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(54) **Controller and control method for aluminum shape extruder.**

(57) A controller for an aluminum shape extruder includes a laser speed sensor for detecting operating speed of a hydraulic unit of the aluminum shape extruder and a computer control unit for controlling the operating speed of the hydraulic unit and control method for an aluminum shape extruder comprises the steps of using a laser speed sensor to detect the operating speed of a hydraulic unit of the aluminum shape extruder, storing the operating speed detected by the laser speed sensor in a computer memory, comparing the detected operating speed with a set value to obtain a comparison value, and computer controlling the operating speed of the hydraulic unit of the aluminum shape extruder using the comparison signal.

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Fig. 1
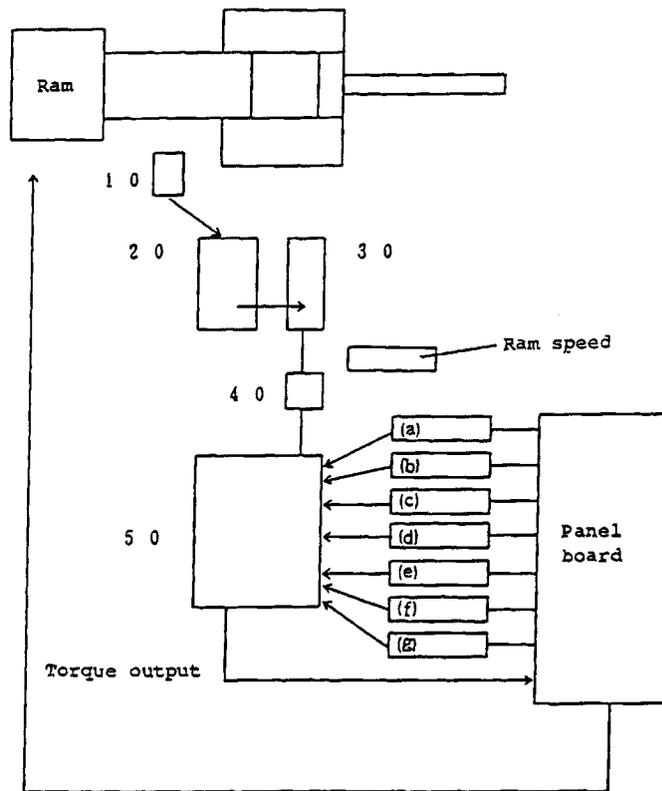
BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to control of an aluminum shape extruder, more particularly to an aluminum shape extruder controller equipped with a laser speed sensor for enabling very fine computer predictive control matched to individual products.

Description of the Prior Art

Prior art aluminum extruders are controlled using signals from measuring instruments associated with the plant equipment. In this method, problems arise owing to the limited accuracy etc. of the measuring instruments. The fact chat most aluminum extruders are controlled by a sequencer or a PID controller also leads to problems, because, even in extruders equipped with a dedicated controller, the control method uses simple integrated values and the control is conducted in a fixed manner using specific parameters. As a result, it is difficult to change the control values from product to product and, therefore, difficult to achieve fine control. Owing to problems related to equipment noise and limited measurement accuracy, moreover, the prior art aluminum extruders require built-in filtering capability.

Therefore, since the control response is slow, and also owing to the problems encountered in connection with measurement accuracy and the computation method based on integrated values, the product extrusion speed may become excessive (overshoot).

Owing to recent changes in demand, moreover, the trend is away from large-scale production of a small number of product types toward small-scale production of a large number of product types. Since the ability of the prior art fixed control method to cope with this trend is limited, a need has arisen for versatile control usable with a huge number of product types each having its own peculiar specifications. With currently available control, the product processing cannot be speeded up even when the machinery is capable of operating at higher speed because of the risk of overshooting.

SUMMARY OF THE INVENTION

An object of this invention is to provide a controller and a control method for an aluminum shape extruder, which enable a computer to finely control the speed of the aluminum extruder according to the type of product being produced based on a detection signal from a laser speed sensor for detecting the speed of the aluminum shape extruder.

