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LINEAR INDUCTION DRIVE SYSTEM COMPLETELY DIGITIAL POSITION CONTROLLED WITH MINIMAL HARDWARE INVESTMENT

CONTROLE DE POSITION ENTIEREMENT NUMERIQUE D'UN MOTEUR LINEAIRE A INDUCTION AVEC UN INVESTISSEMENT MATERIEL MINIMAL

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Abstract

This paper presents practical results of a high performance linear induction drive.
The cascaded position control of the PWM inverter-fed linear induction motor is based on vector control principles. The complete control algorithm is implemented in a Siemens SAB 80C166 microcontroller.
A sampling rate of 10 kHz is determined for the digital current control. The response time of the traction force producing current component control loop amounts to 0.3ms.
The sampling period of the speed and position control is fixed to 500µs.
The disturbing influence of the speed calculated from the measured position by differentiation could be considerable reduced by a speed observer.
The implementation of a position reference generator into the software improves the positioning accuracy. The generator calculates online a smooth trajectory from point to point, observing the desirable acceleration and speed.
The experimental results show the high performance of the described linear drive system.

Keywords

- vector control
- linear induction drive
- fast microcontroller

INTRODUCTION

The requirements of a position controlled drive system are of manifold nature and depend of course of actual operation conditions. Independent of the individual application the requirements of all drives are high positioning accuracy and repeatability, system stiffness in the case of changing parameters, low noises and warming.
This paper presents a high performance position controlled linear induction drive system.
The technical advantages of a linear induction motor are ruggedness, high reliability, low cost, minimum maintenance and the lack of magnets. This advantages could be only used if the total system including inverter and control causes low costs.

The aim of the researches was to design a completely digital position control with a minimal hardware investment. The requirements could be served by a high sampling rate of the control using the fast Siemens SAB 80C166 microcontroller.
The implementation of the vector control involves a lot of computations but the microcontroller fulfill the need of computation speed and has all necessary I/O-hardware on board.

The presented paper decribes practical results with the illustrated drive system in figure 1.

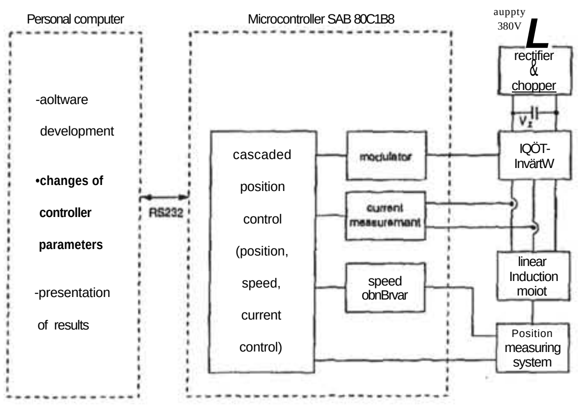

Fig. 1 Structure of the drive system

HARDWARE DESCRIPTION

Microcontroller

The completed control algorithm written in assembler language is implemented in a Siemens SAB80C166 microcontroller [1]. The microcontroller is sited to a evalution board from ertec GmbH [2] supporting RAM, ROM, adressing logic and clocking crystal.

The reduced instruction cycle time and the included necessary I/O-hardware are the advantages of the used microcontroller.

Most instructions can be executed within a 100ns machine cycle. Ten 10bit A/D converter channels and sixteen capture and compare channels have been integrated on this high performance single-chip microcontroller. The cature/compare units have a maximum resolution of 400ns. The General Purpose Timer Unit incorporates five 16-bit timers. Each timer may operate in a number of different modes. The integrated RAM and ROM give sufficient space for the control algorithm, tables and also for logging of control parameters and measurements.

Software development, online changes of the controller parameters and representation of results is performed on a PC connected through the RS232 port.

Linear induction motor

The researches were executed with a single-sided linear induction motor. The primary part consisting of cores with tree phase windings is moveable. The secondary part consists only of iron teeth and copper conductors in the form of a cage winding. It has no magnetic keeper.

The main parameters of the motor are:

- stationary traction force 200 N
- max. traction force 1100 N
- secondary time constant 125ms
- dispersion time constant 5.05 ms
- number of poles 4
- mass of the carriage 27 kg

The existing optical position measurement system has a resolution of 25 urn. Only a simple programmable logic is required to form the two output signals with 90°phase difference to signals of the forward and backward motion. This signals are connected with two counters of the microcontroller.

