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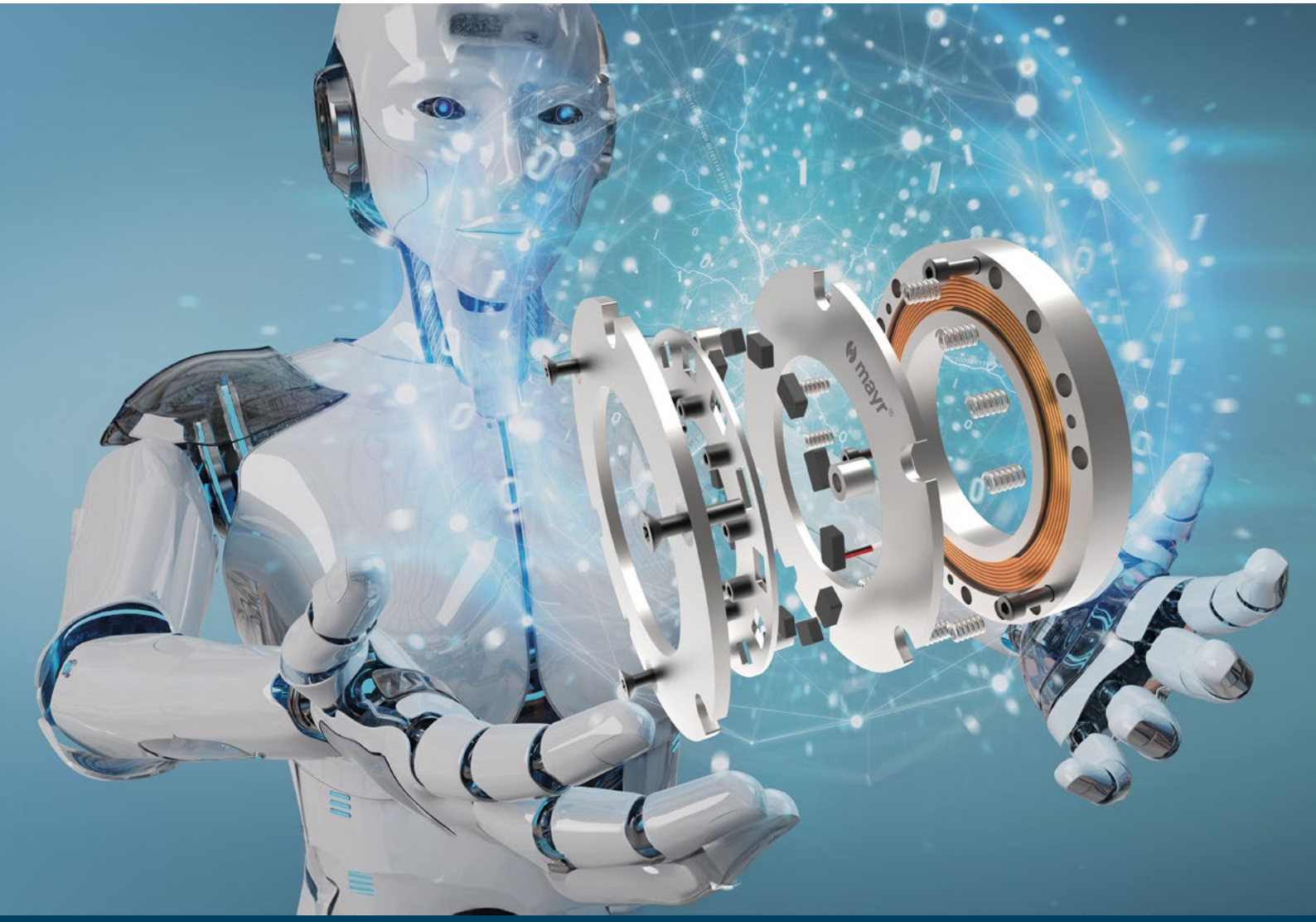
COMPACT SAFETY BRAKES

FOR LIGHTWEIGHT ROBOTS AND SERVO AXES



ready for installation – flexible – cost-effective

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Summary

Devices for deceleration in an emergency and for stopping and locking the axis when the drive is at a standstill are essential aspects of the safety concept for collaborative lightweight robots. Ready-to-install, spring applied safety brakes are best suited for this purpose. They can be integrated easily and flexibly into the drives of robot joints.

Thanks to their excellent idle running properties, their low weight, their low mass moments of inertia and their high performance density, they are the technically perfect and economical solution for all types of lightweight robots – from articulated arm robots, Delta and SCARA robots to mobile robots and driverless transport vehicles.

