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LINEAR INDUCTION DRIVE SYSTEM FOR HIGH PRECISION PROCESSING

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Abstract

This paper presents the efficiency of a position controlled linear induction drive system.

The drive system consisting of personal computer, inverter and microcontroller is suitable for applications of linear induction motors with different force and speed parameter.

The complete digital position control use the principle of the vector control. The microcontroller SAB 80C166 is responsible for the complete control of the drive system including pulse width modulation for the chopper and the inverter. The sampling period of the current control is fixed to lOOus. The sampling frequency of the position and speed control amounts to 500us.

The software structure makes the integration of the common cascaded control and the state control possible.

The experimental results demonstrate the achieved characteristic.

Keywords: vector control, linear induction drive, microcontroller, state control, cascaded position control

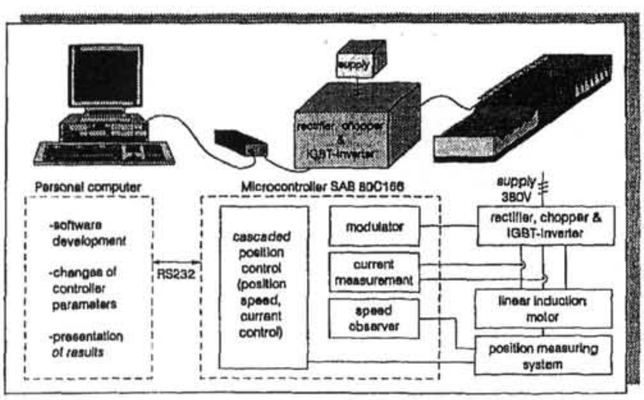

Figure I: Structure of the drive system

1 Introduction

Figure 1 illustrates the structure of the complete drive system for the position control of linear induction motors. This concept is mainly suited for high precision processing over a long distance and with a high speed.

The linear induction motor is fed by a pulse width modulated inverter. The switching frequency of the IGBT-inverter amounts to 10kHz. The high DC-link voltage of 520V after the rectifier is for many applications not necessary. That is why, the system includes a chopper. The chopper reduces the DC-link voltage of the inverter to 260V. The losses of the motor and the inverter can be minimized by that. The maximum inverter output voltage can be adapt to the parameters of the used motor and the seted static and dynamic requests.

The complete control software is integrated on the microcontroller SAB 80C166 [1]. The software includes the measuring of current and position, the control algorithm of the vector control and the control of chopper and inverter. The integrated position reference generator and the speed observer complete the control software.

This paper describes the application of the common cascaded control [2] and the state control [3].

The aim of the researches into state control was to have simple equations to estimate the parameter of the feedback elements. Therefore, the transfer function of the controlled system is simplified in consideration of a constant flux value [4]. The demand to have the possibility to limit the current exists simultaneous. This can be solved with the cascaded state control [5].

The experimental results demonstrate the achieved characteristic of the drive system. The performance during a positioning operation with two values of the reference speed is illustrated. The behaviour during a disturbance force is also presented.

2 Cascaded Position Control

The structure of the cascaded position control is shown in figure 2.

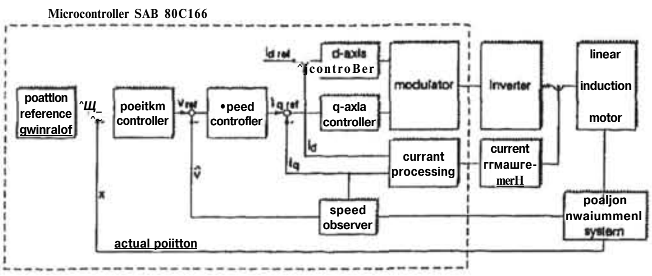

Figure 2: Structure of the cascaded position control

The force and the flux producing current component can be controlled separately by using the vector control principle. The value of the flux producing current component is fixed to simplify the control structure.

The parameter of the PI current controller are designed with pole-placement and guarantee a very good dynamic performance. The response time of the force producing current component amounts to 0.3ms [2].

A incremental optical measurement system with a resolution of 25µm is disposal for the experimental researches. The hardware make the processing of higher resolutions depending on the maximum speed possible. The speed v is calculated from the changing of the position x during a sample time T_{ab} (500µs). The equation is :

$$v(k) = \frac{x(k) - x(k-1)}{T_{ab}} \tag{1}$$

The speed resolution is 0.05m/s. A speed observer is inserted to improve the static performance and the stability. The Luenberger-structure [4] is shown in figure 3. The observer determines from the measured value of the force producing current component i_q and the calculated speed v the observed speed $\hat{v}$.