Inverter

The inverter contributes to the high performance of the total system.

The system uses a 10kHz switching, 10 kVA IGBT-inverter. The inverter consists of two DC-links to reduce the strain of the motor. The first link following the rectifier has a DC-link voltage of 520V. The second DC-link voltage realized with a 20kHz switching chopper is established by 250V.

The resolution of the modulator using the capture/compare microcontroller unit is increased by a programmable logic unit from 400ns to 50ns. Therefore the effects of current higher time harmonics through the inverter are low.

The currents are measured on the outputs of the inverter with LEM-sensors in two phases only, since no zero sequence currents are present. A little interface card is used to connect the LEM-sensor output signals with the analog/digital converter channals of the microcontroller. The conversion time for one channal amounts to 10us.

CONTROL STRATEGY

The aim was to design a easy position control structure with a high performance in respect of the traction force limitation.

The researches show that the well known cascaded control serves the requirements well.

Because of the high sampling rate of the control there is a very good dynamic behaviour of the drive system possible.

The completely digital position control includes one inner current control loop, a speed control loop and an outer position control loop.

All controllers are designed as being continuous and all controller parameters are fixed.

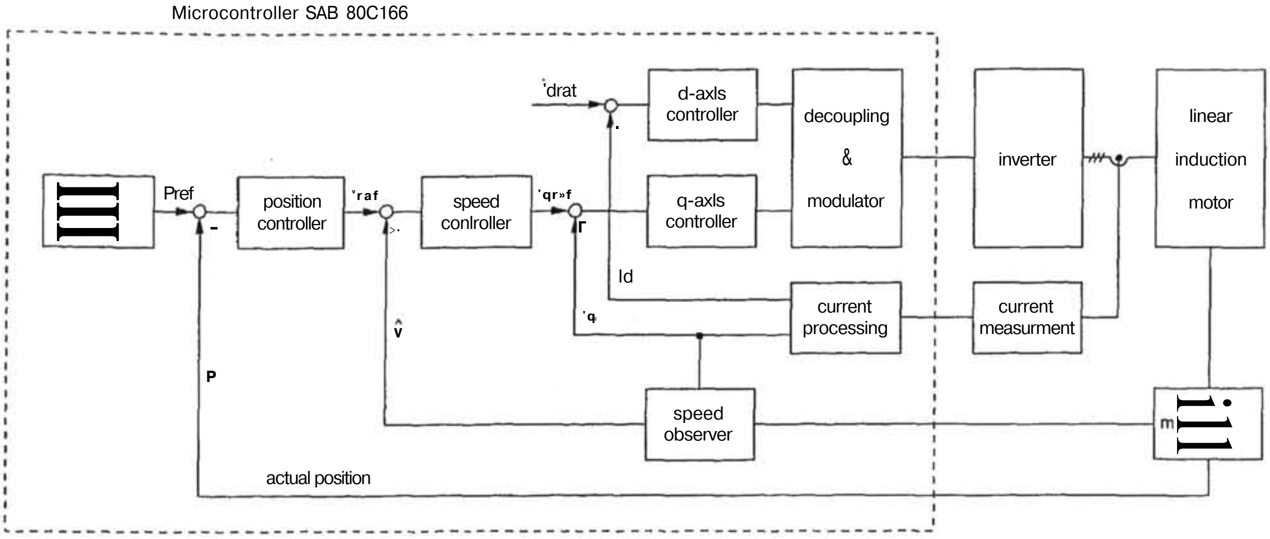

Fig. 2 Structure of the cascaded position control

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

Current control

The current control loop determines the performance of the total system considerable. The necessary high dynamic behaviour is served by a digital realisation and the high sampling rate of 10kHz.

Because of the field-oriented operating mode the flux and the traction force producing components of the current are decoupled and can be controlled seperately. The controllers are designed as PI-controller with constant parameters computed in a classical way with pole-placement.

The operation of the motor at the normal speed range allows a constant value of the flux producing current component i_d fixed of 4 A.

The value of the traction force producing current component i is generates by the speed controller and limited ъ 11 A. The q-current is directly proportional to motor traction force.

Speed control

The sampling period of the speed control is fixed to 500us, which is sufficient for this application.

The used controller algorithm depends on the application. There is P- as well as PD- or PI-algorithm possible.

Using a high amplification of the speed controller the influence of the speed calculated from the measured position by differentiation on the current ripple is high. Because of the resolution of the position measurement system of 25us there is a speed resolution of 0.0488m/s.

