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A Disturbance Force Observer for position controlled Servo Drives

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Abstract:

The main item in servo control applications is position control, which is decisive for the accuracy to be obtained. The accuracy depends on several other things, like controller gains and control structure, on currently acting disturbance forces. Such forces are friction forces, which act very closely at the load, and machining forces, which include reactions from the machining process to the drive. To maintain stiff position control in order to suppress load disturbances large controller gains are needed which trend to reduce system stability. Therefore methods for disturbance compensation are very important. One possibility to estimate and compensate these forces is a disturbance observer, which reduces the error in a position controlled system. The structure is described in detail within this paper and has been combined with common control structures like cascade and state space control. The advantages and disadvantages will be listed and experimental results of a test stand with a disturbance force actuator will underline the mode of action. The final paper will present experimental results in more detail by using the observer in cascade and state space control structure.

Summary:

1 Introduction

Fig. 1 shows the typical model of a servo system containing a mechanical two mass system and a closed current control loop. Measuring signals are the position y, the rotary angle φ and the armature current I_A. Shaft velocity and slide velocity can be calculated by using the position signals. With these values it is easy to realize either the classical cascade control or a state space control.

According Fig. 1 and equation (1) disturbance forces F_{Fr} and machining forces F_M act on the last sum point, that means a change of these forces will be detected by the position and velocity feedback.

$$F_{dist} = F_{Fr} + F_M \qquad (1)$$

The current controller only influences the torque of the motors. To maintain stiff position control in order to suppress the influence of load disturbances large controller gains are needed which trend to reduce system stability. Therefore methods for disturbance compensation are very important [1],[2],[3],[4].

2 Compensation with disturbance observer

Another solution to estimate disturbances in contrary to [1] is the realization of a disturbance force observer which can be seen in Fig. 2. Equation (3) describes the structure of the time continuous observer by using the disturbance differential equation (2) and the description given in equation (1).

$$\dot{F}_{dist} = 0 \qquad (2)$$

In order to implement the observer in a microcomputer it is necessary to transform equation (3) into the time discrete description of equation (4). This leads to more coefficients of the 3x3 Matrix and at last to the structure in Fig. 2.

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ F_{dist} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{c}{m} & -\frac{1}{m} \\ 1 & -\frac{d}{m} & 0 \\ 0 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ F_{dist} \end{bmatrix} + \begin{bmatrix} \frac{c}{m} \\ \frac{d}{m} \\ 0 \end{bmatrix} \cdot j_T + \begin{bmatrix} l_0 \\ l_1 \\ l_s \end{bmatrix} \cdot (y - \hat{y}) \qquad (3)$$

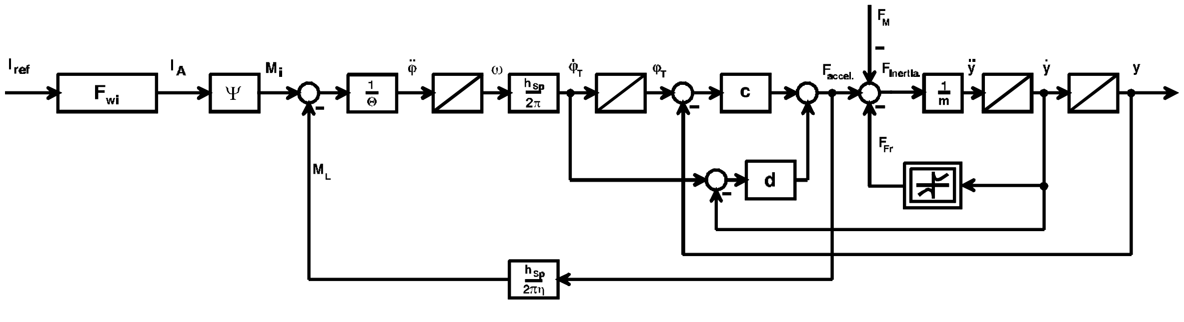
$$\begin{bmatrix} x(k+1) \\ y(k+1) \\ F_{dist}(k+1) \end{bmatrix} = \begin{bmatrix} ad_{11} & ad_{12} & ad_{13} \\ ad_{21} & ad_{22} & ad_{23} \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ F_{dist} \end{bmatrix} + \begin{bmatrix} bd_0 \\ bd_1 \\ 0 \end{bmatrix} \cdot j_T + \begin{bmatrix} ld_0 \\ ld_1 \\ ld_s \end{bmatrix} \cdot (y - \hat{y}) \qquad (4)$$

The problem is to find the right choice of the observer parameters ld_0, ld_1, ld_S. Good results deliver a linear quadratic regulator design, in which weight factors for l_0, l_1 are chosen equally and the weight factor for l_S has to be some powers higher, as well as pole placement with a 3 times pole smaller 1 on the real axis.

The block "feedforward compensation" decides about the compensation value in dependence on the current state of slide.