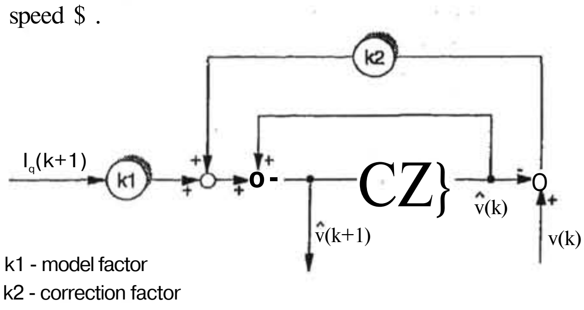

Figure 3: Structure of the speed observer

A position reference generator improves the positioning performance. The generator calculates online every 500µs a position trajectory from point to point and take in consideration the acceleration and speed limitation. The position trajectory guarantees a time optimum positioning without reaching the voltage limitation. A calculated position trajectory is shown in figure 4.

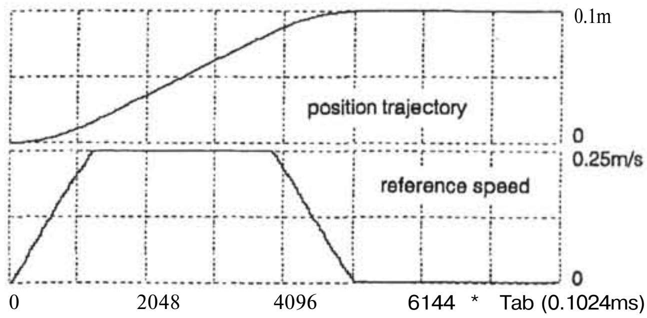

Figure 4: Position reference trajectory

The positioning operation with maximum gain of the position controller demonstrates figure 5.

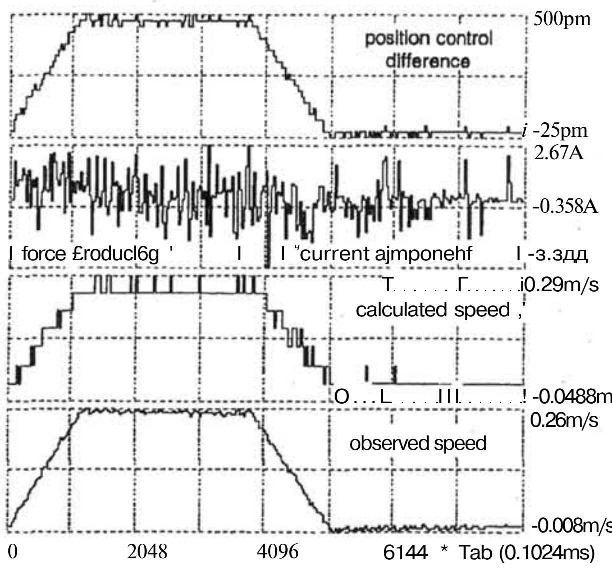

Figure 5: Positioning operation

Figure 6 illustrates a positioning operation with a reference speed of 1.5 m/s.

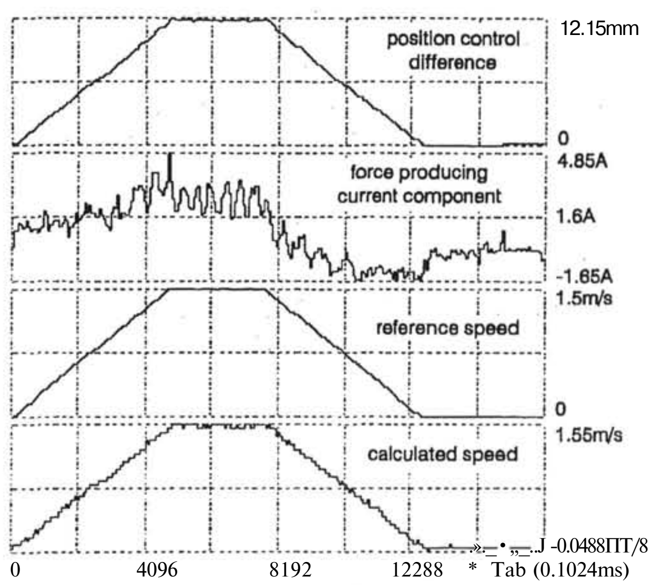

Figure 6: Positioning operation with a speed of 1.5 m/s

Figure 7 demonstrates the performance during a disturbance force of 100N to judge the stiffness of the drive system.

