HeavyDuty Absolute Encoders for Drives with Large Shaft Diameters

Ralf Schenk, Bernhard Hiller

Up to now, drives with a large diameter hollow shaft, such as torque motors, have often been fitted with encoders for the acquisition of the rotor position, which are mounted on the side and driven through toothed belts. But this design is heavy on maintenance and not very robust. Absolute encoders that are mounted directly on the shaft offer a solution that is both maintenance-free and stands up to rough environmental conditions. The example of an encoder installed in a high-power shredder plant is used for a detailed explanation of their advantages.

The shredding of waste material and scrap that is required for recycling is a high-tech operation that makes heavy demands on the solidity of all the drive components used in the plant. In order to get an idea of the stresses that have to be withstood by the encoders that are used, we will first of all explain the method of operation and the drive concept for various commercially available systems [1].

The heart of a shredder plant is usually a large-diameter rotor shaft made from solid steel, which can weigh several tons. The rotor body is fitted with replaceable tool bits, with a size, shape and quantity adapted to the material to be shredded. The shaft is mostly driven by an electromechanical drive, consisting of an asynchronous 3-phase motor, a turbo-clutch and a belt drive or universal-joint shaft with a gearbox. Very large systems generally use an electro-hydraulic drive. However, both concepts involve disadvantages.

The components that are required for a hydraulic solution make it very expensive: it needs an electric motor to drive the hydraulic pump, a hydraulic motor to drive the actual machinery, as well as piping and hose installations for hydraulic oil and the cooling water feed. Not only that, but hydraulics is heavy on maintenance and has a poor level of efficiency.
Drive units fitted with asynchronous motors and output gearboxes, which are used in large numbers, also have their weaknesses. This is because the material being shredded frequently contains massive lumps that can only be broken up with great difficulty. Again and again, they suddenly bring the shredder rotor to a complete standstill – even though the

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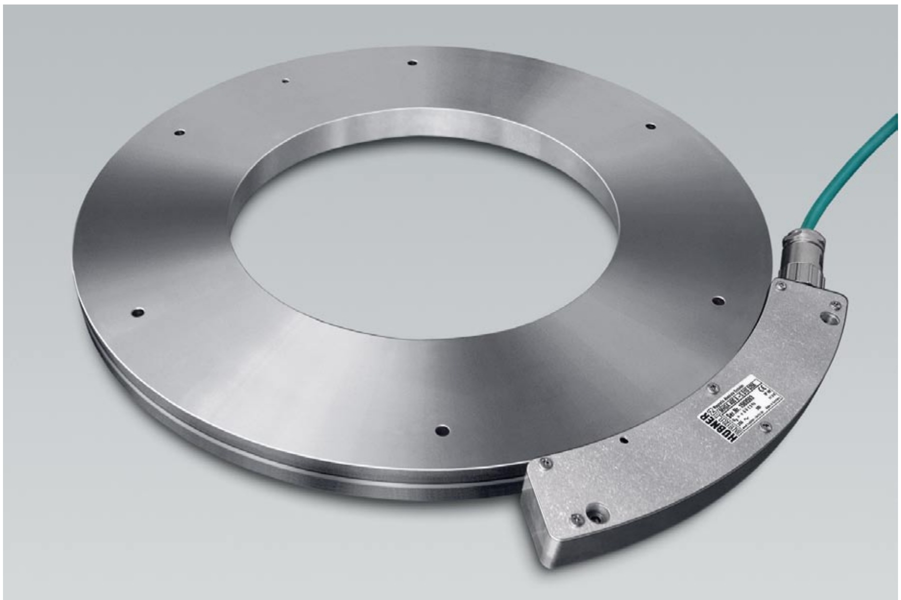


1: Encoder wheel and sensor head

drive motor is adequately dimensioned. These blockages can indeed be removed by an automatic reversal built into the machine control system, so that the rotor moves backwards and forwards repeatedly until the interfering lumps have been broken up. But one can easily imagine that the drive components (motor, gearbox and clutch) suffer severe shock loading in the process, as fast-rotating components have to be braked rapidly to avoid damage to the machinery. And this freeing cycle generated by the automatic reversing puts a heavy strain on the drive components.

