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ACCELERATION SENSOR BASED ON THE FERRARIS PRINCIPLE FOR ROTARY DRIVES

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Abstract: During various transient phenomena of an asynchronous machine, oscillations of mechanical characteristics (speed, torque) of the machine occur very frequently. Very fast oscillations of speed of the electric drive may be detected by using a speed-voltage generator or incremental sensors, however, the precision is not high, or the requirements placed on the measuring instruments are strong.
The submission offers a possibility of how to exploit the advantages of the accelerometer with permanent magnets for determining these oscillations. The requirements on the measuring chain are also substantially lower.

Keywords: acceleration, rotary accelerometer, eddy currents

1 Introduction

Whenever a drive has to be controlled, a signal for the actual speed is required, which is fed back to the control system. This speed signal should be highly precise and ideally without any delay. In most cases this purpose is achieved by a linear or angular encoder (glass scale linear encoder, resolver, optical incremental encoder), where differentiating the position signal yields the desired speed signal. The drawback of this method is that by differentiation, noise and fluctuations are pronounced. This effect can cause some problems for very accurate and stable position signals.

A different approach to get the speed information is to integrate an acceleration signal. The advantage of this method is that by integrating a signal, noise and statistical errors vanish. For this purpose contactless acceleration sensors based on the Ferraris principle are very suitable. With this sensor highly dynamic signals proportional to the change of speed are available, even at standstill.

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2 Principle of accelerometer

In acceleration sensors based on the Ferraris principle, permanent magnets cause eddy currents to flow in a strip of metal (or a disk for rotary applications). Changes in speed change the magnetic field generated by the eddy currents resulting in voltages being induced in sensor windings.

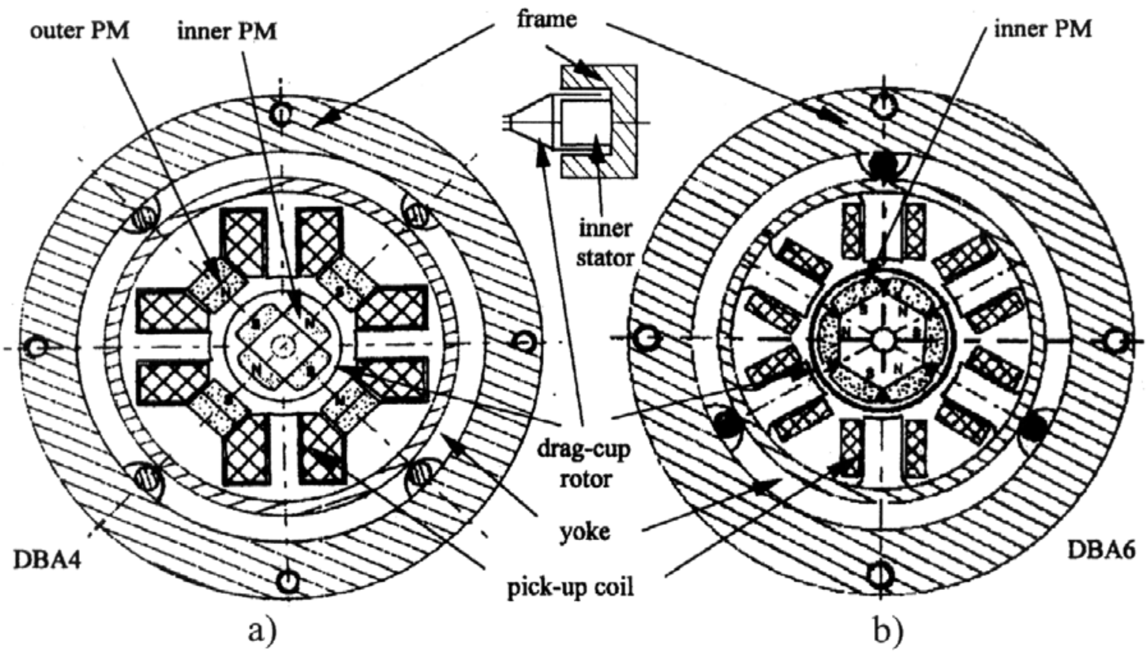


***Fig.1** Cross section of two types of rotational accelerometers. Both types have inner permanent magnets a)4-pole Ferraris accelerometer, b) 6-pole Ferraris accelerometer*

For the basic principle, it is not important whether the construction has inner or outer permanent magnets. For example, in a detail of Fig. 1 a) you can see both of them.

Special demands are placed on the rotor. It is a very simple nevertheless very important part and must satisfy very strict conditions. Only in this case the noise on the accelerometer's output is minimized and we have a signal suitable for another processing.

The rotor must be fastened of the shaft very precisely, e.i. with very small excentricity. Due to the dumping and fast response, the resistivity of the material used is also very important. From another point of view, the material used must have a very small moment of inertia. Generally said, suitable material is brass, or even better, aluminum.