The performance and the stability of the system is improved by a speed-observer with Luenberger-structure [3]. This structure is easy and requires a little raking time.

The structure of the speed observer shows figure 3.

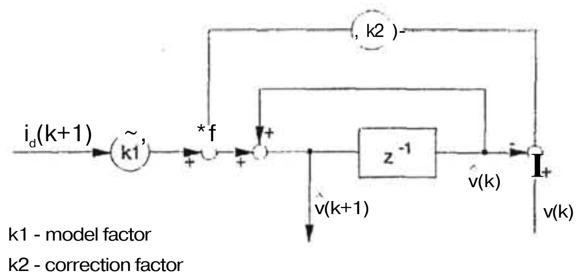

Fig.3 Structure of the speed observer

The model factor k1 depends on the force factor of the motor, the moveable mass and the sampling period. The value of the correction factor k2 depending on the application influences the differences between the observed speed and the speed calculated from the position and so the noises.

Position control

The outer loop of the cascaded structure is the position control with a sampling rate of 500us.

The requirements of the position control are positioning without overshoots and with a lowest difference between position reference trajectory and the measured position as well as stiffness in the case of disturbance forces. This requires a high amplification of the position controller without loss of the stability.

The tracking error, overshoot and settling time could be improved by a position reference generator. The generator calculates online every 500µs a smooth trajectory from point to point, observing the wished acceleration and speed limitation. The input parameter of the generator are target position, max. speed and max. acceleration. The online method demonstrated at figure 4 accepts modifications of the parameter during motion.

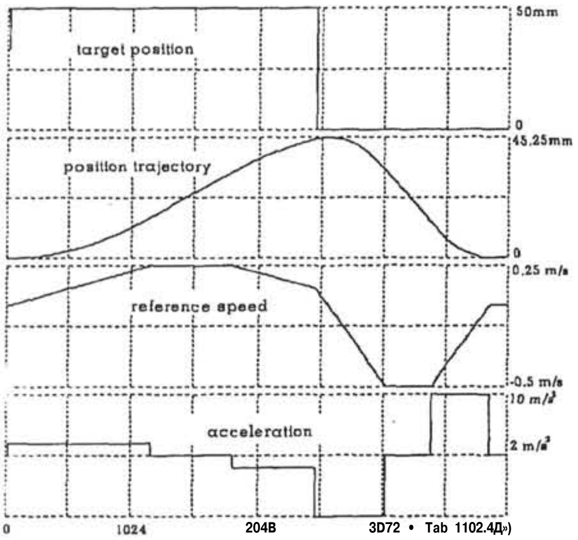

Fig. 4 Position reference trajectory

EXPERIMENTAL RESULTS

Current control

Figure 5 shows the high dynamic behaviour of the digital current control.

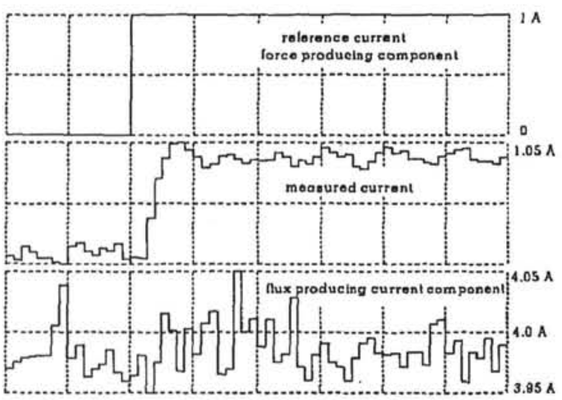

Fig. 5 Step response of the traction force producing current component

The current control loop is designed to reach a good dynamic performance in the sens of a best compromise between rise time and overshoot. Figure 5 illustrates the possible response time of 300µs with the noted controller parameter.

Speed control

Special attention is paid to the influence of the speed resolution. Figure 6 represents the difference between the speed calculated from the measured position and the observed speed. In this figure is also the influence on the force producing current component evident.