3 Test stand

In order to test different principles of disturbance compensation a test stand was built up with a synchronous linear motor as force actuator. Fig. 3 shows the principal construction of the test stand. The force controlled linear motor gets a synchronous signal Sync from the position controlled DC-drive if a load variation should occur. In this moment the force actuator starts to deliver a force profile. The position controlled system is a typical slide with a screw spindle. All control



F_{accel} - accelerating force
F_{Fr} - friction force
$F_{inertia}$ - inertial force
F_M - machining force
F_{wi} - closed current loop
M_i - motor torque

I_A - drive current
I_{Ref} - drive current reference value
y - load position
φ^T - transposed rotor angle
φ - rotor angle
ω - mechanical angular frequency

Θ - inertial moment of rotor and screw spindle
m - load mass
Ψ - flux
c - elastic constant
d - damping constant
η - transmission efficiency of the screw spindle

Fig. 1: Block diagram of the plant

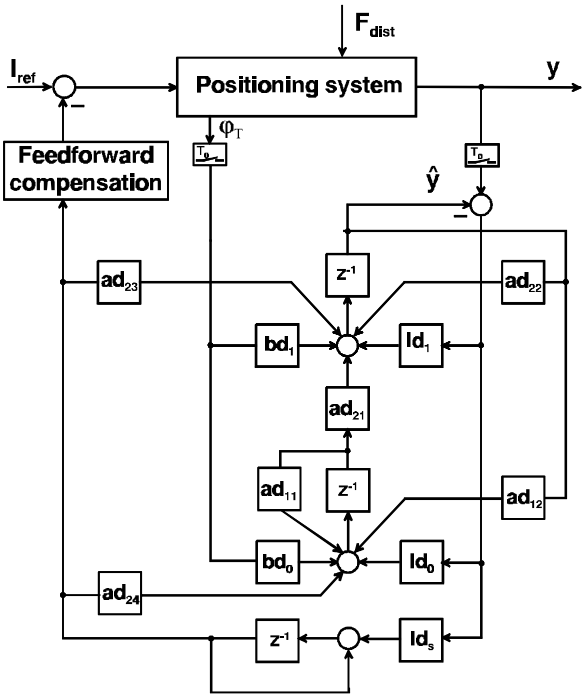


Fig. 2: Compensation with disturbance force observer

algorithms are implemented in a digital signal processor.

4 Results

Fig. 4 shows first experimental results of the position error Δy with and without using the observer described above. A machining force of 5000N acts within the intervalls between 0.3-0.7s and 3.3-3.7s. A reduction of error can be seen if a machining force is acting but also if only friction is acting within the position controlled system.

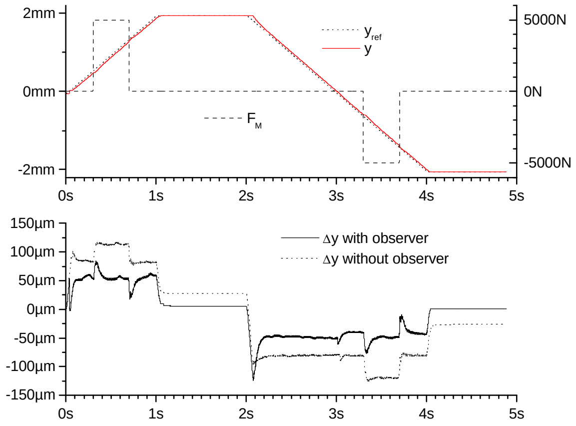


Fig. 4: Experimental results

The final paper will present experimental results in more detail by using the observer in cascade and state space control structure.

5 References

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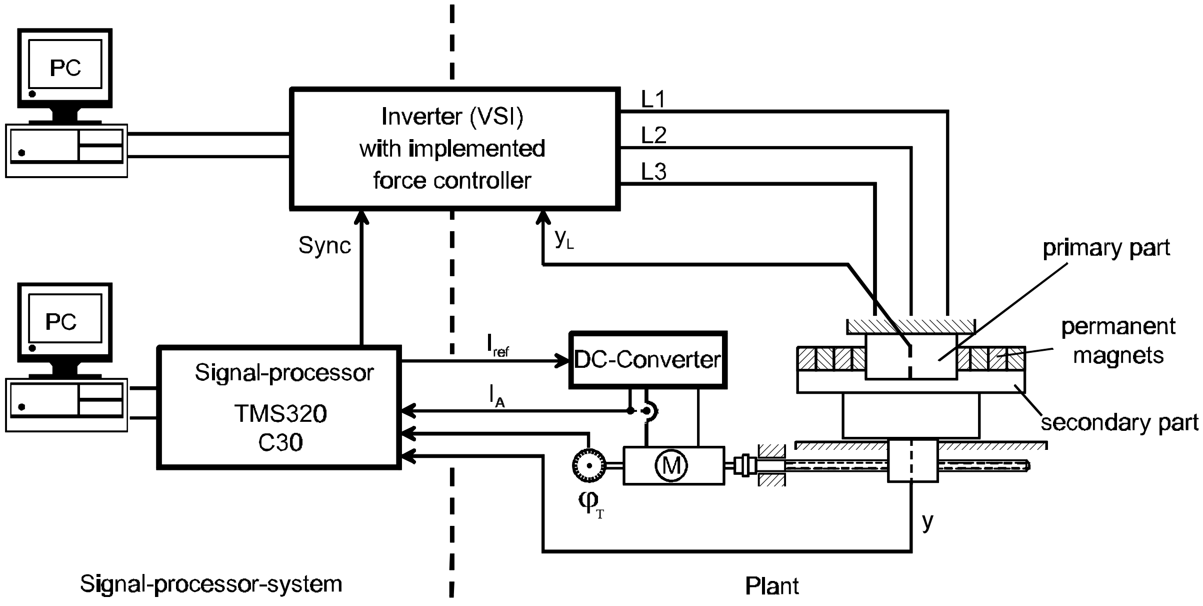

Fig. 3: Hardware of the test stand