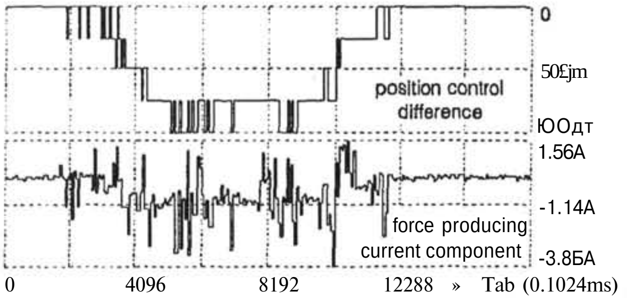

Figure 7: Stiffness with cascaded position control

3 State Control

Figure 8 shows the structure of the cascaded state control with the simplified controlled system. The parameter of the controlled system are:

K_{WR} - voltage factor of the inverter
$\bar{R}$ - total resistance of the motor
T_0 - dispersion time constant.

The parameter to estimate are:

k_U, k_{LV}, k_{LS} - gain of the forward elements
$k_U, k_{V3}, k_{V2}, k_{S3}, k_{S2}, k_{S1}$ - gain of the feedback elements .

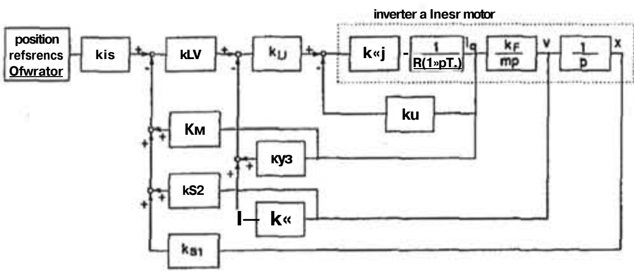

Figure 8: Structure of the complete cascaded state control

A limitation of the speed reference value is by using the position reference generator not necessary. A reduced control structure presented in figure 9 can be implemented at that reason. The reduced structure needs a lower reckoning time.

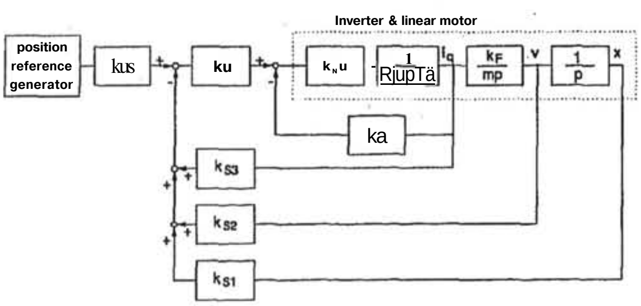

Figure 9: Structure of the reduced state control

Similar position control differences exist at both structures demonstrated in figure 10. The coefficients of the position control loop transfer function are equal.

The noises can be judged with the measured force producing component i_q. Figure 11 shows the current during a positioning operation. It can be shown that there are no considerable differences.

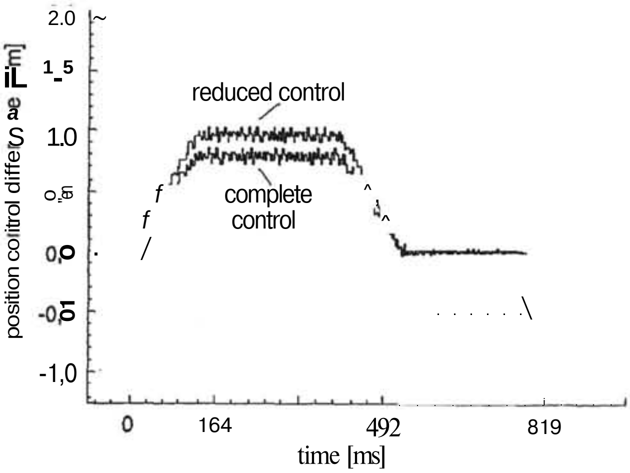

Figure 10: Position control difference with complete and reduced state control

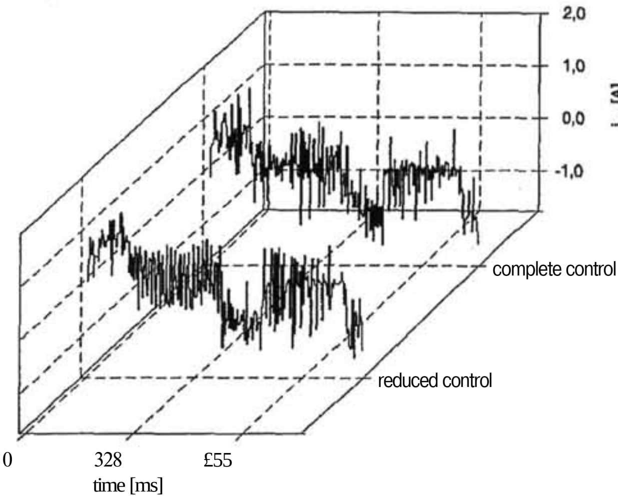

Figure 11: Force producing current component during positioning operation

The performance during disturbance force shown in figure 12 is differing considerable.