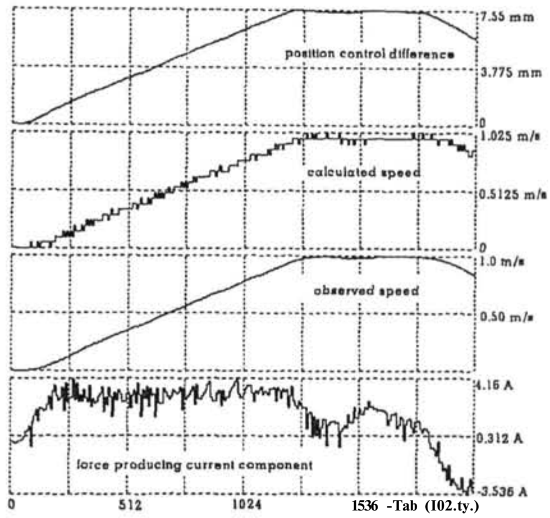

Fig. 6 Positioning operation using caiculated speed

The proposed speed control operates quite well except for slight influence of speed noise depending on the value of the observer correction factor K2. By using of the correction factor value 0.18 realised at the published application the error between observed and real value at the change of speed and during the steady speed operation als well as the noises are quite low shown in figure 7.

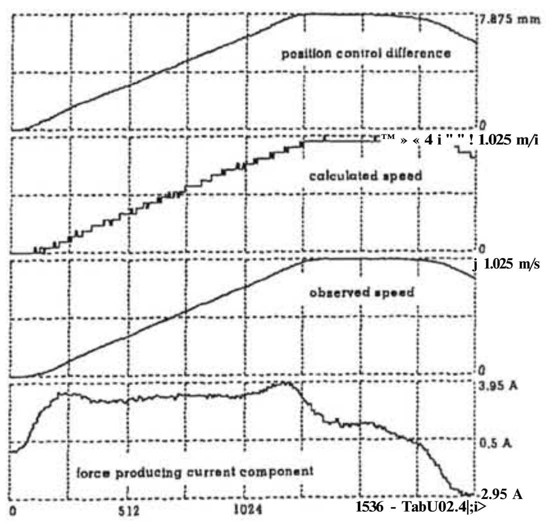

Fig. 7 Positioning operation using observed speed

The following figure 8 represents the performance at a speed of 0.02 m/s.

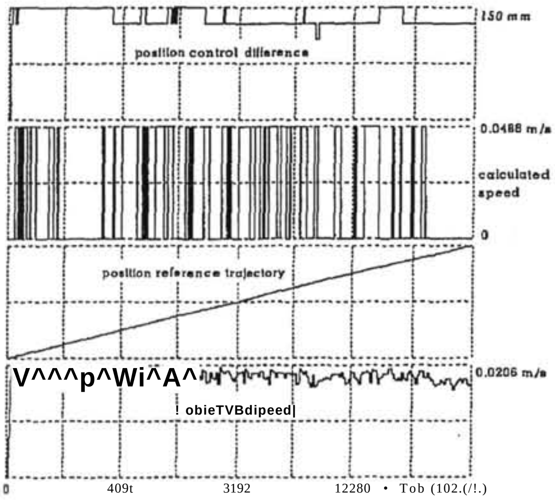

Fig. 8 Positioning operation at a low speed range

Position control

The performance of the position control may now be demonstrated with one selected example.

Figure 9 shows the positioning operation using the position reference generator in the case of nominal parameters. The speed and the position controller are P-controller. It can be shown the reaching of the target position without any overshoot and with an acceptable difference between the reference position trajectory and the measured position.

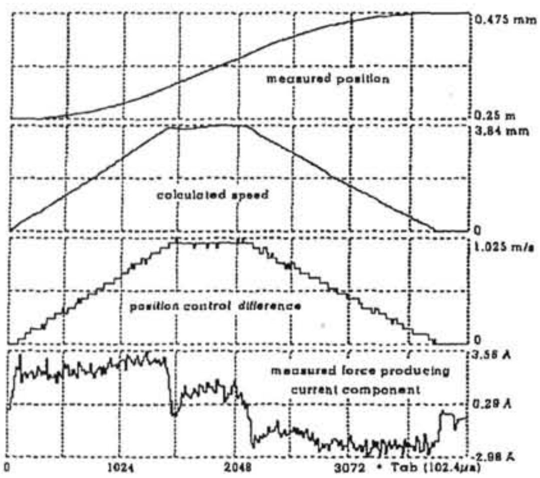

Fig.9 Positioning operation using the position reference generator and the speed observer

CONCLUSION

The published researches turn out that a high performance completely digital position controlled linear induction drive system including speed observer and position reference generator can be realized by using a low cost microcontroller in a compact form.

Another advantage of this hardware is that all kind of controller structures can be easily implemented only by change of the software.

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