CONTENT

1. Development and use of lightweight robots

Collaborative robots (cobots) are designed to work side-by-side with human employees to improve the efficiency, flexibility and safety. Many cobots are lighter and smaller than conventional industrial robots. This makes them more flexible and easier to integrate into different working environments. The programming of cobots is often intuitive and user-friendly. This means that employees without extensive knowledge of robotics can also work with them. Many models can also be taught by manually guiding the robot arm.

However, in order to ensure safe collaboration, it is necessary to comply with the relevant safety standards and guidelines. Depending on the application, i.e. depending on how the human-robot collaboration takes place, many cobots are equipped with sensors – for example for forces and torques – or with image processing systems that allow them to recognize and react to human movements. Other key elements of the safety concept are components that quickly and safely bring the robot's movements to a standstill in the event of a power failure or an emergency stop. Spring-applied safety brakes have proven their worth here since their first use in the lightweight robot LBR II, which was developed by the German Aerospace Center (DLR) more than 20 years ago *(Fig. 1)*. At the time, standard brakes were modified at great expense to reduce installation space and weight as much as possible *(Fig. 2)*

Modern safety brakes for lightweight robots, such as for example the ROBA®-servostop® Cobot *(Fig. 3)*, are specially tailored to the needs of robot axes. They feature an extremely compact design, low weight and mass moment of inertia as well as optimized performance values.

The cooperation between humans and robots is becoming increasingly closer. The use of lightweight robots is advancing in all important industrial branches. They are used in many different industries, including manufacturing, logistics, healthcare and more. They can take on tasks such as handling materials, assembly, packaging, inspection and even care tasks and medical treatments.

Figs. 1+2: Spring applied brakes already ensured the safety of the first lightweight robots (in this case from the year 2000) of the German Aerospace Center (DLR).

Fig. 3: The ROBA®-servostop® Cobot is specially tailored to the needs of robot axes.

2. Lightweight robot designs

Lightweight robot designs vary depending on the requirements and the application. Cobots are often designed as robotic arms. These arms have multiple joints and degrees of freedom of movement to perform a wide range of tasks *(Fig. 4)*.

Delta robots feature characteristic parallel kinematics and are often used in applications that require high precision and speed. They are able to complete tasks such as pick-and-place in a short period of time. SCARA robots (SCARA = Selective Compliance Assembly Robot Arm) have a horizontal, flat design and are often used in assembly and packaging applications. They are known for their speed and precision. Other lightweight robots are mobile and can move freely *(Fig. 5)*.

This type of robot is often found in logistics, warehouses or in environments where autonomous navigation is required. Lightweight robots, which are designed as modular systems, allow different modules to be combined to create different configurations for various tasks *(Fig. 6)*.

This ensures a high degree of flexibility when adapting to specific requirements. The lightweight robot designs are constantly being further developed to meet the changing requirements in the different industries. In general, the aim of the developments is to make robots even safer, more efficient and more user-friendly.

Fig. 4: Cobots can have multiple joints and degrees of freedom of movement to perform a wide range of tasks.
Source: Robco

Fig. 5: Automated guided vehicles take on a variety of tasks in material flow and warehousing.

Fig. 6: Lightweight robots, in which different modules are combined, are flexible when it comes to adapting to specific requirements.
Source: Robco

3. Safety thanks to braking/holding devices

Safety does not allow for compromises – for this reason, lightweight robots must come to a standstill as quickly as possible in the event of an emergency or safety stop and must not move in an uncontrolled manner after the power is switched off or in the event of a power failure. This is particularly true for cobots, which often cooperate directly with humans without a safety fence.

Two fundamentally different construction solutions have become established on the market to stop movements as quickly as possible in an emergency.

3.1. Locking mechanisms

There are locking mechanisms with a downstream friction system, which are sometimes also referred to as pin brakes *(Fig. 7)*. In this solution, a locking disk or star wheel is firmly connected to the hollow shaft of the robot axis. When the brake is de-energized, this locking disk is locked in place by a locking pin, which basically functions like a lifting magnet. When energized, the pin is attracted and thus releases the locking disk, allowing the axle to rotate freely. When the power is switched off, the pin drops into place and abruptly blocks the locking disk. An additional friction mechanism is designed to soften the impact and thus take over the braking.

