

CONTROL CONSTANT IDENTIFICATION SYSTEM

[Technical Field]

This invention relates to a control system of a motor for driving a machine tool, etc., and in particular to a control system for identifying control constants such as inertia and viscous friction coefficients.

[Technical Background]

For example, control constant identification systems include:

(1) an identification system which changes a torque command for changing the rotation speed and calculates torque command integration amount and rotation speed change width, then performs an operation of $(\text{inertia}) = (\text{torque command integration amount}) / (\text{rotation speed change width})$ for finding inertia (see Japanese Patent Unexamined Publication No. Sho 61-88780);

(2) an identification system which inputs a speed command having a ramp section, executes a speed loop under P control, and finds load inertia from the ratio between steady speed deviation in a state in which no load inertia exists and that in a state in which load inertia exists (see Japanese Patent Unexamined Publication No. Hei 6-70566); and

(3) an identification system which time-integrates actual and simulated current detection values or current command values for finding a current area and corrects an initial inertia assumption value from the current area calculation result, thereby finding inertia (see Japanese Patent Unexamined Publication No. Hei 4-325886).

However, conventional examples (1), (2), and (3) have a problem that inertia identification value errors or variations are large if viscous friction or Coulomb's friction exists. The following problems are also involved: Particularly in (1), commands are limited to those for changing

the rotation speed at a given rate; in (2), the effect of disturbance is easily received because integration control is not performed; and in (3), inertia is found while fuzzy inference, etc., is used to repeat a correction so that the initial inertia assumption value approaches the actual inertia, thus resulting in large amounts of complicated operations.

[Disclosure of the Invention]

It is an object of the invention to provide a control constant identification system that can solve the problem.

To solve the problems, according to the invention, there is provided a control constant identification system comprising:

a command generation section for generating a speed command V_{ref} ;

a speed control section for determining a torque command T_{ref} by the speed command V_{ref} and actual motor speed V_{fb} and controlling motor speed;

an estimation section for simulating the speed control section according to a model and outputting an estimated torque command T_{ref}' ; and

an identification section for identifying inertia J according to a ratio between a value ST_{ref} resulting from time integration of the torque command T_{ref} output by the speed control section at a predetermined interval $[a, b]$ and a value ST_{ref}' resulting from time integration of the torque command T_{ref}' output by the estimation section at the predetermined interval $[a, b]$, characterized in that

the predetermined interval $[a, b]$ and the speed command V_{ref} are set so that the actual motor speed V_{fb} and motor speed V_{fb}' found by the estimation section become the same non-zero values at the time b .

According to the invention, the control constant control system can be provided which contains small inertia

identification value errors and variations and moreover can find inertia by performing a small amount of very easy operations even if viscous friction, constant disturbance, and Coulomb's friction exist.

5 [Brief Description of the Drawings]

Figure 1 is a principle diagram to explain the basic concept of the invention;

Figure 2 is a block diagram to elaborate on the principle of the invention;

10 Figure 3 is a block diagram to elaborate on the principle of the invention;

Figure 4 is a block diagram of an embodiment of the invention;

Figure 5 is speed command examples;

15 Figure 6 is a block diagram to show the speed control section, the estimation section, and the identification section in Figure 4 in detail; and

Figure 7 is an operation example using an AC servo motor.

20 [Best Mode for Carrying Out the Invention]

First, the principle of the invention will be discussed, next an embodiment using a motor will be described specifically. Figure 1 is a principle diagram to explain the basic concept of the invention. Numeral 1 is a speed control
25 section and numeral 2 is an estimation section. PI control is programmed in the speed control section 1 and only inertia J is to be controlled. Likewise, PI control is also programmed in the estimation section 2 and only inertia J' is to be controlled. In Figure 1, if speed V_{fb} in the speed control
30 section 1 matches speed V_{fb}' in the estimation section and V_{fb} and V_{fb}' are not zero, relation $J/J' = ST_{ref}/ST_{ref}' \dots (1)$ holds for torque command integration value ST_{ref} and inertia J

in the speed control section and torque command integration value $STref'$ and inertia J' in the estimation section, and inertia J is immediately found from $J = (STref/STref')*J'$... (2). This is the basic principle of the invention.