For achieving this object, this invention provides a controller for an aluminum shape extruder comprising a laser speed sensor for detecting the operating speed of a hydraulic unit of the aluminum shape extruder and a computer control unit for controlling the operating speed of the hydraulic unit based on a comparison of the speed value represented by a detection signal of the laser speed sensor end a set speed value. The invention further provides a control method for an aluminum shape extruder comprising the steps of using a laser speed sensor to detect the operating speed of a hydraulic unit of the aluminum shape extruder (extrusion tendency and product extrusion time during a product extrusion preparatory operation), storing the operating speed detected by the laser speed sensor in a computer memory, comparing the detected operating speed with a set value based on steady torque to obtain a comparison value, and conducting predictive control of the speed of the hydraulic unit taking hydraulic lag into account by steplessly calculating a control gain based on the comparison value obtained and automatically switching between feedback control and feedforward control.

In the control method for an aluminum shape extruder according to this invention the operating speed of the hydraulic unit of the aluminum shape extruder is detected by a laser speed, the detection result is compared with a set value, and the operating speed of the hydraulic unit of the aluminum shape extruder is controlled based on the result of the comparison. The control method for an aluminum shape extruder involves detecting the operating speed (extrusion tendency and product extrusion time during product extrusion preparatory operation), storing the detected operating speed in a computer memory, and conducting predictive control of the speed of the hydraulic unit taking hydraulic lag into account by comparing the detected operating speed with a set value based on steady torque to thereby calculate a control signal and steplessly calculating a control gain based on the comparison value obtained and automatically switching between feedback control and feedforward control.

For controlling maximum torque output, moreover, the dead time is detected and the ram speed behavior during burp operation (air bleeding operation at the time pressure is applied to an aluminum billet after it is loaded in the extruder) is analyzed for judging the startup tendency and enabling predictive control.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of an aluminum shape extruder which is an embodiment of this

invention.

Figure 2(a) is a graph showing the relationship between torque and ram speed in ordinary PID control and Figure 2(b) is a graph showing the relationship between torque and ram speed in a ram control system according to the invention.

Figure 3 is a graph showing the relationship between torque and ram speed in predictive control based on steady torque.

Figure 4 shows graphs for judging startup tendency from ram behavior during burp operation, wherein Figure 4(a) is a graph showing slow startup tendency, Figure 4(b) is a graph showing fast startup tendency, and Figure 4(c) is a graph showing the relationship between pressure rise and the time between extrusion start and the instant of actual product emergence (dead time).

Figure 5 is a block diagram showing the discrimination logic.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The controller and control method for an aluminum shape extruder according to the invention will now be explained with reference to the embodiment shown in Figure 1, which is a block diagram showing an aluminum shape extruder controller according to the invention. The aluminum shape extruder controller, designated by reference numeral 1, comprises a laser speed sensor 10, a sensor amplifier unit 20, a pulse unit 30, an F/V (frequency to voltage) converter 40 and a computer 50.

The laser speed sensor 10 detects the operating speed of a hydraulic unit of the aluminum shape extruder by use of a laser beam. More specifically, the sensor head of the laser speed sensor 10, which consists of a laser beam generator and a laser beam receiver for receiving reflected laser light, is mounted on the crosshead section of the hydraulic unit for projecting a laser beam onto the guide section thereof. In addition to detecting the operating speed of the hydraulic unit of the aluminum shape extruder, the laser speed sensor 10 also detects the extrusion tendency during the product extrusion preparatory operation and the dead time, as well as the product extrusion time.

Since the laser speed sensor 10 is installed as an independent piece of equipment, it is little affected by extrusion equipment noise and since the data gathered at high speed by the laser speed sensor 10 is sent to the computer, the control can be conducted in real time, without need from the viewpoint of control for the data to be passed through a filter.

The sensor amplifier unit 20 receives the electric signal representing the result of the sensor head detection and amplifies it for transfer.

During preparatory operation for extrusion, the laser speed sensor 10 monitors the motion (ram speed) of the aluminum shape extruder hydraulic unit.

The electric signal produced by the laser speed sensor 10 as the detection result and amplified by the sensor amplifier unit 20 is sent to the pulse unit 30, which converts it into a digital pulse signal. This is for preventing the signal from being attenuated and degraded by noise during transfer and thus ensuring stable high-speed transfer of the electric signal.

The electric signal representing the measurement result is converted to an analog signal by the F/V converter 40 and the converted signal is sent to the computer 50 where its tendency is evaluated.

