measuring at least one state variable out of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, and work piece temperature during forming; processing condition computing means computing at least one processing condition out of forming speed, blank holding force, or metal mold temperature from the material characteristic inputted by the material characteristic inputting means and the state variable during forming measured by the state variable detector; and processing condition controller controlling at least one of the punch or die movement speed, temperature, or blank holding force according to the processing condition computed by the processing condition computing means.

DESCRIPTION

PRESS-FORMING DEVICE, PRESS-FORMING METHOD, COMPUTER PROGRAM PRODUCT AND STORAGE MEDIUM

Technical Field

[0001] The present invention relates to a press-forming device, a press-forming method, a computer program and a storage medium, and in particular, relates to a suitable technology to be used for a favorable processing irrespective of characteristic deviation of various metal materials such as iron series, nonferrous series, stacked materials and the like, or environmental fluctuations during processing.

Background Art

[0002] Conventionally, when performing deep-drawing, bending, cutting, or the like to a metal material, using a press-forming device, it is usual to carry out actual production after determining appropriate forming conditions, namely, processing conditions such as the shape of metal molds, lubricating conditions, forming speed, blank holding force, the temperature of metal molds and work, and so on for every metal material in advance by trial production through experience, or through experiment, or by simulation or the like using a finite-element method.

[0003] Whereas, various metal materials being a raw material are plates, pipes, bars, wires, powder or

grains, and the like obtained through multiple processes of melting-smelting-casting-rolling-heat treatment-secondary processing and so on from raw material or scraps, and there inevitably exists some extent of deviation in mechanical properties in a product due to fluctuation of chemical components, or fluctuation of processing conditions such as uneven temperatures.

[0004] Accordingly, even when appropriate forming conditions are determined in advance as described above, occurrence of forming defect may arise due to differences in formability according to material positions or production lot numbers. In order to avoid this defect, execution of quality control during material production process is performed more severely, but excess severity may lead to material cost increase, and is not recommendable.

[0005] Moreover, even when the mechanical characteristics of raw material are identical, occurrence of forming defect may arise due to environmental fluctuation during processing such as temperature change of metal mold caused by continuous operation, abrasion of metal mold, fluctuation of atmospheric temperature or humidity.

[0006] As a countermeasure against these disadvantages, various inventions for a press-forming method to control processing conditions according to metal material or conditions of a metal mold have been disclosed. For instance,

Japanese Patent Application Laid-open no. 7266100 disclosed is a device to control air pressure in an air cylinder to carry out press-forming under an appropriate blank holding force by determining in advance a relation between a physical quantity such as a shape of press material and its mechanical property, chemical property, a laminate layer property of plating or the like, and surface conditions such as oil quantity or the like; and an appropriate blank holding force from which prescribed press quality is obtained; and by determining the appropriate blank holding force according to actual physical quantity from the above-described relation.

[0007] Japanese Patent Application Laid-open No. Hei 5-285700 and Japanese Patent Application Laid-open No. Hei 6-246499 disclose a device which adjusts press conditions based on machine information and metal mold information peculiar to a press machine.

[0008] Japanese Patent Application Laid-open No. Hei 7-265957, Japanese Patent Application Laid-open No. Hei 10-128451 and Japanese Patent Application Laid-open No. Hei 8-300048 disclose various methods to adjust to prescribed bending angles in a bending process using a press brake.

[0009] The inventions disclosed in Japanes Patent Application Laid-open Hei 7-266100, Japanese Patent Application Laid-open No. Hei 5-285700 and Japanese Patent Application Laid-open No. Hei 6-246499 and the like are aimed

at controlling blank holding force based on material characteristics, information peculiar to a machine, and metal mold information. However, since lubrication characteristics, especially with metal molds, vary from moment to moment by the synergistic effect of the fluctuation of material characteristics and the fluctuation of machine and mold conditions, it is very difficult to estimate it in advance.

[0010] The inventions disclosed in Patent Documents 4 to 6 are aimed at adjusting the processing conditions according to the state of deformation during processing of the work in a bending process, but it is difficult to measure complicated three-dimensional shape on the spot in drawing or cutting. Further, since material is cramped with a metal mold during drawing or cutting, there have been very difficult problems in measuring the material shape precisely.

[0011] The present invention has been made in view of the above-described problems, and the object of the invention is to find a method to perform satisfactory press-forming while compensating deviation of various material characteristics and environmental fluctuation during processing

Summary of the Invention

[0012] The press-forming device and the method of the present invention are to obtain a satisfactory press molding product by grasping and computation controlling at least two

or more means out of a material characteristic input means, a material characteristic measurement means, or a state variable detector for the fluctuation of material characteristics or lubrication characteristics between a metal mold and a work, which are conventionally difficult to estimate.

[0013] The press-forming device of the present invention is a press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, including:

at least two or more means of

a material characteristic input means inputting at least one material characteristic out of material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material;

a material characteristic measurement means measuring at least one material characteristic out of material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, and lubricant film thickness, of the material before forming; or

a state variable detector measuring at least one state variable out of the state variables of punch reaction, metal

mold temperature, metal mold distortion amount, work piece deformation amount, or work piece temperature during forming the material;

and further comprising:

a processing condition computer computing at least one processing condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two or more pieces of information out of material characteristics inputted by the material characteristic input means, material characteristics measured by a material characteristic measurement means or a material state variable during forming measured by the state variable detector; and

a processing condition controller controlling at least one processing condition out of the process conditions including punch or die movement speed, metal mold temperature or blank holding force based on the processing condition computed by the processing condition computer.

[0014] Another characteristic of the press-forming device of the present invention is that the material characteristic input means includes any one of or a combination of a manual input device, a bar code reader, an IC tag reader, a flexible disc or a photomagnetic disc reader.

[0015] A press-forming method of the present invention is a press-forming method using a press-forming device having a

punch, die and blank holder, and press-forming a material according to a prescribed forming condition, including the steps of:

at least two or more of

inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material;

measuring at least one material characteristic out of the material characteristics of sheet thickness before forming, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material before forming; or

measuring at least one state variable out of the state variables of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, or work piece temperature, during forming the material;

and further comprising the steps of:

computing at least one processing condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two or more pieces of

information out of material characteristics inputted by the material
characteristic input step, material characteristics measured by a material characteristic measurement step or a material state variable during forming measured by the state variable detection step; and

controlling at least one control condition out of the processing conditions including punch or die movement speed, metal mold temperature or blank holding force based on the processing condition computed by the processing condition computation step.

Another characteristic of the press-forming method of the present invention is to take in the punch reaction maximum value during forming into a computer for every prescribed number of times in the processing condition control process to calculate the moving average value of the punch reaction maximum value, and when the calculated punch reaction maximum value deviates from the prescribed value, control to change the blank holding force is performed.

Still another press-forming method of the present invention is a press-forming method using a press-forming device having a punch, die and blank holder, and press-forming a material according to aprescribed forming condition, including the steps of:

measuring at least one or more state variables out of the

state variables of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount or work piece temperature, for every forming of material;

computing at least one processing condition out of one kind or two or more kinds of processing conditions of forming speed, blank holding force, or metal mold temperature according to comparison result with the past state variables;

controlling at least one or more processing conditions out of the processing conditions including a punch or die movement speed, metal mold temperature, or blank holding force based on the processing conditions computed by the processing condition computation step.