New drive concept for shredder plants

A new drive concept is implemented in the plant shown in the **title picture**. The picture is to be interpreted as follows: the scrap material is fed in from above on a conveyor belt, which distributes it between two separate shredder units. The shredded product is passed on to conveyor belts that are fitted at the side. The new feature of this machine is: the application of specially designed torque motors (with a torque up to 15000 Nm) that can apply the necessary torque directly to the drive shaft over the entire speed range. This saves having a gearbox, in other words: a major heavy-wear item is no longer required. Since the magnetic field between the armature and the housing of the torque drive does not form a rigid mechanical connection, shocks are no longer fed back to the drive. The shredder plant can be run much more economically with a dynamic torque motor, but the permanently excited multi-pole synchronous drive requires precise, uninterrupted and absolute position information for commutation. And so a new challenge has appeared: how to achieve reliable acquisition of the position of a hollow motor shaft with a diameter of up to 300 mm. This is described in detail below.

Up to now, drives with a large diameter hollow shaft have often been fitted with absolute or incremental encoders for the acquisition of the rotor position, which are mounted on the side and driven through toothed belts. However, this solution involves several disadvantages. The belt is subject to heavy wear, especially in arduous operating conditions. It also has to be replaced at regular intervals, thus causing a down-time for the system. In addition, suitable tensioning equipment has to be brought along for the maintenance work. The position information required for commutation is thereby lost, and has to be re-established with the help of special equipment before the system is commissioned again, thus making the maintenance operation even more involved. And there are well-founded fears that, in extreme cases, the shock loading could cause the toothed belt to jump over several teeth on the pinion. Furthermore the rotary movement is transmitted to the shaft of the encoder, and its ball bearings are subject to above-average wear, because they have to withstand high radial forces.

Innovative encoder solution

A maintenance-free and much more robust solution is provided by the absolute encoders developed by Baumer Hübner, with a large-bore hollow shaft and magnetic sensing. They consist of an encoder wheel, which is mounted directly on the drive shaft, and a separate sensor head that is bolted firmly onto the motor housing (**Fig. 1**). Two tracks (elastomer strips) that have embedded magnetic patterns are to be found on the outer face of the encoder wheel. These are detected by sensors that are mounted in the sensor head. **Fig. 2** shows the encoder that was built into the shredding plant. Integrated signal processing is used not only to derive the absolute information, but also to simultaneously generate incremental sin/cos signals for dynamic control of the system. If necessary, the elastomer strips can be covered by a special stabilizing bandage, to provide additional protection.

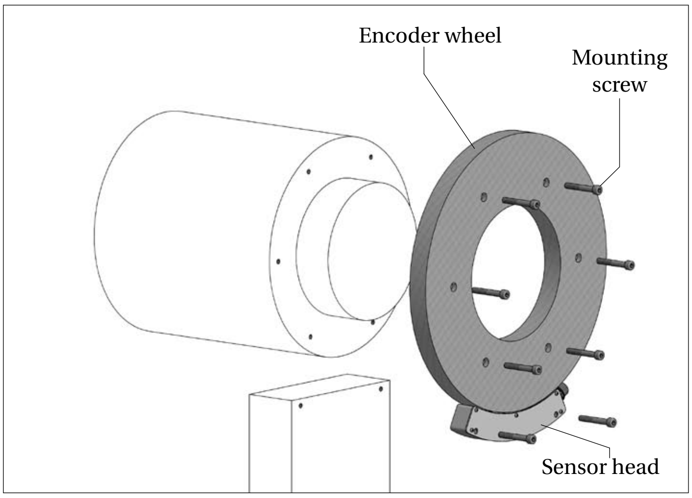
A lot of know-how went into it

Although the encoder has a very simple construction, it nevertheless required quite a bit of development work to match up the materials (encoder wheel, elastomer strip) and the magnetization method to one another in such a way that it not only ensured the mechanical robustness that was required, but also permitted a generous clearance between the encoder wheel and the sensor head. For instance, the encoder type that is used in the shredder plant permits a radial gap of 1 mm and an axial displacement of +/- 1 mm. This is considerably more than for other commercially available magnetic encoders, but in this case it was absolutely necessary in order to allow for the thermal expansion and bearing movement that arises in operation. In the final result, there must be no possibility of a crash between the encoder wheel and the sensor head, and the measurement acquisition must not be interrupted if the path of the encoder components drifts a little. Initial fears of a possible weak spot proved to be unfounded: stray magnetic fields do not, in practice, appear to be