5 However, in a system in which viscous friction D exists, the viscous friction D cannot be ignored and to make the relation hold, a condition that the integration value of speed Vfb at a predetermined interval $[a, b]$ is zero must be added. The reason why the condition must be added is as follows: Figure 2 is a block diagram where the targets to be controlled are represented as inertia J and viscous friction D . Figure 3 is a block diagram provided by rewriting Figure 2. As seen in Figure 3, if the integration value of speed Vfb at the interval $[a, b]$ is zero, the effect of the viscous friction D can be eliminated. Thus, if the condition is added, expression (1) holds and the inertia J can be found immediately from expression (2). Here, the integration value of speed Vfb is zero, but if positions are managed, the effect of the viscous friction D may be eliminated if the positions at time a and time b at the interval $[a, b]$ match. An average value of inertia found at a plurality of such intervals at which the time integration value of motor speed Vfb becomes zero may be adopted as inertia J . Next, when constant disturbance Td is applied, if an average value of inertia $J1$ found by one speed command $Vref1$ and inertia $J2$ found by $Vref2$ provided by inverting the positive and negative of the speed command $Vref1$ is adopted as inertia J , the effect of the constant disturbance Td can be eliminated. When Coulomb's friction exists, if the interval $[a, b]$ and the speed command $Vref$ are set so that the forward rotation time and the reverse rotation time of a motor become equal to each other at the interval $[a, b]$, the effect of the Coulomb's friction can also be eliminated. The constant disturbance Td can be found by dividing an average value of torque command integration value $STref1$ found by the speed

command V_{ref1} and torque command integration value ST_{ref2} found by V_{ref2} provided by inverting the positive and negative of the speed command V_{ref1} by integration time $b-a$. The viscous friction D can be found from the inclination (time change) of torque command T_{ref} when the speed command V_{ref} is constant acceleration or constant deceleration.

Next, an embodiment using a motor will be described specifically. Figure 4 is a block diagram of an embodiment of the invention. In the figure, numeral 41 is a command generation section for outputting a speed command V_{ref} to a speed control section 42 and an estimation section 43. Numeral 44 is an identification section for inputting a torque command T_{ref} of the speed control section 42 and a torque command T_{ref}' of the estimation section 43 and finding inertia J , constant disturbance D , and viscous friction D .

Next, the sections will be discussed with reference to Figures 5 and 6 based on an experimental configuration. Figure 7 shows an operation example using an AC servo motor. The command generation section 41 generates a speed command V_{ref} . The speed command V_{ref} can be any of commands as shown in Figures 5(A)-5(F), for example. Here, speed command V_{ref} shaped like a trapezoid where the absolute values of the maximum speed and the minimum speed are the same and acceleration and deceleration are the same as shown in Figure 5(A) is adopted. Figure 6 shows the configuration of the speed control section 42, the estimation section 43, and the identification section 44. The speed control section 42 programs a speed loop so that speed V_{fb} matches the speed command V_{ref} ; here PI (proportional integration) control is adopted. The speed control section 42 outputs a torque command T_{ref} to a current controller for driving a motor and the identification section 44. Assume that load 4.16 times that of motor inertia J_M , $J_L (=4.16 \cdot J_M)$, is attached to the motor and that speed V_{fb} is output from the motor. Like the speed control section 42, the estimation

section 43 adopts PI control, models a control target as $1/J'S$, and outputs a torque command T_{ref}' to the control target $1/J'S$ and the identification section 44. The identification section 44 receives the torque command T_{ref} output from the speed control section 42 and the torque command T_{ref}' output from the identification section 43 and finds inertia J according to $J = (ST_{ref}/ST_{ref}')*J'$ from values ST_{ref} and ST_{ref}' resulting from time integration of the torque commands between time "a" and time "b" and inertia J' of the estimation section.