Still another characteristic of the press-forming method of the present invention further including the steps of:

inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material,

in which the processing condition computation step computes at least one processing condition out of the processing conditions of forming speed, blank holding force, or metal mold temperature from material characteristics inputted in the material characteristic input process and a

material state variable for every forming processing measured by the state variable detection step.

Yet another characteristic of the press-forming method of the present invention is that the comparison result with the past state variables is the result of comparing the difference between the past state variable and that of the present value, and the moving average value and the prescribed value within a prescribed time period or a prescribed number of times.

[0016] A computer program product of the present invention is a computer program product to be used in a computer for a press-forming method using a press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, including:

at least two or more steps of

a material characteristic input process to input at least one material characteristic among the following characteristics: material sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, and lubricant film thickness;

a material characteristic measurement process to measure at least one material characteristic among the following characteristics: material sheet thickness before forming, yield strength, 0.2% proof stress, tensile strength,

elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, and lubricant film thickness, or

a state variable detection process to measure at least one state variable among the following state variables: punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, and work piece temperature during forming the material,

and the steps to be executed in a computer, comprising:

computing at least one processing condition out of the processing condition of forming speed, blank holding force and metal mold temperature from at least two or more pieces of information. out of material characteristics inputted by the material characteristic input step, material characteristics measured by the material characteristic measurement step or material state variable during forming process measured by the state variable detection step, and controlling at least one processing condition out of the processing conditions including punch or die movement speed, metal mold temperature or blank holding force based on the processing condition computed by the processing condition computation step.

[0017] A storage medium of the present invention is a computer readable recording medium on which a program product is recorded, the program product for a press-forming method using a punch, die and blank holder, and press-forming a

material according to a prescribed forming condition, including:

at least two or more steps of

inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material;

measuring at least one material characteristic out of the sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, and lubricant film thickness of the material before forming, or

measuring at least one state variable out of the state variables of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, and work piece temperature during forming the material,

and the steps to be executed in a computer, comprising:

computing at least one forming condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two. or more pieces of information out of material characteristics inputted by said material characteristic input process, material characteristics

measured by said material characteristic measurement process or material state variable during forming process measured by said state variable detection process, and

controlling at least one processing condition out of the processing conditions including punch or die movement speed, metal mold temperature and blank holding force based on the processing condition computed in the processing condition computation step.

Brief Description of the Drawings

[0018]

Fig. 1 is a view showing a diagrammatic structure of a press-forming device of an embodiment;

Fig. 2 is a flow chart showing a procedure of the press-forming;

Fig. 3 is a view showing an example of an influence function matrix relating to material characteristics and standard processing conditions;

Fig. 4 is a view showing an example of an influence function matrix relating to state variables and corrected processing conditions;

Fig. 5 is a view showing an example of reference values of material characteristics;

Fig. 6 is a view showing an example of standard processing conditions;

Fig. 7 is a view showing another example of an influence function matrix relating to material characteristics and standard processing conditions;

Fig. 8 is a view showing an example of reference values of state variables;

Fig. 9 is a view showing another example of an influence function matrix relating to state variables and corrected processing conditions;

Fig. 10 is a view showing an example to attach an IC tag to a cut plate package;

Fig. 11 is a view showing an example to attach an IC tag to a material coil;

Fig. 12 is a view showing an example to attach a bar code to a cut plate material; and

Fig. 13 is a characteristic figure showing a relation between punch reaction and blank holding force.

Detailed Description of the Preferred Embodiments

[0019] -First Embodiment-

Hereinafter, preferable embodiments of a press-forming device, a press-forming method, a computer program, and a storage medium of the present invention will be explained referring to the drawings Fig. 1 shows a diagrammatic structure of a press-forming device of an embodiment to which the present invention is applied.

[0020] More concretely, in a press-forming device 5, "1" denotes a punch, "2" denotes a die, "3" denotes a blank holder, and "6" denotes a metal mold device. "7" denotes a state variable sensor (load cell), and other than these, there is provided a state variable sensor (a thermocouple). "10" denotes an air cylinder, "11" denotes a hydraulic cylinder, and "12" denotes a heater.

[0021] "15" denotes a material characteristic reader which includes a material characteristic reader (IC tag reader) 9 and a material characteristic reader (controller) 14.

[0022] "13" denotes a hydraulic controller. "16" denotes a state variable detection device. "17„ denotes a blank holding force controller.

[0023] "22" denotes a control computer, which includes a standard material characteristic storage device 18, a reference state variable storage device 19, a standard processing condition storage device 20, and an arithmetic unit 21. The control computer 22 of the present embodiment is composed of a computer system including a CPU, a RAM and a ROM, and a processing condition controller, a material characteristic input means, a state variable detector, a processing condition computer, a material characteristic measurement means, and the like of the present embodiment are programmed by the computer system.

[0024] A procedure of a press-forming method of the present

embodiment will be explained next referring to Fig. 2. A metal material is read by the above-described material characteristic reader 15 from an IC tag (refer to Figs. 10 and 11) or a bar code (refer to Fig. 12) pasted on the surface of the metal material at a stage of being set to the press-forming device 5. The material characteristic information thus read is inputted by the material characteristic input means (Step S201). Here, the material characteristic is one kind or a combination of two or more kinds of the following characteristics: sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, coefficient of stress-strain relation equation, table showing each point value approximated to the stress-strain relation with a line graph, hardness, temperature, surface roughness, friction coefficient, and lubricant film thickness and so on for every material.

[0025] As a means to input material characteristics, the material characteristics are directly read here for every material from a bar code or an IC tag. When the amount of data is great, it is also adoptable to read an ID (identification) number from a bar code or an IC tag and receive the real valued data corresponding to the identification number from a server via a network or to input directly from a mill sheet, a flexible disc or the like attached from a material manufacturer for every coil material into the material

characteristic input device.

[0026] In general, when performing press processing, since the material is cut in an appropriate size from, for instance, a coiled material before the material is set in a press machine, and heat treatment or surface treatment is given in some cases, it is often difficult to obtain the above-described material characteristic in advance.

[0027] For this problem, it is possible to obtain further precise material characteristic information by directly measuring one kind or combination of two or more kinds among the above-described material characteristics, or more preferably, from easiness of measurement, one kinds or a combination of two kinds or more out of sheet thickness, hardness, temperature, friction coefficient, and lubricant film thickness, before the material is set to a press-forming device 5 or just at the time of setting.

[0028] Then, initialization values of processing condition are corrected (Steps S202, and S203) based on the read material characteristic values and the reference material characteristic values to the material stored in the reference material characteristic storage device 18 in advance. Here, the processing condition is one kinds or a combination of two or more kinds of forming speed, blank holding force, and metal mold temperature.

[0029] A concrete correction method of a processing

condition will be shown next. Material characteristic values to the respective material characteristics are taken respectively as P(j)(j = 1 M; where M is the number of the material characteristic values), the reference values for the respective material characteristics are taken as PO (j) (j = 1-M).The initialization values to the above-described respective standard processing conditions are taken respectively as CO(i) (i = 1-L, where L is the number of processing condition set values). An influence function matrix which indicates the relation between the deviation of the material characteristic of a material from its reference value and the amount of correction of the processing condition is taken as Ti (I, j), and the initialization value of the processing condition is corrected with the following equation (1).