2: HeavyDuty absolute encoder on the torque motor in the shredder

any problem. For although these encoders have, in the meantime, been fitted to a considerable number of large torque motors, always being mounted close to the motor end-plate, not a single case has become known where measurement acquisition has been disturbed by the magnetic field of the motor, or where the measurement has been falsified. Only in the event that ferromagnetic particles are present would it be advisable to provide a protective covering, to prevent such particles from accumulating on the outer surface of the encoder wheel.

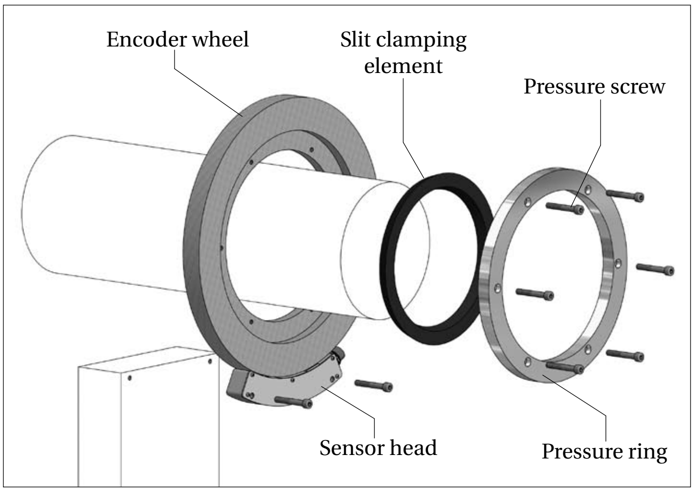
3: Encoder wheel bolted directly onto the face of the shaft shoulder



Various mounting options

The encoder wheel can be mounted on the shaft in various ways. In this example, screws were used to fix it onto the front end of the motor shaft (**Fig. 3**). Clamping rings or clamping fixtures (**Fig. 4**) are available as alternatives. Or the wheel can be shrink-fitted. Whichever method is used, the result is a very compact arrangement for the encoder, with a short fitted length – in spite of the large diameter. There are not moveable parts in the sensor head to be subject to wear, and it is fully encapsulated with a special compound. This means that it can not only withstand extreme vibration and shock loading, but also has a high level of enclosure protection – up to IP 68.

4: Encoder wheel mounted with clamping fixtures



A spacing gauge that is included in the delivery package can be used to position the sensor head, simply and quickly, and then fix it with screws. By the way, in the torque drive that is shown here, the vibration that occurred was so strong that, at first, the sensor head kept on shifting slightly in operation, even though substantial bolts had already been used to screw it onto the motor end-plate. This initial problem was cured by the additional use of alignment pins.

In addition to shredder plants, the absolute encoders presented here are also, for instance, in operation on test beds and injection molding machines. Furthermore, they are predestined for drive machinery with large-hole hollow shafts, such as are indispensable for tool clamping devices or rods.

Features of the magnetic absolute encoders at a glance
- suitable for very large shaft diameters
- compact dimensions, very short axial fitted length
- very robust and free from wear, as they have no bearings and the electronics is completely embedded in the sensor head
- extremely high vibration and shock resistance
- insensitive to dirt, high enclosure protection level up to IP 68
- wide operating temperature range
- large permissible spacing between the encoder wheel and the sensor head
- simple, fast installation
- easy adaptation to existing fittings

Literature:
[1] Wolfgang Lipowski, Johannes Oswald: „Effizient zerkleinern - Torque-Motoren optimieren Zerkleinerungsmaschinen“ published in: A & D Fachzeitschrift für industrielle Automation, February 2006