Fig. 7: Schematic layout of a pin brake. A locking pin locks the locking disk, which is firmly connected to the hollow shaft of the robot axis

The “lifting magnet” of the locking pin has a low energy consumption. In addition, the locking pin takes up little space and is very lightweight. However, these advantages are also offset by serious disadvantages. The engagement of the locking pin and the associated start of the deceleration depends on the shaft position and the speed. Under certain circumstances, the resulting torsional backlash might cause the axle to run free for an unacceptably long time.

Another disadvantage of pin brakes is their design. There are no ready-to-install designs available on the market. Design engineers have to put together a customized solution from different components, such as a locking pin, locking disk and friction mechanism. Furthermore, they have to familiarize themselves with friction technology and carry out all the necessary tests in order to know the suitability, properties and limits of the product.

3.2. Safety brakes

By contrast, the lightweight safety brakes in the ROBA®-servostop® series are specially adapted to the needs of robotics and come ready to install *(Fig. 8)*. As technically perfect solutions, they are easy to integrate into the design of robot joints. These spring applied, electromagnetic safety brakes, which operate according to the fail-safe principle, permanently and reliably prevent the load from dropping unintentionally in the event of an emergency stop, power failure or other interruption to the power supply, and also prevent unacceptably long stopping distances. Furthermore, this brake is suitable for use as a safety-related component: It fulfills the requirements of category 1 according to EN ISO 13849-1 as a proven component and, in addition to the B10d characteristic values, a validation aid is also provided.

In de-energized condition, several thrust springs located in the coil carrier press against an armature disk. The springs with a coil distance which is smaller than the wire diameter are designed in the dynamic fatigue strength range. The rotor or a rotor disk with friction linings is held and braked between the armature disk and friction flange by the secure spring force. The rotor toothing or a screw connection transmits the braking torque onto an externally toothed hub or shaft. When voltage is applied to the magnetic coil of the brake, a magnetic field builds up which pulls the armature disk against the spring pressure to the coil carrier. The brake is released, and the shaft can rotate freely.

When developing the brakes, particular emphasis was placed on short switching times so that the braking distance is reduced to a minimum in the event of a power failure or emergency stop. The braking torque is generated through special organic friction linings, which were specially selected for this application after extensive testing. These temperature-resistant linings can even be used at high ambient temperatures of up to 120 °C and are characterized by a high, uniform friction coefficient. They ensure a stable static and dynamic braking torque with low tolerances. Furthermore, brakes with these special linings stand out thanks to their high permitted friction work during dynamic braking actions. For servo drives, normally load mass ratios (load/motor) of 3:1 or smaller are selected for the benefit of good control characteristics and high dynamics. With ROBA®-servostop® brakes, load mass ratios of 30:1 and more are possible thanks to the high permitted friction work and friction power.

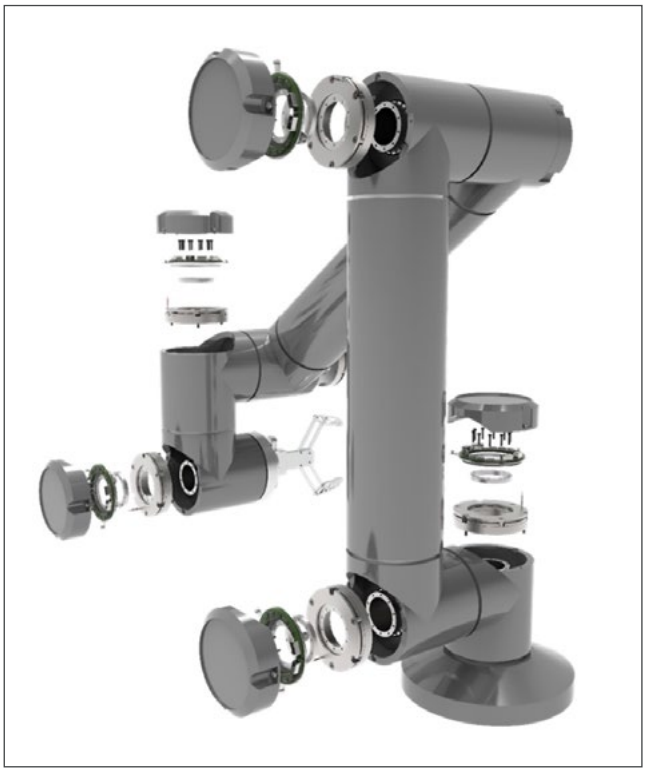

Fig. 8: ROBA®-servostop® safety brakes are ready-to-install and easy to integrate into the design of robot joints.