CO(i) (after correction) = CO(i) (initialization value)x(1+$\sum$ (T1(ij)x(P(j)/PO(j)-1))) (i = 1-L, j = 1-M) ... (1)

[0030] The setting value CO(j) of the standard processing condition may be a fixed value during forming, and when it is changed during forming, for instance, a setting value to each punch stroke amount may be given. A formation example of the influence function matrix Ti is shown in Fig. 3. When the sheet thickness is, for instance, thicker than the reference value by 1%, the function of Ti corresponds to that the

forming speed and blank holding force are increased by 0.2% and 0.4% respectively, and there is no change for the metal mold temperature, using the equation (1).

[0031] Each component of the influence function matrix can be determined from the following methods: a method to determine from the change (sensibility analysis) of the optimum forming condition to the change of various material characteristics using a forming simulation by a finite element method; a method to statistically determine from a relation between material characteristic variation and processing condition, product quality (cracks, creases, spring back, surface distortion, and the like) in actual mass production press process; a method to input actual measurement value on product quality into the press-forming device as instruction data and prepare and update using, for instance, a learning function by a neural network; or the like. Note that formation of material characteristic value and processing condition or formulation method is not limited to the above, and arbitral setting is also adoptable.

[0032] Then, based on initial processing conditions, using the blank holding force controller, a forming speed controller, and a metal mold temperature controller, a load is applied on the blank holder, an upper metal mold is descended and forming is started (Step S204). Note that controllers are not limited to these, other controlling means, either single

or a combination of multiple means, any arbitrary form is adoptable.

[0033] During processing, using the state variable detection device 16, at least one state variable out of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, work piece temperature, and the like is measured, and the processing condition is corrected from moment to moment by a processing condition computer (Steps S205 to S208).

[0034] Concretely, processing conditions are corrected from moment to moment according to the following equation (2),

$$C(i) = CO(i)x(1+\sum (T2(i,k)x(S(k)/SO(k)-1))) \quad (i = 1-L, k = 1-N) \text{--} (2)$$

where the state variable is S(k) (k = 1-N; where N is the number of the state variable), reference state variable stored in the reference state variable storage device is SO(k) (k = 1-N), correction values for the respective processing conditions is C(i) (i = 1-L), the influence function matrix indicating a relation between deviation of measured each state variable to its reference value and correction amount of the processing condition is T2(i, k) (i = 1-L, k = 1-N).

[0035] A formation example of the influence function matrix T2 is shown in Fig. 4. When the punch reaction is, for instance, higher than the reference value by 1%, the function of the influence function matrix T2 corresponds to that, using

the above-described equation (2), the forming speed and blank holding force are decreased by 1% and 0.5% respectively and there is no change for the metal mold temperature. It has been known that each component of the influence function matrix T2 can be determined from a method to determine from the change (sensibility analysis) of the optimum forming condition to the change of various material characteristics using a forming simulation by a finite element method, similarly to the above-described influence function matrix T1.

[0036] Further, there are a method to statistically determine from a relation between state variable variation and processing condition, product quality (crack, creases, spring back, surface distortion, and the like) in actual mass production press process, a method to input actual measurement value on product quality into the press-forming device as instruction data and prepare and update using, for instance, a learning function by a neural network, or the like. Note that formation of state variable or formulation method is not limited to the above, and arbitral setting is also adoptable.

[0037] Here, a method to correct the forming conditions based on three pieces of information on the material characteristic inputted in advance, the material characteristic measured just before the press-forming, and the state variable during forming is explained. It is insufficient to correct the forming conditions based on only

one piece of information out of three pieces of the above-described information, therefore it is desirable to do so based on at least two or more pieces of information to perform highly reliable control.

[0038] Because it is impossible to avoid influence of disturbance which is difficult to predict in advance such as a lubrication condition during forming or the like with only one piece of information of material characteristic inputted in advance or material characteristic measured just before press-forming. Furthermore, there is a problem in that it is impossible to separate influence due to material characteristic deviations with only the state variable during forming. This is because reduction effect of material characteristic deviations or product quality deviations caused by disturbance during forming cannot be obtained satisfactorily.

[0039] -Embodiment-

As an embodiment of the present invention, a press-forming device shown in Fig. 1 is prepared and press-forming is performed using a thin steel plate. As for material characteristics, sheet thickness and hardness are measured for every blank, and typical mechanical properties attached by a material manufacturer for every coil are used for yield strength or 0.2% proof stress, tensile strength, and total elongation and inputted into a material characteristic input

means for every blank respectively. As a state variable during forming, a punch reaction is monitored using a load cell, the metal mold temperature is monitored using a thermocouple and the forming speed, blank holding force are controlled based on the equations (1) and (2).

[0040] In the above-described procedure, 4 points of sheet thickness, yield strength, 0.2% proof stress, tensile strength, total elongation, and hardness are used as the material characteristic value P(j) (j = 1-5), two points of forming speed, and blank holding force are used as the processing condition C(i) (i = 1-2), and N points of punch reaction (N-1 point) for every punch stroke and metal mold temperature are used as the state variable S(k) (k = 1-N).

[0041] As a raw material, a "150 mm" blank stamped from the same cold rolling coil for deep drawing having an average thickness of 1.2 mm and a width of 1000 mm is used to perform "50 mm" square cup drawing with a forming height of "40 mm". Typical mechanical properties and the reference values of the coil are shown in Fig. 5.

[0042] Standard processing conditions for the typical characteristics of this material are shown in Fig. 6. Then, based on the actual measurement value for the sheet thickness and the typical mechanical properties of the coil inputted for every one sheet of the blank, initialization of the processing conditions are performed using the influence function matrix

Ti shown by the equation (1) and in Fig. 7 and forming is started.

[0043] During processing, forming is performed without changing the initialization during forming in example 1 of the present invention, in other words, forming conditions are set based on the material characteristics inputted in advance and the material characteristics measured before forming, and forming is performed without using a state variable during forming, and the forming speed and blank holding force set to be constant.

[0044] In example 2 of the present invention, the punch reaction and the metal mold temperature are measured for every 10 mm stroke until the maximum punch stroke (=forming height 40 mm), taking the punch reaction and the metal temperature at the time of obtaining a good product under the same processing conditions by a trial pressing in advance as reference values of the state variable shown in Fig. 8, using the influence function T2 shown in Fig. 9, forming speed and blank holding force are adjusted with the equation (2). In other words, the press conditions are controlled using the material characteristics inputted in advance, the material characteristics measured before forming, and the state variable during forming.

[0045] In example 3 of the present invention, using measured value of only sheet thickness and hardness for every

one blank sheet, without using material characteristics such as yield strength or 0.2% proof stress, tensile strength, and total elongation, the punch reaction and the metal mold temperature are measured for every 10 mm stroke until the maximum punch stroke (=forming height 40 mm) similarly to the manner in embodiment 2, taking the punch reaction and the metal temperature at the time of obtaining a good product under the same processing conditions by a trial pressing in advance as reference values of the state variable shown in Fig. 8, using the influence function T2 shown in Fig. 9, forming speed and blank holding force are adjusted with the equation (2). In other words, the press conditions are controlled using the material characteristics measured before forming, and the state variable during forming.