The computer 50 includes a memory for storing the operating speed of the aluminum shape extruder hydraulic unit detected by the laser speed sensor 10 and a main computer unit for comparing the detected value with a set value and computing a control value.

The computer 50 is supplied with data indicating (a) pressure applied by hydraulic unit, (b) product speed, (c) set speed, (d) extrusion start, (e) extrusion end, (f) burp (air bleeding operation at the time pressure is applied to an aluminum billet after it is loaded in the extruder), and (g) ram speed.

The ram speed measured by the laser speed sensor 10, namely the movement of the aluminum shape extruder hydraulic unit during extrusion preparatory operation, is supplied to the computer, which calculates the ram speed behavior and gradient for judging the product extrusion tendency. After the hydraulic unit starts to apply pressure to the aluminum billet, there is a certain amount of dead time before the product begins to emerge from the dies. The length of this dead time and the gradient of the ram speed (movement of the aluminum shape extruder hydraulic unit during extrusion preparatory operation) are measured and an automatic calculation is conducted for selecting the control method (feedback or feedforward control) for the product concerned. Further, since the control signal during startup (until the product reaches the set speed) is calculated and output based on a steady torque value calculated from the set speed ascertained beforehand, the control is not affected by error such as that in control based on an integrated value.

Figure 2(a) shows the experimentally determined relationship between torque and ram speed in ordinary PID (proportional integral and derivative) control. As can be seen, this type of control responds to sudden changes in ram movement by following the rise and fall in the ram speed so that

the control value inputs exactly the opposite force from what is required. Ordinary PID control is therefore disadvantageous in that it is uncertain as to where the ram speed and torque will converge on constant speed operation or how long it will take them to converge.

In the control according to the controller and control method of this invention, the steady torque is calculated from the measured set speed (ram speed) end torque output control is conducted based on the calculated value. Since predictive control can therefore be conducted with the hydraulic lag taken into account, it is possible to achieve stable control which eliminates erratic ups and downs during startup.

As shown in Figure 2(b), since the set value is given, convergence on the target value can be achieved relatively quickly unaffected by rising and falling of the measured value. In this example, even if the ram should start vibrating abnormally during startup at dies which start up rapidly, the control according to this invention, differently from ordinary PID control, which tends to follow the ram movement and require considerable time for convergence, will be able achieve quick convergence and stable control owing to the fact that the torque is output based on steady torque as a standard.

In the case of predictive control based on steady torque, the control using steady torque calculation is conducted by calculating the torque output from the measured ram gradient and arrival time values, thus enabling predictive control taking the hydraulic delay into account. Since, as shown in Figure 3, the torque effect starting point A and the steady torque point B are decisively calculated as control information, control based on a torque curve that takes the hydraulic delay into account can be achieved.

For increasing the startup speed from the start of extrusion, the control method effects the maximum torque state from immediately after startup and continues the maximum torque output up to the limit point. Figure 4 shows how the startup tendency is discriminated from the characteristics of the ram behavior during burp operation, with Figure 4(a) illustrating a slow startup tendency and Figure 4(b) illustrating a fast start up tendency. The tendency is judged from the difference between α and β.

Figure 4(c) shows the time between extrusion start and the instant at which the product actually appears (dead time) and the pressure rise tendency during the dead time.

Figure 5 shows the discrimination logic. Based on the ram behavior during burp operation, a discrimination is made as whether the startup is slow or fast. If it is fast, the startup is subjected to special (feedback) control. If it is slow, an additional

discrimination based on the dead time up to the emergence of the product and the pressure rise condition is made to determine whether the startup is fast or slow. If it is fast, feedback control is conducted. If it is slow (normal), maximum torque output control is further implemented for increasing the ram speed to a fixed value.

Thus, based on the steady torque, the detected ram speed and the set value are compared to calculate a control signal and computer control is conducted by using the value obtained by the comparison for switching between automatic feedback control and feedforward control of the operating speed of the hydraulic unit by a steplessly calculated control gain.

Since the processing is conducted inside the controller according to a computer program, the control can respond to complex movements of the extruder.

This effect can be obtained since the controller is constituted as a combination of a high-performance sensor and a computer.