These servo brakes are characterized by compact dimensions. They are very lightweight and extremely fast when it comes to magnetic actuation. The simple and robust construction allows safe and reliable installation. The operating air gap is factory-specified. The ROBA®-servostop® brakes always work precisely and reliably; the magnetic air gap is neither influenced by the mechanical installation situation nor by bearing backlash or temperature expansions.

Before delivery, safety brakes from the ROBA®-servostop® series undergo a 100% final inspection at the factory. All important technical properties such as spring force, air gap, attraction and release tension are recorded, documented and permanently assigned to the serial number. A high-voltage test is additionally carried out. The delivery status of each individual brake can therefore be traced back at any time. If the brakes are used in demanding applications, further tests (e.g. braking torque and switching time measurements) are carried out.

3.2.1 Variable solutions based on the modular system

The ROBA®-servostop® modular system provides customized solutions for a wide variety of installation situations. There is a choice of servo brakes with hub and toothed rotor, in classic or slim design. They are preferably used in the field of conventional servomotors. The ROBA®-servostop® Cobot is an optimized, slim and lightweight variant for lightweight robots. This so-called pad solution has a very large inner diameter and is specially designed for integration into robot joints. But also the classic brakes with hub and toothed rotor can be customized and integrated directly into a joint.

Servo brakes are the preferred choice for installation into the A-bearing shield of a motor, because the fixed bearing is located here and temperature expansions cannot influence the brake severely. Safety brakes of the ROBA®-servostop® Classic *series (Fig. 9)* can also be integrated into the B-bearing side of the motor without restriction. The Classic series features high braking torques of up to 100 Nm and is particularly wear-resistant. A large number of dynamic braking actions, caused for example by emergency stops, is permitted.

ROBA®-servostop® Lean is a slim series, also designed for installation into the A or B bearing shield of servomotors *(Fig. 10)*. The small space requirement resulting from the short design makes installation easier. A striking feature of this series is the high cable density combined with low energy consumption.

When it comes to lightweight robots, a hollow-shaft design is usually preferred for the cable feed-through in the interior, so that no external cables interfere and impair safety. The ROBA®-servostop® Cobot series can be perfectly integrated into such designs thanks to its construction *(Fig. 11)*. These brakes were specially developed for use in lightweight robots. With their very large inner diameter, they are perfectly suited for connecting hollow shafts. The low space requirement, reduced weight and low mass moment of inertia also make integration into robot joints easier. Thanks to the low weight of the friction lining pads, these servo brakes also score points for their excellent idle running properties.

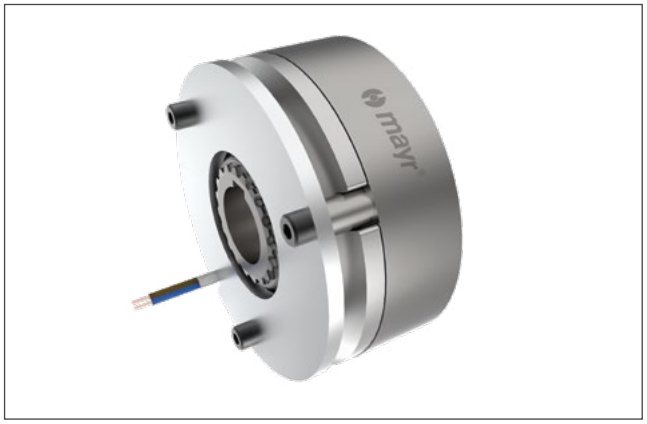

Fig. 9: ROBA®-servostop® Classic –Tried and tested safety brake for installation in the A or B bearing shield of servomotors
Nominal torques from 1.5 to 100 Nm
Max. speed values up to 9500 rpm

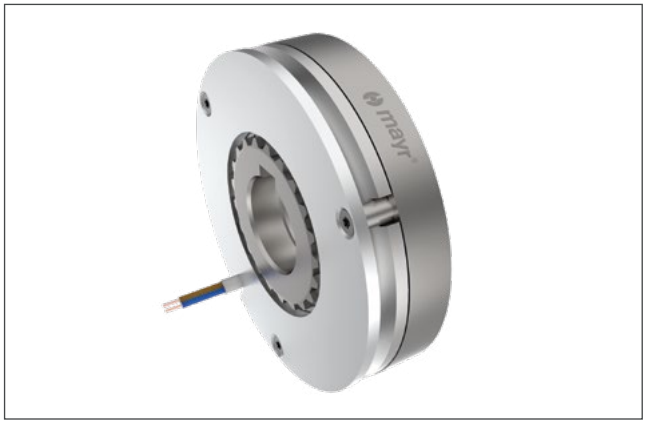

Fig. 10: ROBA®-servostop® Lean – Slim servo brake in a classic design – Nominal torques from 0.31 Nm to 11.5 Nm
Max. speed values of up to 10500 rpm