[0046] In example 4 of the present invention, using only material characteristics inputted in advance: yield strength or 0.2% proof stress, tensile strength, and total elongation, similarly to embodiment 2, the punch reaction and the metal mold temperature are measured for every 10 mm stroke until the maximum punch stroke (=forming height 40 mm), taking the punch reaction and the metal temperature at the time of obtaining a good product under the same processing conditions by a trial pressing in advance as reference values of the state variable shown in Fig. 8, using the influence function T2 shown in Fig. 9, forming speed and blank holding force are adjusted with the

equation (2). In other words, the press conditions are controlled using the material characteristics inputted in advance, and the state variable during forming.

[0047] As a comparison example, using forming speed and blank holding force without changing processing conditions to the reference material characteristics, forming is performed without correcting the reference processing conditions during forming.

[0048] The above-described forming experiment is carried out by punching total 1000 pieces of blanks from the same coil, percent defective due to occurrence of cracks and creases are compared.

sheet thickness standard deviation : 5 μm

percent detective .

(Example 1 of the present invention)	0.9%
(Example 2 of the present invention)	0.1%
(Example 3 of the present invention)	0.5%
(Example 4 of the present invention)	0.5%
(Comparative Example)	1.2%

[0049] The percent defective is reduced by changing the initialization of the processing conditions according to the deviation of the sheet thickness, and the percent defective is further reduced by adjusting the processing condition according to punch reaction and metal mold temperature during forming.

[0050] Fig. 10 shows an example of a cut plate package 100 supplied from a coil processing center, to which an IC tag 101 is attached. Information such as "tensile strength", "yield strength or 0.2% proof stress", "total elongation", "sheet thickness", "production date" and the like are stored in the IC tag 101. The information is read with the material characteristic reader (IC tag reader) 9, and is transmitted to the computation device 21, thereby saving the labor that would otherwise be incurred if the data were inputted manually.

[0051] Fig. 11 shows an example to attach an IC tag 111 to a material coil 110. Also in the case of this example, information such as "tensile strength", "yield strength or 0.2% proof stress", "total elongation", "sheet thickness", "production date" and the like is stored in the IC tag 111. Therefore, it becomes possible to save labor to manually input the material characteristics when the material coil 110 is pressed.

[0052] Fig. 12 shows an example to attach a bar code 121 to a cut plate material 120. Information showing a product lot number is displayed on the bar code 121. By reading the information with a bar code reader in the material characteristics reader, information relating to the corresponding material can be obtained from, for instance, a server computer on a network.

[0053] Next, an example in the case of performing press-

forming is explained with reference to Fig. 13. In Fig. 13, punch reactions and blank holding forces are expressed along the vertical axis, and the number of forming times is expressed along the horizontal axis: the heavy-curve donates a punch reaction 10 points moving average, which is expressed along the vertical scale, and the polygonal line donates blank holding force, which is expressed along the right vertical scale.

[0054] In this example, the punch reaction maximum value during forming is captured and stored in a computer for every one time of forming. Further, the moving average of the punch reaction maximum values is calculated and an example of controlling to change the blank holding force when the punch reaction maximum value exceeds a prescribed value (in an example in Fig. 13, 500 ton ± 10 ton) is shown.

[0055] As a result, as shown in Fig. 13, since the 10 points moving average value exceeds a permissible range, forming is carried out under reduced blank holding force from fiftieth times. As a result, the punch reaction maximum value can be kept within the prescribed value, forming of prescribed number of sheets can be achieved without occurrence of a defective piece.

[0056] It should be noted that in the above explanation, an example in which the punch reaction maximum value during processing is taken in a computer for every one time of

forming is shown, but it may be taken in for every prescribed time. Furthermore, in an example in Fig. 13, an example in which the blank holding force is reduced from the fiftieth times because the 10 point moving average exceeds a permissible range is shown, however, on the contrary, the blank holding force may be increased when the moving average value falls short of the permissible range.

[0057] In the above explanation, the blank holding force is adjusted using the history of the punch reaction maximum values. However, the present invention is not limited to this, and it is also adoptable to adjust other processing condition, for instance, the forming speed or the like using a history of other state variables for instance, the metal mold temperature, the metal mold distortion amount, or the like.

[0058] -Other Embodiments-

As explained above, the control computer 22 includes a computer CPU or MPU, RAM, ROM, RAM, and the like, and a press-forming method of the present embodiment is realized by operating a program stored in the above-described RAM, ROM, or the like.

[0059] Accordingly, the program itself realizes the function of the above-described embodiment, which constitutes the present invention. As a program transmission medium, a communication medium (wire circuit such as optical fiber or wireless circuit or the like) in a computer net work system

(LAN, WAN such as internet, wireless communication network or the like) to propagate and supply program information as a carrier wave can be used.

[0060] Further, a means supplying the above-described program to a computer, for instance, a storage medium storing such a program composes the present invention. As such a storage medium, for instance, a flexible disc, hard disc, optical disc, magneto-optic disc, CD-ROM, magnetic tape, nonvolatile memory card, ROM, or the like can be used

[0061] The present embodiments are to be considered in all respects as illustrative and no restrictive, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein. The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof.

Industrial Applicability

[0062] According to the present invention, it is possible to obtain appropriate processing conditions avoiding an influence due to unpredictable deviation factors such as variation in material characteristics environmental change, lubricity between a metal mold and work, surface property, and the like, and it is possible to always obtain a favorable product.

What is claimed is:

1. A press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, comprising:

at least two or more means of :

a material characteristic input means inputting at least one material characteristic out of material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material;

a material characteristic measurement means measuring at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material before forming; or

a state variable detector measuring at least one state variable out of the state variables of punch reaction, metal

mold temperature, metal mold distortion amount, work piece deformation amount, or work piece temperature during forming the material;

wherein, said state variable detector is included in the two or more means,

and further comprising:

a processing condition computer computing at least one processing condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two or more pieces of information out of material characteristics inputted by the material characteristic input means, material characteristics measured by a material characteristic measurement means or material state variable during forming measured by the state variable detector;

a processing condition controller controlling at least one processing condition out of the processing conditions including punch or die movement speed, metal mold temperature or blank holding force based on the processing condition computed by the processing condition computer.

2. The press-forming device according to claim 1, wherein said material characteristic input means comprises any

one of or a combination of a manual input device, a bar code reader, an IC tag reader, a flexible disc or a photomagnetic disc reader.

3. A press-forming method using a press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, comprising:

measuring at least one state variable out of the state variables of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, or work piece temperature, during forming the material; and

at least two or more steps of:

inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material;

measuring at least one material characteristic out of the material characteristics of sheet thickness before forming, yield strength, 0.2% proof stress, tensile strength,

elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material before forming,

and further comprising the steps of:

computing at least one processing condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two or more pieces of information out of material characteristics inputted by the material characteristic input step, material characteristics measured by a material characteristic measurement step or a material state variable during forming measured by the state variable detection step; and

controlling at least one control condition out of the processing conditions including punch or die movement speed, metal mold temperature or blank holding force based on the processing condition computed by the processing condition computation step.

4. The press-forming method according to claim 3, wherein said material characteristic input step comprises any one of or a combination of a manual input method, a bar code

read method, an IC tag read method, a flexible disc or a photomagnetic disc read method.

5. A press-forming method using a press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, comprising the steps of:

measuring at least one or more state variables out of a state variables of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, or work piece temperature, for every forming of the material;

computing at least one processing condition out of one kind or two or more kinds of processing condition of forming speed, blank holding force, or metal mold temperature according to comparison result with the past state variables;

controlling at least one or more processing conditions out of the processing conditions including a punch or die movement speed, metal mold temperature or blank holding force based on the processing conditions computed by the processing condition computation step.