Owing to the fact that the ram speed gradient is calculated from the detection signal produced by the laser speed sensor and that a control gain is calculated in accordance with the calculated gradient separately for each type of product based on its extrusion state, it is possible to conduct the control using the optimum control gain irrespective of the product configuration. In contrast, the commonly used PID control based on an integrated value cannot switch the control finely since the control gain is determined as a fixed value.

The length of the period up to the start of product extrusion (the dead time) varies linearly with the extrusion tendency. Specifically, the easier it is to extrude from a die, the shorter is the dead time and the lower is the pressure rise. Since the product extrusion tendency can therefore be judged by detecting the dead time, it is possible to switch between feedforward and feedback control based on the maximum torque.

As a product extrusion preparatory operation, bleeding of air (burp operation) is conducted with pressure applied to the aluminum billet (a rod-shaped piece of aluminum). The ram speed behavior at this time is such that the vibration becomes smaller with decreasing billet length and increasing extrusion ease. As a result, by detecting the ram speed behavior during the extrusion preparatory operation, it is possible to judge the extrusion tendency before extrusions starts. Since this makes it possible to conduct control based on the maximum torque output from immediately after extrusion of a hard to extrude product has started, the startup time can be shortened.

Owing to the combined use of a computer and a laser speed sensor the controller and control

method according to his invention make it possible to collect highly accurate data and, by ascertaining the ram behavior during extrusion of aluminum products from this data, to determine the extrusion tendencies of individual aluminum products in advance, thereby enabling fine control utilizing real time data with respect to a large number of product types. Moreover, since the control signal is not calculated from ordinary integrated values but from the steady torque, overshooting resulting from integration error and low measurement accuracy is reduced. In addition, since the extrusion tendency can be judged during product extrusion preparatory operation and the dead time, it becomes possible to switch between feedback control and feedforward control based on maximum output from immediately after the start of extrusion. In combination, these advantages of the invention reduce the time required for extrusion processing, increase production per unit time, and increase operating efficiency.

Moreover, since the laser speed sensor is provided independently of the other equipment, measurement error resulting from noise can be reduced. As data can therefore be collected at high speed and no need arises from the viewpoint of control for the data to be filtered, the internal filtering capability required by conventional systems is unnecessary and control response is proportionally higher.

Since the speed of the hydraulic unit can be computer controlled automatically in real time using a control gain calculated in a stepless manner from the comparison value, fine response can be achieved and predictive control taking hydraulic lag into account can be realized.

Claims

1. A controller for an aluminum shape extruder comprising a laser speed sensor for detecting operating speed of a hydraulic unit of the aluminum shape extruder and a computer control unit for controlling the operating speed of the hydraulic unit based on a comparison of the speed value represented by a detection signal of the laser speed sensor and a set speed value.

2. A control method for an aluminum shape extruder comprising the steps of using a laser speed sensor to detect the operating speed of a hydraulic unit of the aluminum shape extruder, storing the operating speed detected by the laser speed sensor in a computer memory, comparing the detected operating speed with a set value to obtain a comparison value, and computer controlling the operating speed of the hydraulic unit of the aluminum shape extruder using the comparison signal.

3. A control method for an aluminum shape extruder according to claim 2, wherein the step of computer controlling the operating speed of the hydraulic unit of the aluminum shape extruder using the comparison signal consists of steplessly calculating a control gain in accordance with load and using the calculated control gain for automatically adjusting the speed of the hydraulic unit.

4. A control method for an aluminum shape extruder according to claim 2, wherein the step of using a laser speed sensor to detect the operating speed of the hydraulic unit of the aluminum shape extruder consists of detecting a product extrusion time and outputting a control signal optimized for load.

5. A control method for an aluminum shape extruder according to claim 2, wherein the step of using a laser speed sensor to detect the operating speed of the hydraulic unit of the aluminum shape extruder consists of detecting a product extrusion tendency during a product extrusion preparatory operation period of the aluminum shape extruder and a period up to product emergence (dead time) thereof, thereby enabling control by an optimum control signal (torque output) from immediately after start of extrusion.

6. A control method for an aluminum shape extruder according to claim 2, wherein the step of computer controlling the operating speed of the hydraulic unit of the aluminum shape extruder using the comparison signal uses a control signal calculated based on steady torque instead of an ordinary integrated control value.