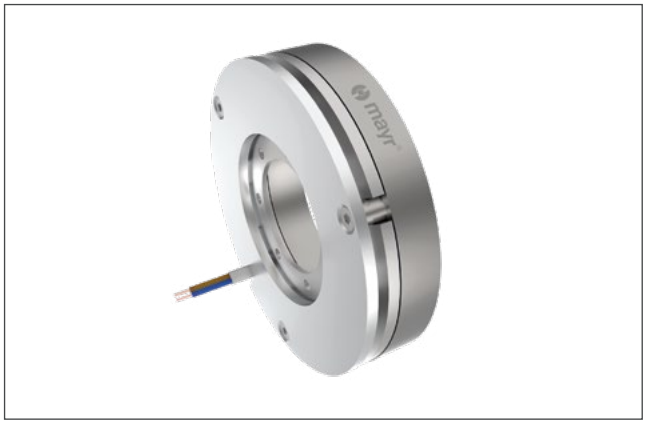

Fig. 11: ROBA®-servostop® Cobot – The proven series for lightweight robots, which can be integrated into even the smallest installation spaces
Nominal torques from 0.23 to 9 Nm
Max. speed values of up to 10500 rpm

3.2.2 Installation variations

Brakes from the ROBA®-servostop® series are ready-to-install, tested complete systems. When mounting via the coil carrier facing side, the brake is screwed on via through-holes in the coil carrier and threaded holes in the customer's attachment part, e.g. the bearing flange *(Fig. 13)*. When mounting via the coil carrier rear side, the customer-side attachment part features through-holes; the threaded holes are in the coil carrier of the brake *(Fig. 12)*.

Brakes in the ROBA®-servostop® Classic and ROBA®-servostop® Lean series are equipped with an aluminum rotor with friction linings and a toothed hub. The braking torque is transmitted via the internal toothing of the rotor onto the hub and via a key connection from the hub onto the shaft *(Fig. 14)*. Instead of a rotor and hub, the ROBA®-servostop® Cobot is equipped with a rotor disk with recesses in which the friction lining pads are guided *(Fig. 15)*. This rotor disk is screwed to the shaft or the hollow shaft at the facing end *(Fig. 12)*.