6. The press-forming method according to claim 5, further comprising the steps of:

inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness, of the material,

wherein said processing condition computation step computes at least one processing condition out of the processing conditions of forming speed, blank holding force, or metal mold temperature from material characteristics inputted by said material characteristic input process and from state variables of the material for every forming processing measured by said state variable detection step.

7. The press-forming method according to claim 5, wherein the comparison result with the past state variables is the result of comparing a difference between the past state variable and that of the present value, a moving average value and a prescribed value within a prescribed time period or a prescribed number of times.

8. The press-forming method according to claim 6, wherein said comparison result with the past state variables is the result of comparing a difference between the past state

variable and that of the present value, a moving average value and a prescribed value within a prescribed time period or a prescribed number of times.

9. A computer readable memory having recorded thereon statements and instructions for execution by a computer of a press-forming method using a press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, comprising:

at least two or more steps of:

a material characteristic input step inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material;

a material characteristic measurement step measuring at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature,

surface roughness, friction coefficient, or lubricant film thickness of the material before forming; or

a state variable detection step measuring at least one state variable out of the state variables of punch reaction, metal mold temperature, metal mold distortion amount, work piece deformation amount, or work piece temperature, during forming the material,

wherein said state variable detection step is included in the two or more steps,

and the steps to be executed in a computer, comprising:

computing at least one processing condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two or more pieces of information out of material characteristics inputted by said material characteristic input step, material characteristics measured by said material characteristic measurement step or the material state variable during forming measured by said state variable detection step;

and controlling at least one processing condition out of the processing conditions including punch or die movement speed, metal mold temperature or blank holding force

based on the processing condition computed by the processing condition computation step.

10. A computer readable recording medium on which a program product is recorded, said program product for a press-forming method using a press-forming device having a punch, die and blank holder, and press-forming a material according to a prescribed forming condition, comprising:

at least two or more steps of:

inputting at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material;

measuring at least one material characteristic out of the material characteristics of sheet thickness, yield strength, 0.2% proof stress, tensile strength, elongation, n value, r value, stress-strain relation equation, hardness, temperature, surface roughness, friction coefficient, or lubricant film thickness of the material before forming; or

measuring at least one state variable out of the state variables of punch reaction, metal mold temperature,

metal mold distortion amount, work piece deformation amount, or work piece temperature, during forming the material,

wherein said step of measuring the state variables is included in the two or more steps,

and the steps to be executed in a computer, comprising:

computing at least one processing condition out of the processing conditions of forming speed, blank holding force or metal mold temperature from at least two or more pieces of information out of material characteristics inputted by said material characteristic input steps, material characteristics measured by said material characteristic measurement step or material state variable during forming measured by said state variable detection step; and

controlling at least one processing condition out of the processing conditions including punch or die movement speed, metal mold temperature or blank holding force based on the processing condition computed by the processing condition computation step.

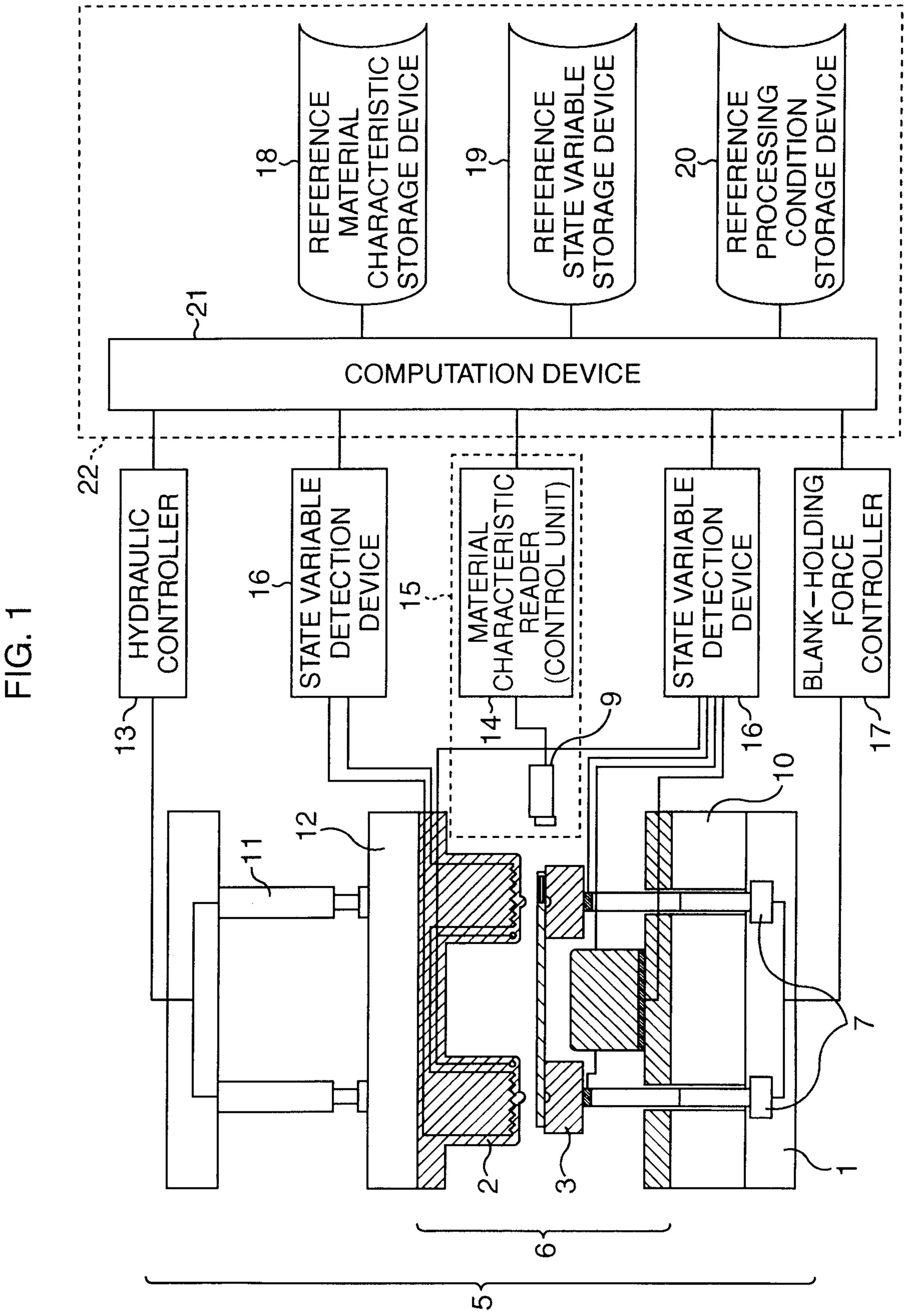

18
REFERENCE MATERIAL CHARACTERISTIC STORAGE DEVICE
19
REFERENCE STATE VARIABLE STORAGE DEVICE
20
REFERENCE PROCESSING CONDITION STORAGE DEVICE
21
COMPUTATION DEVICE
22
HYDRAULIC CONTROLLER
13
STATE VARIABLE DETECTION DEVICE
16
MATERIAL CHARACTERISTIC READER (CONTROL UNIT)
15
14
9
STATE VARIABLE DETECTION DEVICE
16
BLANK-HOLDING FORCE CONTROLLER
17
10
11
12
7
2
3
1
6
5