7. A control method for an aluminum shape extruder according to claim 2, wherein a control signal calculated based on steady torque is switched between feedback control and feedforward control based on product extrusion tendency during a product extrusion preparatory operation period and a dead time of the aluminum shape extruder.

8. A control method for an aluminum shape extruder according to claim 2, wherein the step of computer controlling the operating speed of the hydraulic unit of the aluminum shape extruder using the comparison signal consists of controlling torque output based on a prediction based on a calculated steady torque and tak-

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ing hydraulic lag into account.

Fig. 1

Fig. 2

(a)

Torque

Set speed

Ram speed

(b)

Fig. 3

Torque fall point

Steady torque

Fig. 4

(a)

(b)

(c)

Torque output

Pressure

Product speed

Set speed

Ram speed

Dead time

Fig. 5

Discriminate from ram behavior during barb operation whether startup is fast or slow

Fast

Slow (Normal)

Discriminate from period up to emergence of product (dead time) and pressure rise state whether startup is fast or slow

Fast

Slow (Normal)

Max. torque output control

Special control for fast startup
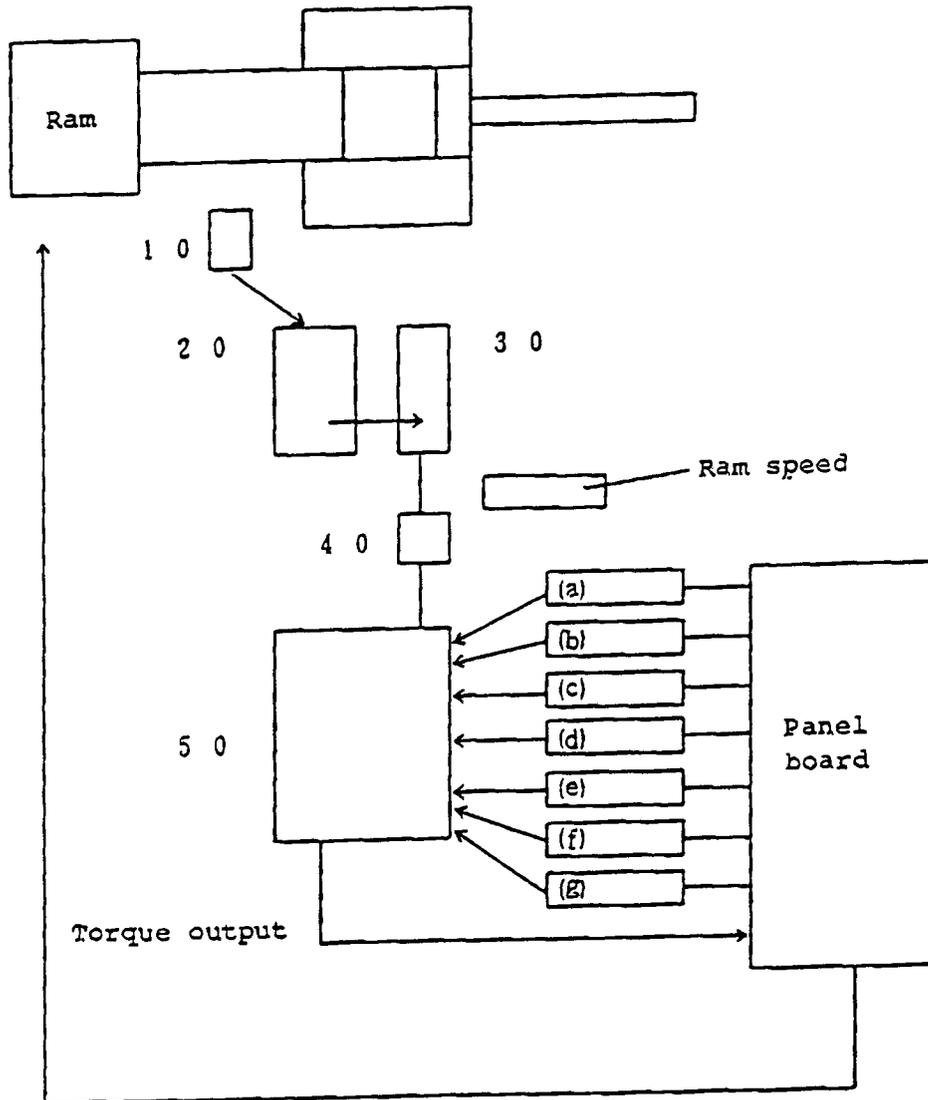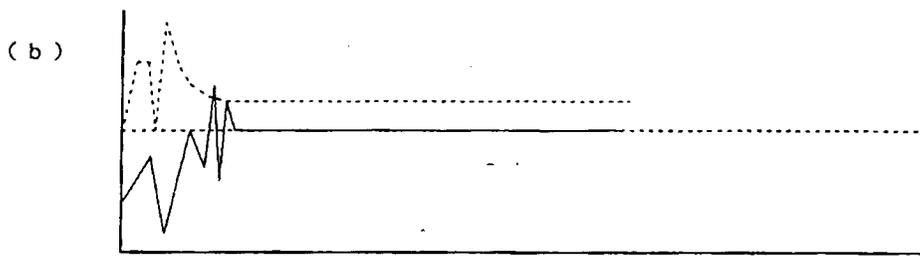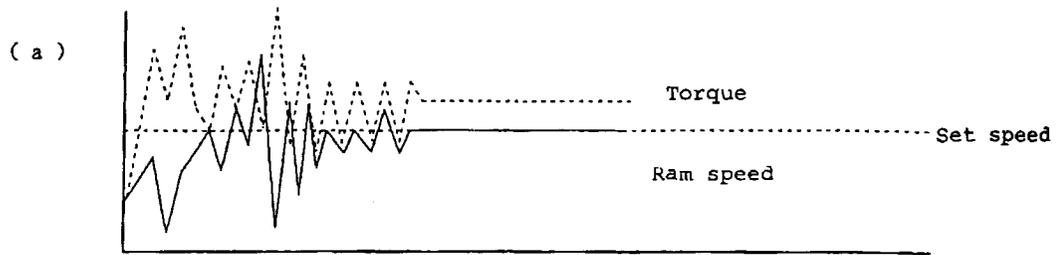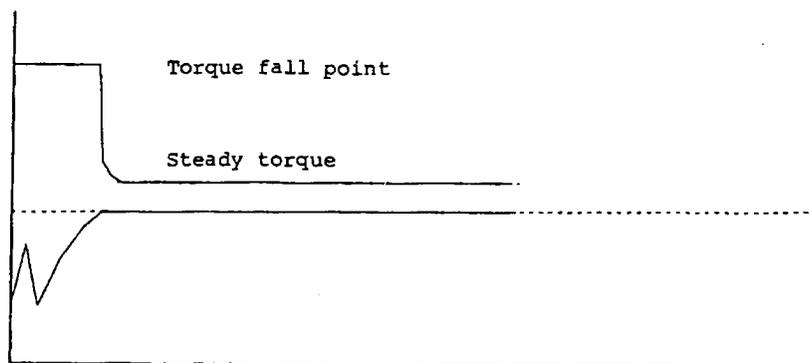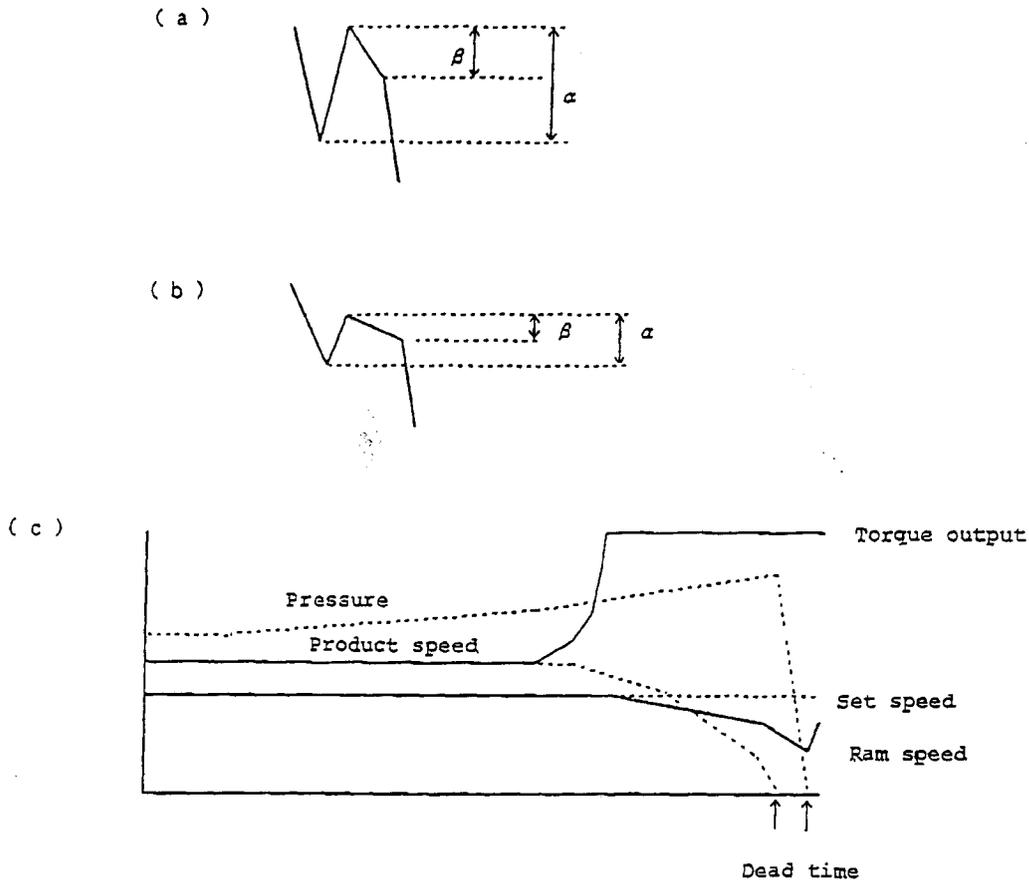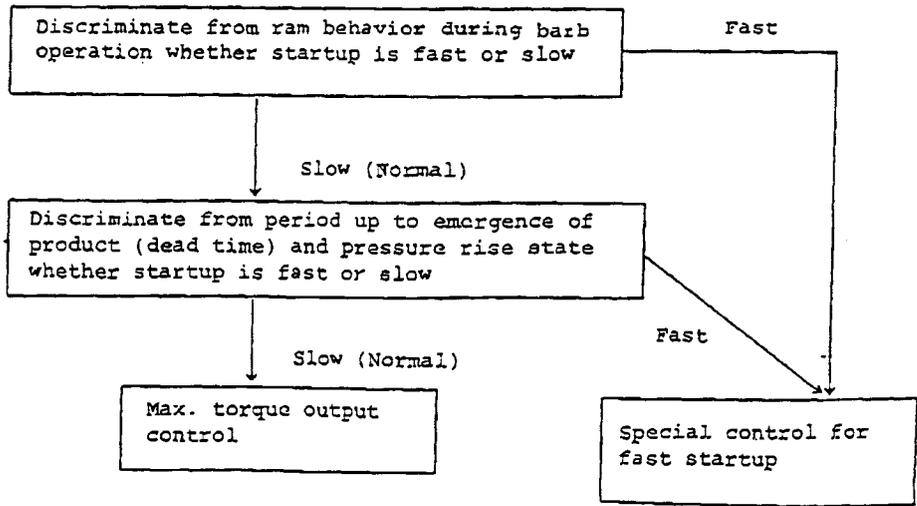
DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	DE-A-33 07 415 (MANNESMANN REXROTH GMBH) * abstract; page 5, line 3 - page 10, line 30; figure 1 *	1,2	B21C31/00
A	DE-A-33 29 314 (JULIUS & AUGUST ERBSLÖH GMBH & CO) * the whole document *	1,2	
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 331 (M-533) (2387) 11 November 1986 & JP-A-61 135 416 (UBE IND LTD) 23 June 1986 * abstract *	1,2	
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 424 (M-761) (3271) 10 November 1988 & JP-A-63 160 720 (KOBE STEEL LTD) 4 July 1988 * abstract *	1,2	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US-A-3 649 816 (JOHNES ET AL.) * abstract; column 1, lines 49-70; column 2, line 1 - column 4, line 12; figure 1 *	1,2	B21C B29C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	19 June 1995	Beitner, M

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