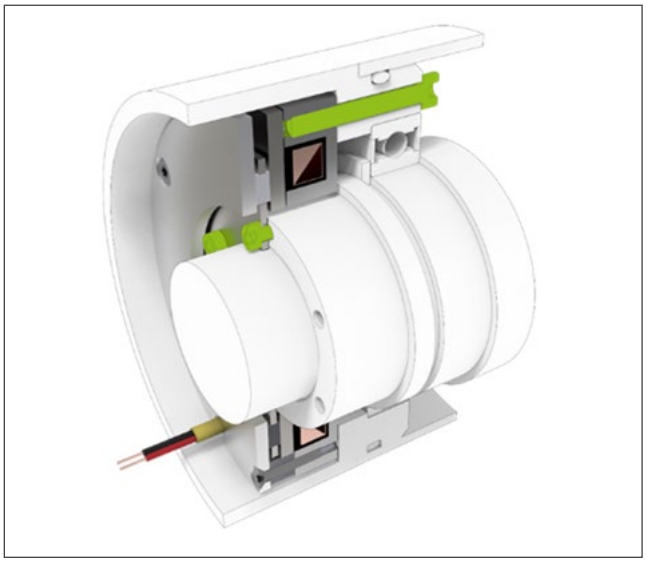

Fig. 12: Mounting the ROBA®-servostop® Cobot via the coil carrier rear side

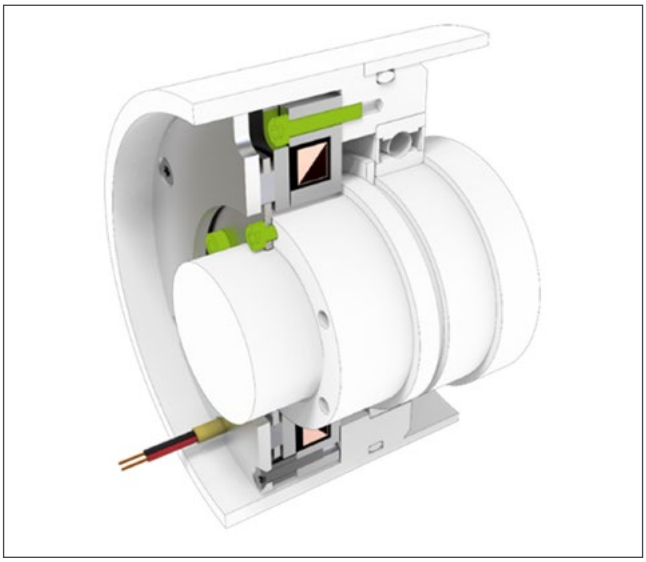

Fig. 13: ROBA®-servostop® Cobot – Screwed on via the coil carrier facing side and facing-side screw connection of rotor disk and shaft

Fig. 14: The braking torque is transmitted via the internal toothing of the rotor onto the hub and via a key connection from the hub onto the shaft

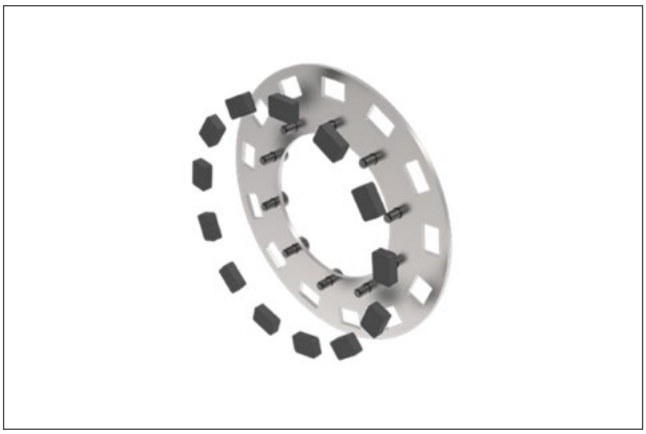

Fig. 15: Instead of a rotor and hub, the ROBA®-servostop® Cobot is equipped with a rotor disk with recesses in which the friction lining pads are guided

3.2.3 Sensorless monitoring and supply of servo brakes

Reliable monitoring solutions are important for the safety of people and machines. Previously, servo brakes were very difficult or impossible to monitor due to the small air gaps or their installation situation. Thanks to the ROBA®-brake-checker, there is now an intelligent module that can monitor servo brakes without sensors and supply them with energy at the same time *(Fig. 16)*. The module releases the brake by applying overexcitation voltage and, after a defined time in which the brake is open, reduces it to a reduced holding voltage, for example from 24 VDC overexcitation to 8 VDC holding voltage. This reduces the power consumption of the brake coil drastically, for example from 20.7 W to 2.3 W with the ROBA®-servostop® Cobot, Size 40.

The ROBA®-brake-checker detects the movement of the armature disk through extended analysis of current and voltage, and knows what condition the brake is in, i.e. whether it is closed or released. In addition to monitoring the switching condition and critical coil temperature, the module also performs preventative function monitoring for wear, functional reserve and malfunctions. In an extended version, the ROBA®-brake-checker module is equipped with an additional PCB with a customer-specific interface (e.g. Ethernet based). Via this interface, it can provide data on the switching time, current, voltage, resistance, performance und relative attraction current. This means that processes can also be evaluated. Anomalies in the process can be detected quickly and conclusions can be drawn from complex interrelationships. Furthermore, integration into remote maintenance systems is also possible.

The supply monitoring module operates from the control cabinet, i.e. in a protected environment. This is a considerable advantage, for example for ground-level drives in driverless transport vehicles. Dust and dirt do not influence the reliable function of the module. Sensors and microswitches, on the other hand, might generate false signals due to contamination and would have to be checked or cleaned from time to time. The elimination of sensors including cabling, particularly in unprotected areas, therefore increases reliability and prevents downtime caused by faulty sensors.