FIG. 1

FIG. 2

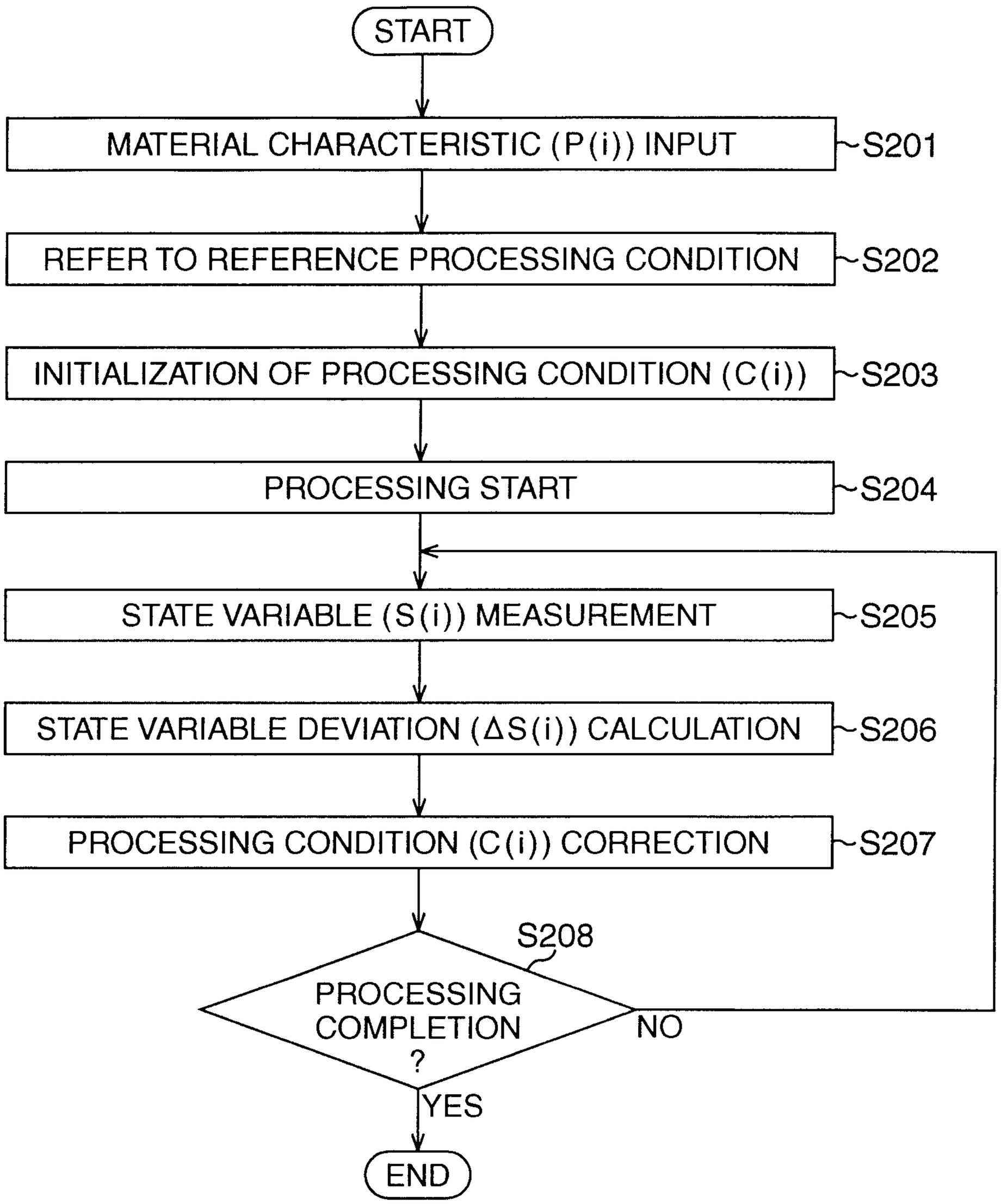

START
MATERIAL CHARACTERISTIC (P(i)) INPUT
S201
REFER TO REFERENCE PROCESSING CONDITION
S202
INITIALIZATION OF PROCESSING CONDITION (C(i))
S203
PROCESSING START
S204
STATE VARIABLE (S(i)) MEASUREMENT
S205
STATE VARIABLE DEVIATION (ΔS(i)) CALCULATION
S206
PROCESSING CONDITION (C(i)) CORRECTION
S207
S208
PROCESSING COMPLETION ?
NO
YES
END

FIG. 3

		MATERIAL CHARACTERISTIC VALUE (P)										
		SHEET THICKNESS	YIELD STRENGTH	TENSILE STRENGTH	ELONGATION	n VALUE	r VALUE	PLASTICITY COEFFICIENT	HARDNESS	TEMPERATURE	ROUGHNESS	FRICTION COEFFICIENT
FORMING CONDITION INITIALIZATION VALUE (C0)	FORMING SPEED	0.2	0.2	0.3	0.4	0.5	0.2	0.3	0.2	−0.1	−0.2	−0.5
	BLANK-HOLDING FORCE	0.4	0.4	0.6	0.8	1.0	0.4	0.6	0.4	−0.2	−0.4	−1.0
	METAL MOLD TEMPERATURE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	.....	* * .	* * .	* * .	* * .	* * .	* * .	* * .	* * .	* * .	* * .	* * .

FIG. 4

		STATE VARIABLE (S)							
		PUNCH REACTION	METAL MOLD TEMPERATURE	METAL MOLD DISTORTION No.1	METAL MOLD DISTORTION No.2	METAL MOLD DISTORTION No.3	DISPLACEMENT No.1	DISPLACEMENT No.2	DISPLACEMENT No.3
FORMING CONDITION CORRECTION AMOUNT (C)	FORMING SPEED	−1.0	−0.5	−0.2	−0.2	−0.2	−0.2	−0.2	−0.2
	BLANK-HOLDING FORCE	−1.0	−0.5	−0.2	−0.2	−0.2	−0.2	−0.2	−0.2
	METAL MOLD TEMPERATURE	0.0	−1.0	0.0	0.0	0.0	0.0	0.0	0.0
	.....	* * .	* * .	* * .	* * .	* * .	* * .	* * .	* * .

FIG. 5

	P(1) (SHEET THICKNESS /mm)	P(2) (YIELD STRENGTH /MPa)	P(3) (TENSILE STRENGTH /MPa)	P(4) (TOTAL ELONGATION /%)	P(5) (HARDNESS /Hv)
COIL TYPICAL MECHANICAL PROPERTIES	1.175~ 1.225	145	285	43	145
REFERENCE VALUE	1.200	140	280	42	140

FIG. 6

STANDARD PROCESSING CONDITION	VALUE
C0 (1) (FORMING SPEED)	50mm/sec.
C0 (2) (BLANK−HOLDING FORCE)	50kN

FIG. 7

	P(1) (SHEET THICKNESS)	P(2) (YIELD STRENGTH)	P(3) (TENSILE STRENGTH)	P(4) (TOTAL ELONGATION)	P(5) (HARDNESS)
C0 (1) (FORMING SPEED)	0.2	0.2	0.3	0.4	0.2
C0 (2) (BLANK− HOLDING FORCE)	0.4	0.4	0.6	0.8	0.4