Figure 7 provides an operation example using an AC servo motor. V_{ref} is a speed command, ① is motor speed V_{fb} in the speed control section 42, ①' is speed V_{fb}' in the estimation section, ② is a torque command T_{ref} in the speed control section 42, and ②' is a torque command T_{ref}' in the estimation section. When inertia J_1 is found from values ST_{ref1} and ST_{ref1}' resulting from time integration of ② and ②' between time a_1 and time b_1 and inertia J' of the estimation section, $J_1 = (ST_{ref1}/ST_{ref1}')*J' = 5.49*JM$. Likewise, when inertia J_2 is found from values ST_{ref2} and ST_{ref2}' resulting from time integration between time a_2 and time b_2 and inertia J' of the estimation section, $J_2 = (ST_{ref2}/ST_{ref2}')*J' = 4.81*JM$. Thus, inertia J can be identified as $J = (J_1 + J_2)/2 = 5.15*JM$. This identification value almost matches (motor inertia JM) + (load inertia $J_L = 4.16*JM$) = $5.16*JM$. However, inertia J' of the estimation section is simulated as $J' = JM$. In the experiment, the operations of the estimation section are also performed in real time. However, if the speed command V_{ref} is fixed, the torque command integration value ST_{ref}' in the estimation section can be previously calculated, thus only the torque command integration value ST_{ref} in the speed control section 42 needs to be calculated.

In fact, if the speed becomes zero, the relation of expression (1) does not hold because of the effect of statical friction. Therefore, when the speed V_{fb} is $X_1 \leq V_{fb} \leq X_2$

(where $X1 \leq 0$ and $X2 \geq 0$), if time integration of the torque command T_{ref} of the speed control section and the torque command T_{ref}' of the estimation section is not executed, $J/J' = ST_{ref}/ST_{ref}'$ holds and inertia J is immediately found from expression $J = (ST_{ref}/ST_{ref}') * J'$. When viscous friction D exists as in Figure 2, as seen in Figure 3 provided by rewriting Figure 2, if the integration value of the speed V_{fb} at the interval $[a, b]$ is zero, the effect of the viscous friction D can be eliminated. Thus, when the speed V_{fb} is $X1 \leq V_{fb} \leq X2$ (where $X1 \leq 0$ and $X2 \geq 0$), if time integration of the torque command T_{ref} of the speed control section and the torque command T_{ref}' of the estimation section is not executed and the interval $[a, b]$ and the speed command V_{ref} are set so that the time integration value of the speed V_{fb} becomes zero except during the time $t1$ ($t1 \geq 0$) when the speed V_{fb} is $X1 \leq V_{fb} \leq X2$, the effect of the viscous friction D can also be eliminated. Thus, a control constant control system can be provided that can identify inertia without receiving the effect of statical friction, etc., occurring when the speed is zero or is close to zero.

If the actual operation and the model operation differ largely, the speed V_{fb} in the speed control section and the speed V_{fb}' in the estimation section may be hard to match. In this case, an adjustment section 45 for adjusting speed loop gain Kv' may be provided, as shown in Figure 6.

The adjustment section raises the speed loop gain Kv' of the estimation section if the torque command T_{ref}' of the estimation section is greater than 0 and the speed V_{fb} is greater than the speed V_{fb}' ;

lowers the speed loop gain Kv' of the estimation section if the torque command T_{ref}' of the estimation section is less than 0 and the speed V_{fb} is greater than the speed V_{fb}' ; and

raises the speed loop gain Kv' of the estimation

section if the torque command T_{ref}' of the estimation section is less than 0 and the speed V_{fb} is less than the speed V_{fb}' .

[Field of Industrial Application]

5 This invention can be applied to control systems of motors for driving industrial machines, particularly machine tools, sorting machines, etc., with less load change.