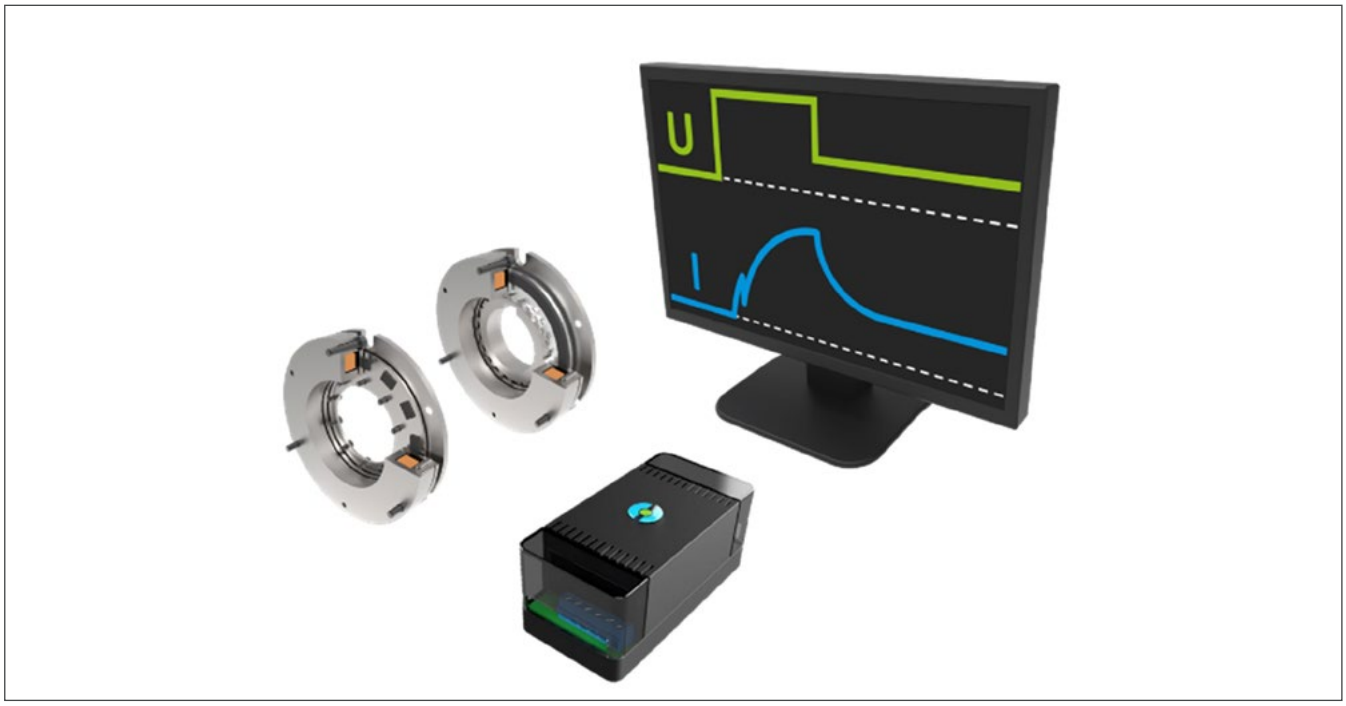

Fig. 16: The intelligent ROBA®-brake-checker module is able to monitor servo brakes without the use of sensors and also supply them with energy.

3.2.4 Selection and dimensioning

mayr® power transmission provides all the data required for the dimensioning and selection of the ROBA®-servostop® series. This includes the definition of the braking torques, switching times, mass moments of inertia, friction work in the event of an emergency stop, the number of permitted emergency stops under various application conditions, or even information on the geometric connection. Furthermore, the company supports users when it comes to the safety assessment in accordance with the EN ISO 13849 standard, for example by providing the B10d values for determining the performance level.

The Mauerstetten-based brake specialist *mayr*® power transmission can draw on more than 50 years of experience in the development, production and application of safety brakes and provides competent and comprehensive support when it comes to selecting and dimensioning application-optimized servo brakes. Additionally, the product configurator on www.mayr.com - the company website - provides a convenient selection and dimensioning tool as well as approval drawings and CAD files for the design *(Fig. 17)*.

