Reliable Drive Monitoring

Sensor combinations for drive engineering

LOTHAR WILHELMY, KAI-HANS OTTO

Speed-controlled drives are usually fitted with a sensor that measures the actual speed of the drive, converts it into an electrical value, and then passes this value on to the setpoint/actual value comparison of the inverter.
In addition to this primary task – measuring the speed – the specification of many drives also requires the sensor or sensor combination to perform other functions.

Tasks of the sensor system

The sensor system should signal when one or more limit speeds has been reached or exceeded, make an analog measurement of the speed while simultaneously making a digital measurement of the position, or present the signals in dual form, as identical (redundant) signals for safety monitoring, or in different forms for separate control loops. It is often necessary to measure not only the speed, but also the acceleration.

Some drive engineering applications even require triple combinations to fulfill the needs of the control, monitoring and safety functions – in rolling mill drives, for instance, where a digital encoder for positioning, an analog tachogenerator for speed control, and an electronic overspeed switch for speed monitoring are combined into a single unit.

Twin combinations

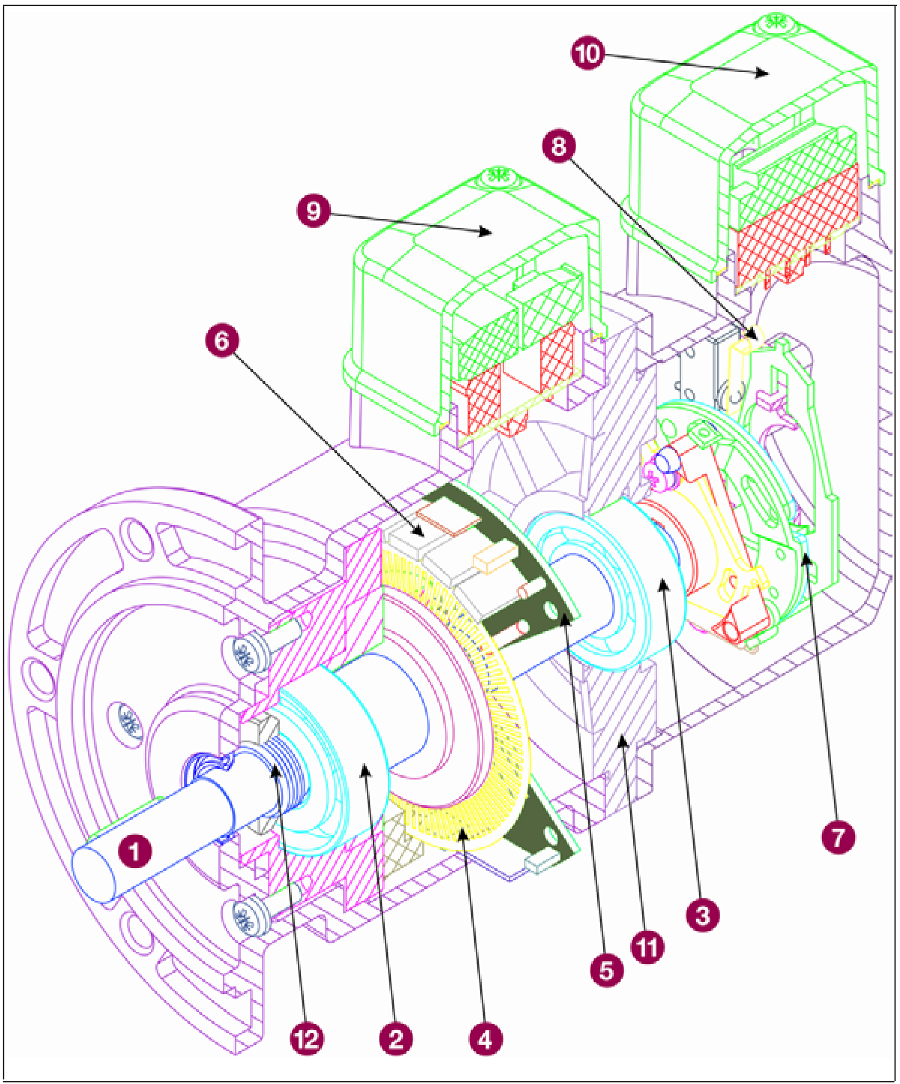
Twin combinations are widely used, and form an important part of the activities of Hübner in Berlin. In crane installations, for instance, they may consist of a speed sensor combined with an speed switch. Another application is in windenergy generators, which must be protected from excessive speeds when running off-load (**Fig. 1**).

Speed switches, which operate on the purely mechanical centrifugal principle, for safety reasons, release a switch when limit speed is reached, thus triggering a safety function. In optical rotary encoders, the shaft normally has a bearing at one end, in other words the encoder disk and the sensor electronics are at the end of the shaft and the overspeed switch would have to be attached as a flying fitting.

However, the tight tolerance of the spacing between the encoder disk and the sensor grid make it impossible to build on centrifugal weights, because when the limit speed is reached they produce a sudden switching impulse that applies a shock to the encoder.

1: Combination of type POG 90 + FS 90 on a wind-energy generator: The encoder measures the speed and the mechanical centrifugal switch monitors the speed limit

Dr.-Ing. Lothar Wilhelmy is CEO and Dipl.-Ing. Kai-Hans Otto is Head of Design at Hübner AG in Berlin



2: The characteristic feature of Hübner combinations is the common shaft with bearings at both ends

Bearings at both ends

Hübner has encoders with bearings at both ends in its product range for more than 25 years. They are notable for being particularly robust, thanks to the optical sensor system being located between the bearings. The free shaft end can be used to mount an additional device, such as the centrifugal weights for a speed switch. **Fig. 2** illustrates this basic principle as a combination of encoder and centrifugal overspeed switch composed of a **POG 9** with a **FS 90**.