WHAT IS CLAIMED IS;

1. A control constant identification system comprising:
a command generation section for generating a speed
command V_{ref} ;

5 a speed control section for determining a torque
command T_{ref} by the speed command V_{ref} and actual motor speed
 V_{fb} and for controlling motor speed;

an estimation section for simulating said speed control
section according to a model and for outputting an estimated
10 torque command T_{ref}' ; and

an identification section for identifying inertia J
according to a ratio between a value ST_{ref} resulting from time
integration of the torque command T_{ref} output by said speed
control section at a predetermined interval $[a, b]$ and a value
15 ST_{ref}' resulting from time integration of the torque command
 T_{ref}' output by said estimation section at the predetermined
interval $[a, b]$, characterized in that

the predetermined interval $[a, b]$ and the speed command
 V_{ref} are set so that the actual motor speed V_{fb} and motor speed
20 V_{fb}' found by said estimation section become the same non-zero
values at the time b .

2. A control constant identification system as claimed
in claim 1, wherein the speed command V_{ref} generated by said
command generation section is previously fixed.

25 3. A control constant identification system as claimed
in claim 1 or 2, wherein said speed control section performs
control containing an integration operation.

30 4. A control constant identification system as claimed
in any one of claims 1 to 3, wherein the predetermined interval
 $[a, b]$ and the speed command V_{ref} are set so that a time



integration value of the actual motor speed V_{fb} at the predetermined interval $[a, b]$ becomes zero.

5 5. A control constant identification system as claimed in any one of claims 1 to 4, wherein an average value of inertia found at a plurality of such intervals at which the time integration value of the actual motor speed V_{fb} becomes zero is adopted as inertia J .

10 6. A control constant identification system as claimed in any one of claims 1 to 3, wherein the interval $[a, b]$ and the speed command V_{ref} are set so that forward rotation time and reverse rotation time of a motor become equal to each other at the interval $[a, b]$.

15 7. A control constant identification system as claimed in any one of claims 1 to 6, wherein an average value of inertia J_1 found by one speed command V_{ref1} and inertia J_2 found by V_{ref2} provided by inverting positive and negative of the speed command V_{ref1} is adopted as inertia J .

20 8. A control constant identification system as claimed in claim 7, wherein constant disturbance T_d is found according to a torque command integration value ST_{ref1} found by one speed command V_{ref1} and a torque command integration value ST_{ref2} found by V_{ref2} provided by inverting the positive and negative of the speed command V_{ref1} .

25 9. A control constant identification system as claimed in any one of claims 1 to 3, wherein a viscous friction coefficient D is found from inclination (time change) of the torque command T_{ref} when the speed command V_{ref} is constant acceleration or constant deceleration.



10. A control constant identification system as claimed in claim 1, wherein when the speed V_{fb} is $X1 \leq V_{fb} \leq X2$ (where $X1 \leq 0$ and $X2 \geq 0$) in the interval $[a, b]$, time integration of the torque command T_{ref} of said speed control section and the torque command T_{ref}' of said estimation section are not executed.

11. A control constant identification system as claimed in claim 10, wherein the interval $[a, b]$ and the speed command V_{ref} are set so that a time integration value of the speed V_{fb} becomes zero except during the time $t1$ ($t1 \geq 0$) when the speed V_{fb} is $X1 \leq V_{fb} \leq X2$.

12. A control constant identification system as claimed in claim 1, further including an adjustment section for adjusting speed loop gain K_v' of said estimation section from information of the motor speed V_{fb} of said speed control section, and the speed V_{fb}' and the torque command T_{ref}' of said estimation section.

13. A control constant identification system as claimed in claim 12, wherein said adjustment section raises the speed loop gain K_v' of said estimation section if the torque command T_{ref}' of said estimation section is greater than 0 and the speed V_{fb} is greater than the speed V_{fb}' ;

lowers the speed loop gain K_v' of said estimation section if the torque command T_{ref}' of said estimation section is less than 0 and the speed V_{fb} is greater than the speed V_{fb}' ; and

raises the speed loop gain K_v' of said estimation section if the torque command T_{ref}' of said estimation section is less than 0 and the speed V_{fb} is less than the speed V_{fb}' .