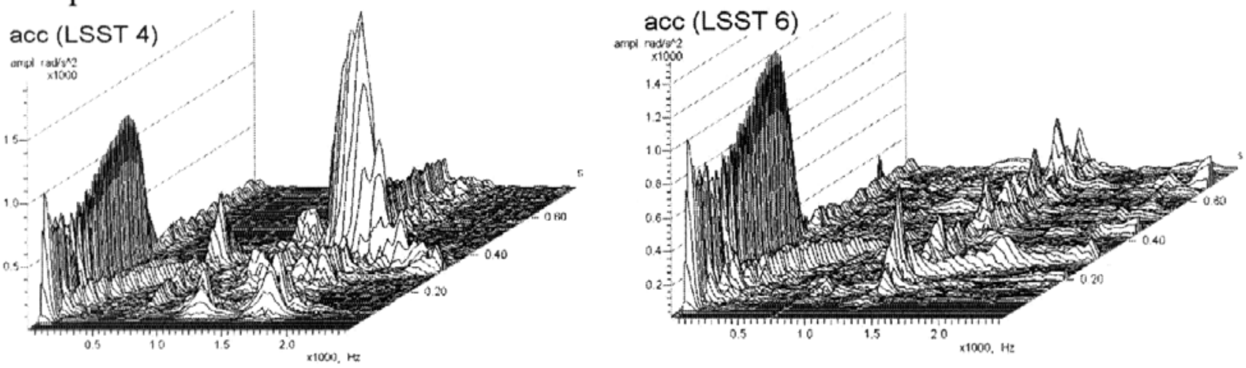
The equipment measuring angular acceleration must not noticeably disturb the performance of the drive or machine under test, i.e. it:

- must posses only small moment of inertia

- must place minimal load
- must be fastened to the shaft in as stiff manner as possible

3 Comparison of various types of accelerometers

The comparison tests were focused on four various accelerometers. The first and the second specimens can be seen in Fig. 1. For testing purposes, the run-up of asynchronous machine has been chosen as a transient phenomenon. Thanks to FFT-time analysis we can compare the contents of noises-components.



a) b)

Fig.2. *FFT-time analysis of the specimen under run-up asynchronous machine test. a) 4-pole acceleration sensor, b) 6-pole acceleration sensor, inner permanent magnets in both cases.*

On the left side of each Figure we can see the DC component which is a useful signal. Any higher frequencies are just a useless noise.

4 Example of utilization

We can use this accelerometer for measurement of very fast transient phenomena and the requirement placed on measurement devices are not too high.

One of typical utilization is a speed measurement in electrical machines. The following equation is valid

$$a = \frac{d\omega}{dt}. \tag{1}$$

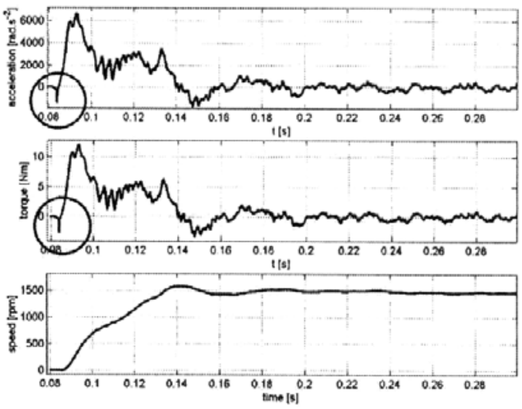
To obtain an angular speed ω, we must integrate the signal of the accelerometer a. Some problems are sometimes caused by the DC component, especially if we integrate over extremely long time, but this problem usually is not difficult to solve.

If the moment of inertia of the tested machine is known and the machine is not loaded mechanically, we can calculate also torque thank to equation

$$T = I\frac{d\omega}{dt}. \tag{2}$$

The acceleration, torque and speed of asynchronous machines are shown on the Fig. 3.

***Fig.3** Run-up of the asynchronous machine (U=440V delta connection, I=2A, P=0,9kW, f=60Hz speed 1705 rpm). In the very beginning of the curve we can see the peak of torque, which has an opposite direction with respect to main starting torque. This is the effect of slots (torque of reluctance) and it depends on the time of switching on. It depends on the rotor position as well. Afterwards immediately follows the creation of a rotation field.*



Under these tests the machine was connected to a voltage of 420V (line to line value), 50 Hz. Due to this fact the synchronous speed (speed under the no-load test) is 1500 rpm.

5 Conclusion

The accelerometer sensor has provided encouraging results. The advantages of this sensor are high sensitivity, simple construction and minimum temperature effect. To get the speed from the acceleration, integration has to be performed, which additionally reduces noise. It is possible with rather small effort to obtain a low noise high dynamic speed signal.

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