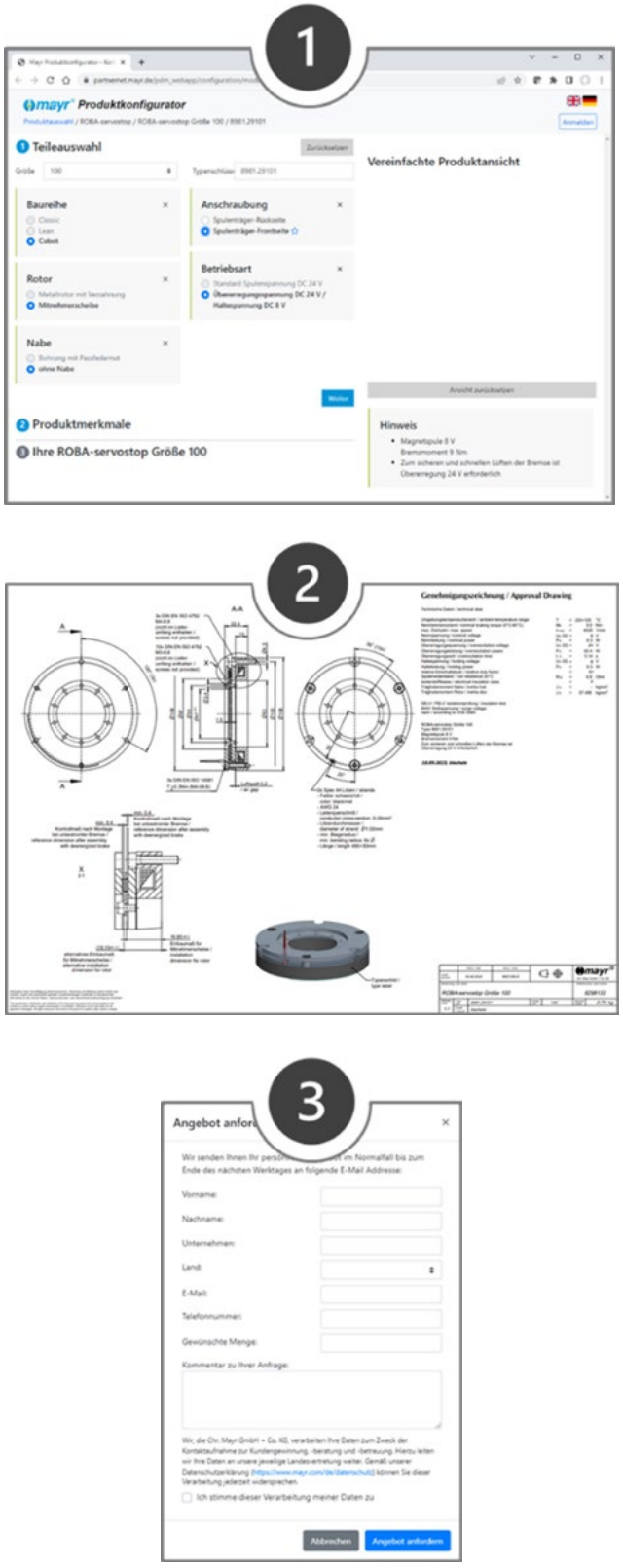

Fig. 17: Product configurator for selecting and dimensioning servo brakes from the ROBA®-servostop® series

Checklist: Purchasing servo brakes

- Define the requirements on the safety brakes as precisely as possible based on the technical data of your drive and the drive constellation. Carry out an application test and make sure that the selected brake fits the ambient conditions which actually prevail in practical applications.

- Ensure that the safety brakes are also suitable for dynamic braking actions and have been tested under realistic conditions. Please also enquire here about the testing possibilities of the manufacturer.

- Make sure that the supplier carries out a 100% final inspection, including the automated storage of all test data. For gapless traceability, the brakes must also be labelled with a unique serial number.

- Check the response times of the brake (attraction/drop-out). You can only achieve short, reliable stopping distances using a quick brake and consistant switching times throughout the service lifetime.
  Make sure that the supplier provides safety parameters for their brakes.
  You need these values for your safety review.

- Make sure to rely on manufacturers with experience in the development of lightweight brakes. Ask for a consultation to see the differences.

Company profile

In 2022, *mayr*® power transmission, the renowned family business from the Allgäu region in Germany, celebrated its 125th company anniversary. A glance at the company history reveals that stability is a central component of the corporate philosophy. After all, the values of safety and reliability are not just an advertising slogan for the products.

The company, which was founded in 1897, is today a leading manufacturer of safety brakes, torque limiters and shaft couplings. These products are primarily designed for application in electrically driven machines and systems. They can be found, amongst other things, in filling plants, machine tools, packaging and printing machines as well as in elevators, wind power plants and in the stage technology. The company is active in over 60 branches worldwide. Currently, approximately 750 employees work at the headquarters in Mauerstetten, in the Allgäu region. Worldwide, *mayr*® power transmission has more than 1350 employees.

The company runs two additional production plants in Poland and China and is currently setting up a branch office in India. With subsidiaries in the USA, in France, Great Britain, Italy, Singapore, Japan and in Switzerland as well as around 40 additional country representatives, *mayr*® power transmission has a global presence.

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