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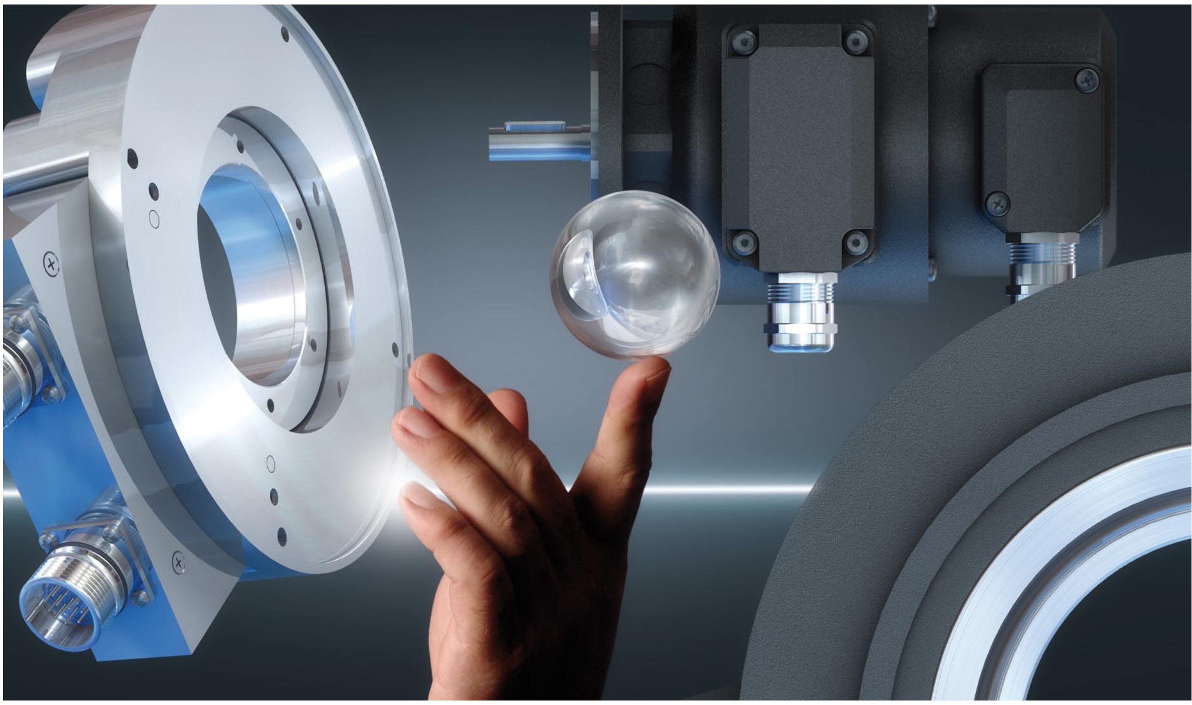
HeavyDuty Sensors for Drive Technology

Motion Control



Baumer Hübner's domain is where movement is controlled. Sensors which are intrinsically designed for extreme industrial applications show their benefits particulary in rugged operation, such as extreme ambient conditions. Baumer Hübner Components for drive technology have contributed greatly to the quality and reliability of machines and heavy equipment – worldwide and over many decades. Let's talk about *your* drive task.

2006 Absolute Encoders without gearbox and without battery, Programmable Digital Speed Switches

2005 Analyzer for Encoders

2004 Precision Interpolators

2002 Magnetic Encoders with hollow shaft up to Ø 690 mm

2001 Absolute Encoders in HeavyDuty Technology

1998 Ferraris Acceleration Sensors: linear/rotary in patented technology

1995 Sine Encoders: Sine signals with an especially low harmonic content – the standard for precision

1989 Explosion Proof Devices: Labelled »II 2 G EEx de IIC T6 resp. T5« (ATEX 95)

1982 Combinations: Incremental Encoders, Tachogenerators and/or Speed Switches in one single housing with common shaft

1978 Incremental Encoders in HeavyDuty Technology: rugged electrical and mechanical construction

1970 Speed Switches: mechanical (centrifugal) or electronic with internal or external power supply

1955 Tachogenerators: Their rugged construction provides the foundation for HeavyDuty Technology

1934 Foundation of the company in Berlin

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