FIG. 8

	S(1) PUNCH REACTION 10mm	S(2) PUNCH REACTION 20mm	S(3) PUNCH REACTION 30mm	S(4) METAL MOLD TEMPERATURE (AT FORMING START)
REFERENCE VALUE	20kN	40kN	65kN	30°C

FIG. 9

	S(1) PUNCH REACTION 10mm	S(2) PUNCH REACTION 20mm	S(3) PUNCH REACTION 30mm	S(4) METAL MOLD TEMPERATURE (AT FORMING START)
C(1) (FORMING SPEED)	−1.0	−1.0	−1.0	−0.5
C(2) (BLANK−HOLDING FORCE)	−1.0	−1.0	−1.0	−0.5

FIG. 10

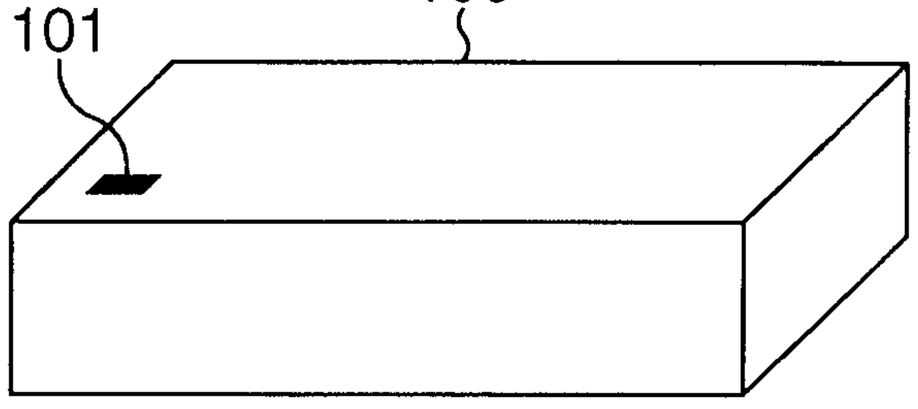


FIG. 11

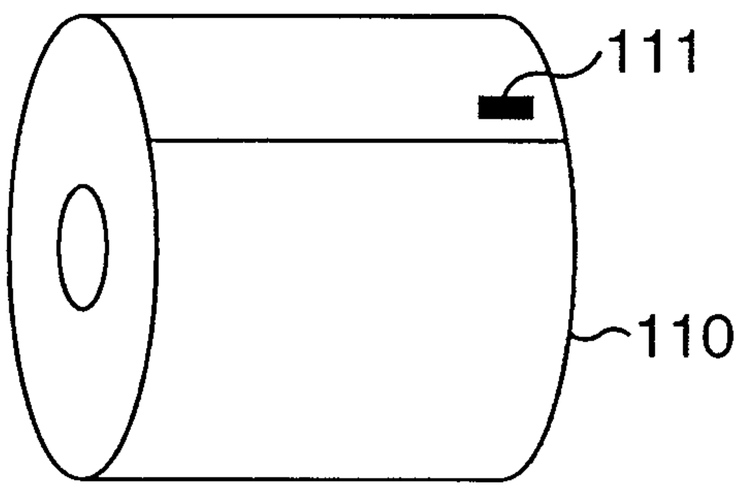
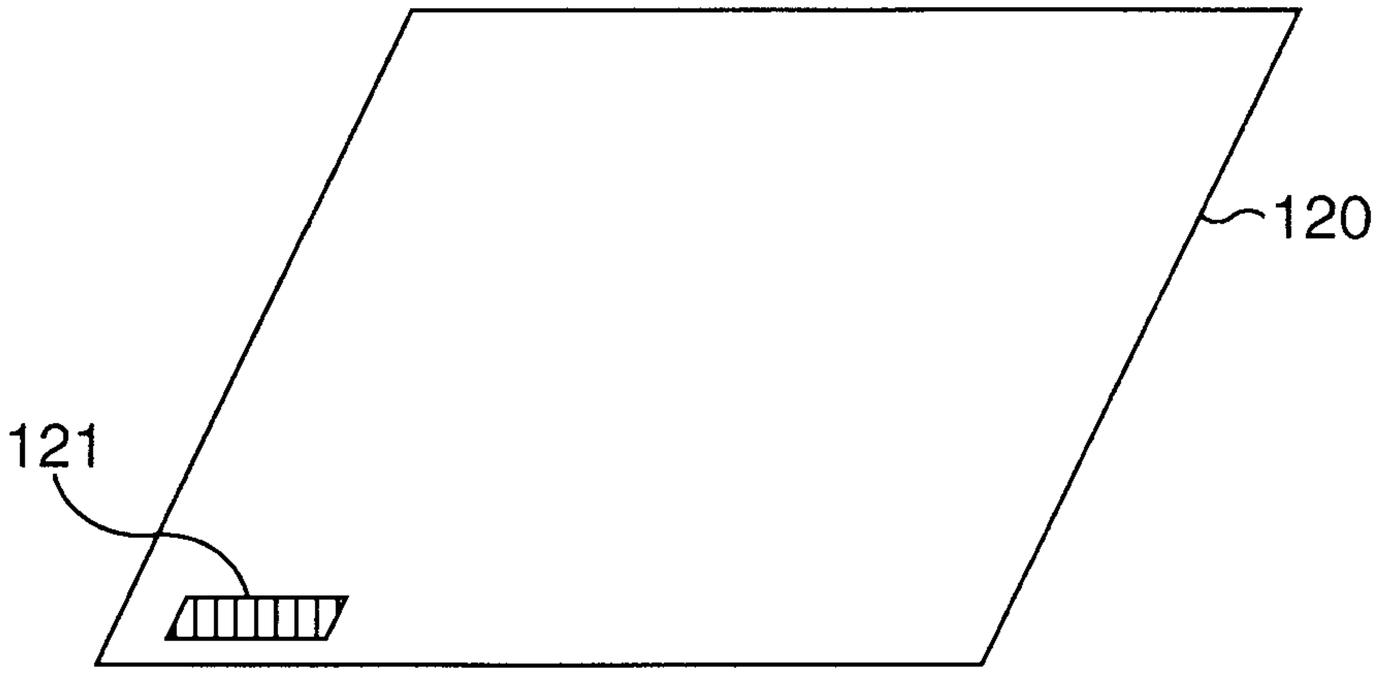