The POG 9 encoder is mounted on the shaft (1) between the generously dimensioned ball-bearings (2, 3), with the incremental disk (4), the electronics board (5) and the power transistors (6). The rotor section of the centrifugal switch for monitoring the speed limit is mounted on an extension of the shaft (1). The centrifugal weights (7) are subject to a pre-loaded spring force, but as the speed approaches the limit they suddenly move radially outwards and operate the switch (8). The signals from the rotary encoder and the centrifugal switch are brought out to the terminal boxes (9) and (10) for further processing. The two systems are separated from one another by the internal bearing plate (11). This mechanically and electrically robust HeavyDuty technology, together with the special seal (12), guarantees a high level of enclosure protection that is suitable for the area of application.

The characteristic feature of the combinations described below is that they all consist of a basic device with a common shaft mounted on two bearings, with at least one sensor system fitted between the bearings and an additional device behind the bearing at the free („B“) end of the shaft. Bearings at both ends mean that the system can withstand high radial and axial forces on the shaft. The rigid connection between the devices produces a high degree of torsional rigidity and results in optimum control characteristics.

Mechanical and electronic

It is also possible to mount an electronic overspeed switch onto the basic device, instead of a mechanical centrifugal switch. On the **ES 90** model, the rotor with the centrifugal weights is replaced by a permanent magnet rotor, which produces a speed-proportional 3-phase voltage in the stator windings. This is rectified, and triggers the switching action in the built-in electronics when an adjustable speed threshold is reached.

The rectified voltage is also used as the supply voltage, so that no external power source is required, just as for the mechanically operated centrifugal switch.

With the electronic speed switch, type **ES 93**, that is also used for combinations, a switching action can be initiated on

3: In the FOG 9 + GT 7 combination, digital- and analog technologies join forces for optimal adaptation to a hydraulic drive

4: In spite of heavy dust pollution, the combination of a tacho-generator and centrifugal speed switch (TDP 0,2 + FSL) provides reliableoperation on a web printing press

5: The POG 10G twin encoder, with a B10 Euro-flange and two separate sensor systems, fitted to the drive of a container crane

6: The twin hollow-shaft encoder HOG 10G is also fitted with two separate sensing systems

reaching three different adjustable speeds. This is intended primarily for process control applications rather than for speed limit monitoring. The electronics requires an external power supply, and produces output signals from transistor outputs. An additional relay module can be fitted to provide floating output signals.

Tachogenerators

Tachogenerators perform real-time measurement of the speed, and their mechanical and electrical robustness, together with their wide operating temperature range from –30°C to +130°C continues to make them a very worthwhile type of speed sensor. So it's no surprise that they are also to be found in combinations. **Fig. 3** shows an application where a tachogenerator is built onto a rotary encoder. The tacho monitors the low speed of the hydraulic motor, while the encoder takes care of positioning.

Alternatively, the tachogenerator is the basic device and an encoder or speed switch is built onto it (**Fig. 4**). In this case too, the tachogenerator provides the speed signal and the encoder is used for the positioning task.

As already mentioned, combinations with speed switches are used to monitor one or several speed limits. The list of combinations that is presented in **Table 1** is therefore available, depending on the requirements of the applications:

Basic device		2nd device
Rotary encoder	+	Tachogenerator
Rotary encoder	+	Speed switch
Tachogenerator	+	Rotary encoder or Speed switch

Table 1: Possible combinationen of Rotary encoders and tachogenerators

The combination of a sinewave encoder and an acceleration sensor, intended for precision drives, is undergoing customer trials at the moment. Control-loop requirements mean that particular attention must be paid to the design of the attachment of the acceleration sensor, and this should therefore be undertaken in cooperation with the manufacturer.

Devices with the same technological function but with two electrically separate systems are also combinations in a wider sense. Examples are: twin digital encoders (**Fig. 5**), analog double-tacho-generators, and double speed switches. The signals can be different or the same, to be fed to separate control loops and/or provide redundancy functions, such as monitoring for cable-breaks. In this way, the range of available combinations is expanded as shown in **Table 2**:

Double device		Function
Twin encoder	=	Encoder + Encoder
Double-tacho	=	Tacho + Tacho
Double speed switch	=	Speed switch + Speed switch

Table 2: Possible combinations of double devices

New developments

Up to now we have only described devices with a solid shaft and a flange, whereby the preferred flange is the B10 Euro-flange that has become a standard. More recently, however, devices with a hollow-shaft have become increasingly important, that are attached to the free („B“) shaft end of the drive and prevented from rotating by a torque arm. Combinations with a hollow-shaft are accordingly also available, which are constructed to the same design principles as the solid-shaft versions. **Fig. 6** shows a hollow-shaft twin encoder, to illustrate this type of design.

The triple combinations that were mentioned above also use a common shaft, if the basic device is a double tachogenerator with bearings at both ends, whereby the third device (encoder or speed switch) is mounted on the free end of the shaft. In other cases, the third device is attached to the double combination via a coupling.

Combinations form an important expansion of the spectrum of sensors for drive engineering. In spite of the large number of possibilities that have already been implemented, it is quite conceivable that tailor-made combinations for individual situations will be developed in future, to achieve the optimum engineering results for drives.

Original version in "antriebstechnik 43, (2004) No. 6"