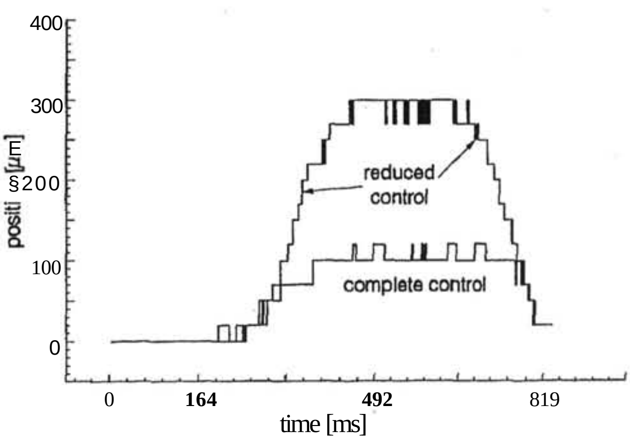

Figure 12: Stiffness of the state control

The results show that the reduced structure can be used if there are no high demands referring to the disturbance performance.

The influence of the speed estimation on the noises at the state control demonstrates the following figures. The speed observer, the calculated speed refer to (1) and the average value are compared. The equation for the average speed is:

$$Я» - \frac{xjk) * v(*-l) ; 4*-2)}{3} \qquad (2)$$

Figures 13 and 14 show the comparison between the methods. It can be shown that the average value is a good compromise between low noises and little reckoning time.

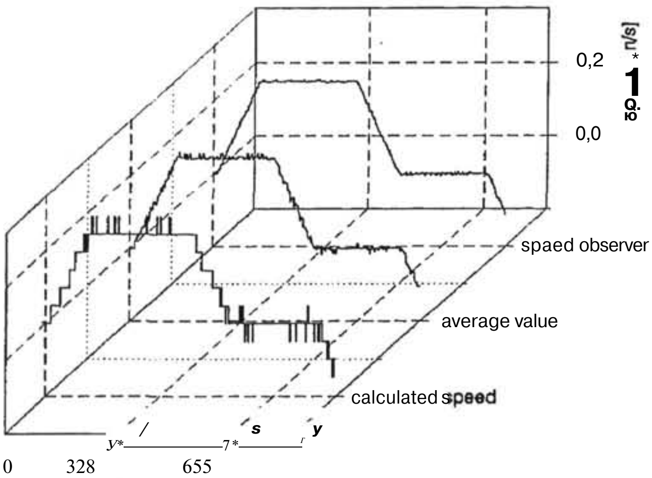

Figure 13: speed during positioning operation

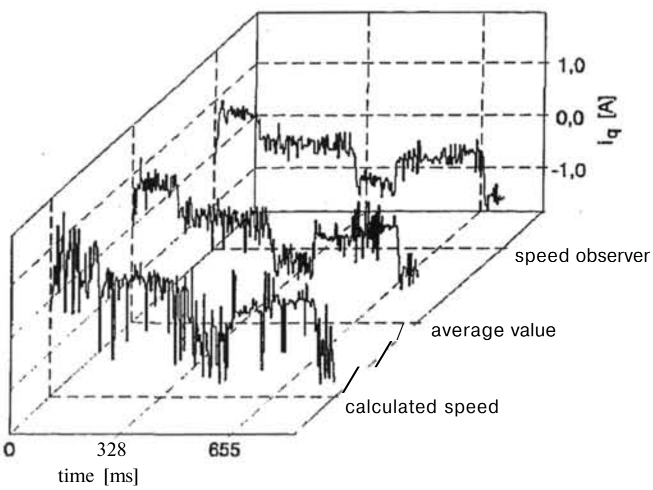

Figure 14: force producing component i_q during positioning operation

4 Conclusion

This paper demonstrates the high efficiency of the introduced drive system. The advantages of the linear induction motor can be used comprehensive.

The microcontroller SAB 80C166 minimizes the hardware investment of the drive system. The selected sampling periods of 1OOjis for the current control and 500|is for the speed- and position control guarantee a very good dynamic and static behaviour. The efficiency of the microcontroller make the implementation of the cascaded position control and the state control possible.

The adjustable DC-link voltage of the inverter through the chopper reduces the inverter and the motor losses. The maximum inverter output voltage can be adapt to the parameters of the used motor.

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