An observer to improve the speed signal using a Ferraris acceleration sensor

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Abstract

This paper presents the use of a state observer to improve the speed signal for servo drives with the help of a commercial acceleration sensor. Methods to improve the acceleration signal are also described and the possible performance, the advantages and disadvantages of such a system are shown.

Summary

Servo drive systems for high dynamic applications need precise measuring signals. The incremental encoder for position measurement is well known. In recent time there is also an acceleration sensor for rotational drives available. The combination of both sensors – a Ferraris sensor and an incremental encoder – promises great benefits [1]. In a speed controlled system the accurate speed signal is very important. If a state control is chosen to improve the performance of the system the accurate acceleration of the machine rotor is also interesting. These signals could also be generated by a state observer using the calculated machine torque and the measured position, but especially in an application with high disturbance torques the measured acceleration is preferable. The generation of the speed and acceleration signal by time discrete differentiation of the position signal amplifies the measuring noise inherently in control systems with small cycle times. In this paper the performance, advantages and disadvantages of the two sensor devices are discussed. Possible algorithms to correct the acceleration signal and a state observer to generate a better speed signal are presented.

1. Speed signal generation with the incremental encoder

For position measurement a hollow shaft incremental encoder with sine/cosine signal output and 5000 line counts is used [2]. The subsequent electronic [3] samples these sine/cosine signals at the beginning of each control interrupt with the cycle time of $150\,ms$ [4]. To get the correct coarse position the zero crossings of the encoder signals are detected by comparators and evaluated by a 15-bit-counter. The accuracy of position measurement is limited only by the incremental encoder. The noise which is produced by the encoder limits the resolution to about 2560000 steps per revolution. The guaranteed accuracy of the encoder is much smaller. It is 100000 increments per revolution. A time discrete differentiation of the position information is used to generate a speed signal. This differentiation amplifies the noise and inaccuracies of the position signal. The ripple of the speed signal is therefore about 0.4 rpm . Another disadvantage is the low-pass behaviour of the encoder concerning high frequent oscillations of the rotor. The big advantage of this sensor signal is the missing offset or offset drift. The average value of speed is always correct.

2. Estimation of the speed signal by integration of the acceleration signal

The principle of an Ferraris sensor can be described in a way that the field of a permanent magnet induces eddy currents in a rotating disc. These eddy currents and their associated magnetic field changes if the speed of the disc changes. Caused by the changing magnetic field, a voltage is induced in sensor-coils whenever speed changes, i.e. during acceleration. This voltage is amplified and converted to a digital signal by the subsequent analogue and digital electronic [3]. The acceleration is then integrated and represents a speed signal. The main advantages of this signal are the high dynamic of the measured acceleration and the low noise. But like all analogue electronic circuitry there is some offset and offset drift, the amplification of the sensor is not constant and there is saturation and clipping of the acceleration sensor. Another disadvantage is the sensitivity of the sensor to low frequent magnetic disturbance. The final paper will discuss this more detailed.

3.1 Correction of the offset and the varying amplification of the acceleration signal with the help of the position signal

The information on acceleration and position is digitally available in our system. The correction is therefore made by software. The offset of the acceleration signal is corrected by the comparison of the mean acceleration signal and the mean value of the two times differentiated position signal.
The integrated acceleration and the differentiated position signal are compared to correct the amplification of the acceleration signal (correction of K_g in fig. 1,2) . The difference between two speed values of the integrated acceleration and the differentiated position at different times are used to correct the acceleration signal. A rather big time difference reduces the influence of noise. Both corrections are implemented in a way that they change the offset or the amplification only slowly to reduce the influence of noise and disturbance. The final paper will explain the algorithms more detailed and show the measured performance.