FIG. 12



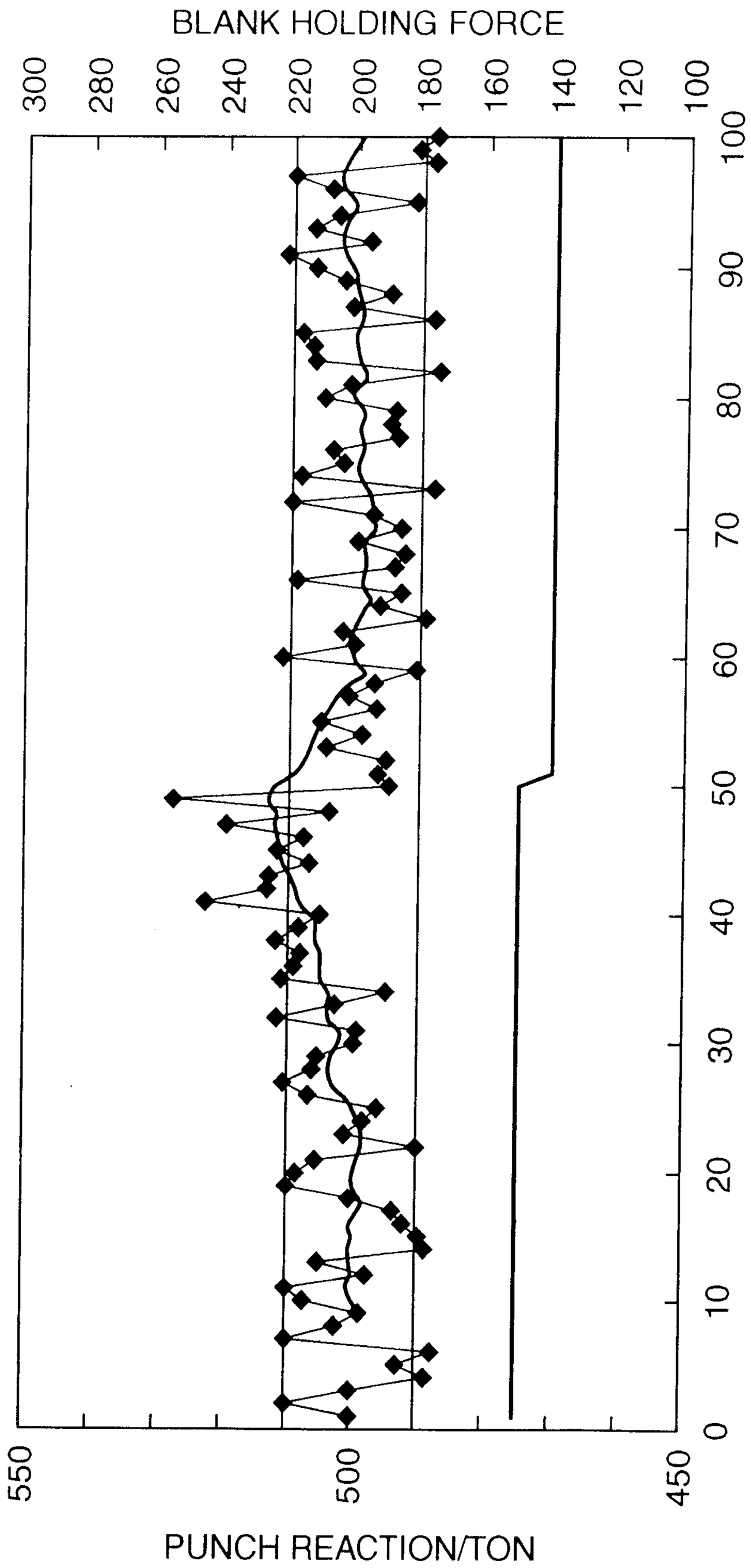
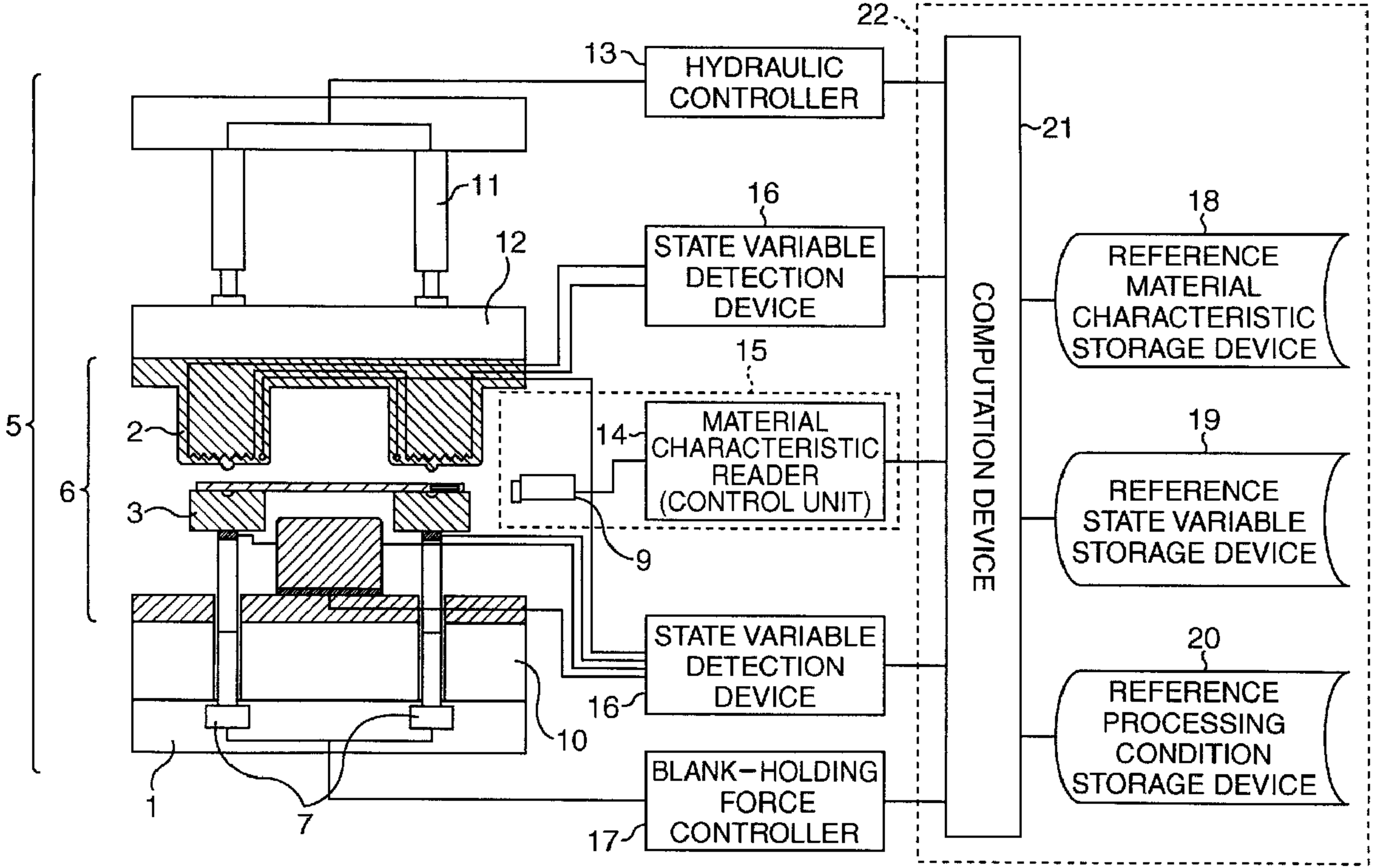

BLANK HOLDING FORCE
300
280
260
240
220
200
180
160
140
120
100
100
90
80
70
60
50
40
30
20
10
0
NUMBER OF FORMINGS/TIMES
550
500
450
PUNCH REACTION/TON

FIG. 13


22
13
HYDRAULIC CONTROLLER
21
11
16
18
12
STATE VARIABLE DETECTION DEVICE
REFERENCE MATERIAL CHARACTERISTIC STORAGE DEVICE
15
5
2
14
MATERIAL CHARACTERISTIC READER (CONTROL UNIT)
19
6
3
9
REFERENCE STATE VARIABLE STORAGE DEVICE
COMPUTATION DEVICE
STATE VARIABLE DETECTION DEVICE
20
16
10
REFERENCE PROCESSING CONDITION STORAGE DEVICE
BLANK-HOLDING FORCE CONTROLLER
1
7
17