3.2 A state observer to generate a high dynamic accurate speed signal

There are two main possibilities to implement a state observer for speed with the help of an acceleration sensor. The first one is to use two integrators to estimate the position and compare this position to the measured value of the incremental encoder. The other observer structure consists of one integrator which estimates the speed signal. This estimated speed signal is compared to the differentiated position information of the incremental encoder. This structure is less complex and therefore it is easier to place the eigenvalues in the Laplace-area. None of these observers needs special parameters of the machine. Therefore no parameter identification is necessary.
The estimated speed signal in the observer according fig. 2 follows better the differentiated encoder signal. Therefore this structure is considered in the following.
The maximum acceleration of the real machine rotor exceeds the measuring range of the Ferraris sensor. Therefore the observer is switched off if the acceleration

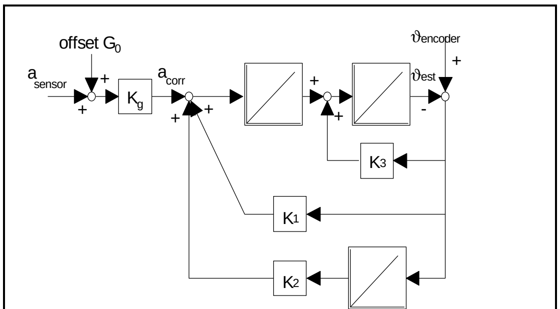

Fig. 1: speed observer with position estimation

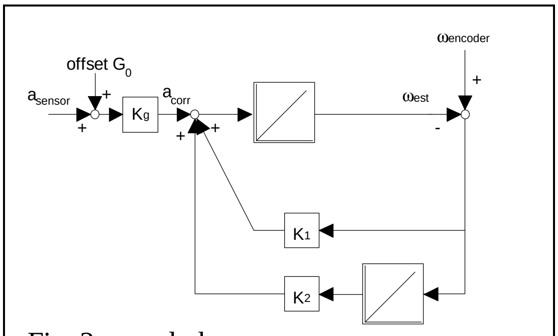

Fig. 2: speed observer

leaves the measuring range of the sensor. Then the differentiated position signal of the encoder is used as speed signal. Because the amplification and the offset of the Ferraris-sensor changes with speed and the in 3.1 mentioned correction is to slow to correct this immediately while great acceleration transients the accuracy of the available acceleration signal a_{corr} is lower than in steady-state operation. To improve the estimated speed the parameters K_1, K_2 and if used K_3 are increased while acceleration transients. With this combination it is possible to generate a speed signal with low noise in steady-state operation which is also correct while great acceleration transients. The exact generation of the signal will be explained in the final paper.

4. Measured results

The performance of the new speed signal observer is shown in the following figures. The figures compare the speed signal which is generated by the speed observer (wm_est) with the differentiated position signal of the encoder (wm_enc).

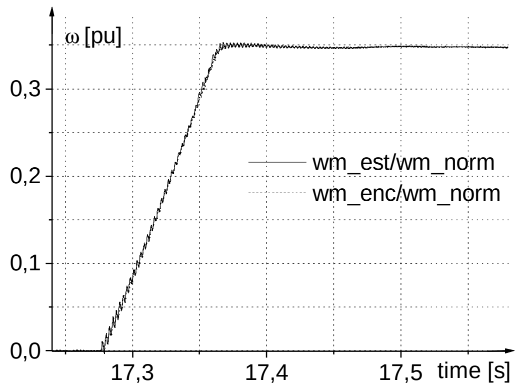

Fig. 3: acceleration transient 0 to 500 rpm

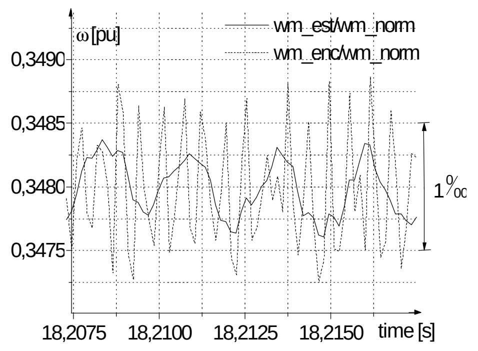

Fig. 4: steady-state rotation at 500 rpm

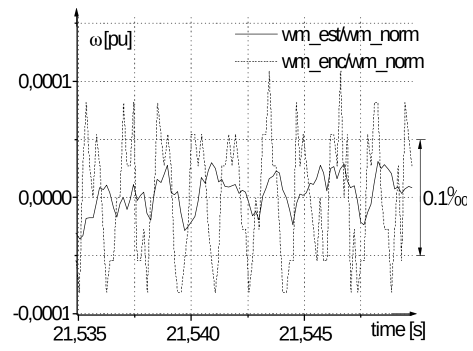

Fig. 5: steady-state operation at 0 rpm

The estimated speed signal shows a better dynamic performance and less noise than the differentiated position. It is therefore well suited for control purposes. The final paper will show more experimental results.

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