Safety First - Reliable Brakes For Latest Elevator Designs

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Key Words: Electromagnetic Brakes, fail safe brakes for elevators,

ABSTRACT

When it comes down to passenger safety and reliability, there is hardly a more important component in elevators than brakes. However, in advanced elevator designs, with gear-less drive technology and no machine room, the traditional, proven drum brake design can hardly suffice all the new requirements. Innovative disk brake designs have been introduced to the market and are rapidly being accepted as the preferred choice for new and traditional designs. This paper introduces the new designs, explains the benefits and points out important details of alternative designs. After all, if there would be only one component that deserves your full attention for reliable quality, it must be the brakes.

INTRODUCTION

For a long time, the market for drive systems and brakes in elevators has favoured very traditional designs, with only gradual evolution. However, in recent years many factors triggered design changes that are revolutionising the way elevator drive systems are being built. This paper shall introduce innovative brake designs, compare them in reference to their special features, explain the critical factors that must be considered and thus help you to become a more knowledgeable decision maker when you have to select a brake for your next generation elevator.

What triggered the search for alternatives to traditional drum brakes ?

When I have been visiting a US elevator sales and service company some years ago, I had an opportunity to visit their shop floor, where numerous drive units were sitting, waiting to be refurbished. I was amazed to see these fairly old units, but I was also astonished how little change has happened to these drive systems over the last 50 years or more. They were built with electric motors, a worm gear and a drum brake. Obviously, the efficiency and the quality of similar drive systems have changed over the years, but the principal concept has been kept the same for all this time and many of these drive systems are still in the field. ***(Figure 1)***

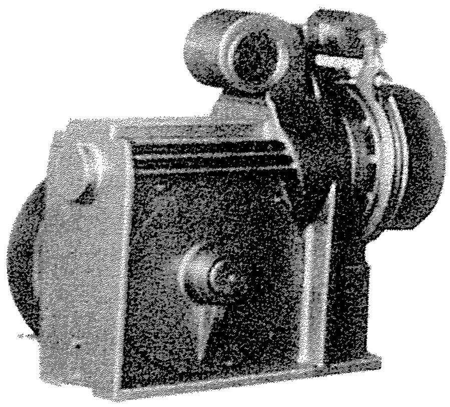


Figure 1.
(Conventional warm gear drive with drum brake)

With the awareness of limited energy resources and a stronger focus on minimising operating cost, increasing efficiency and minimising physical size was a target with all new drive developments. When the planetary gears ***(Figure 2a+b)*** came to market, first initiatives have been started to replace the traditional drum brake design.

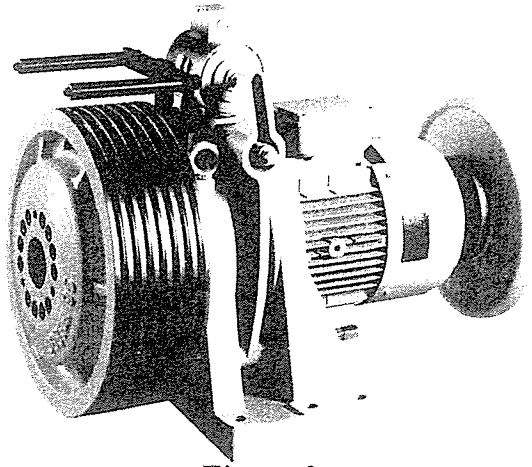


Figure 2a.
(Planetary gear with drum brake)

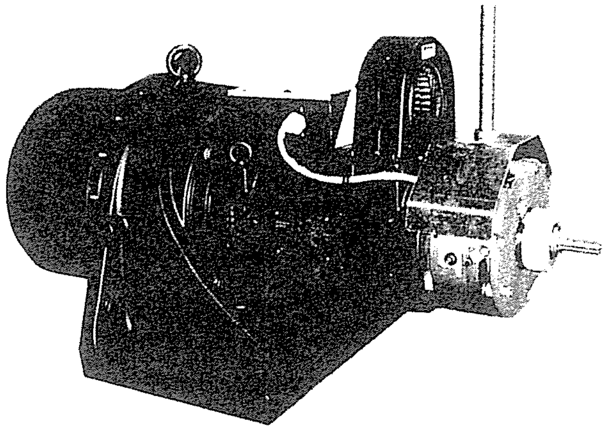


Figure 2b.
(Planetary gear with ROBA-stop®-Z disk brake)

(The substantially lower inertia of disk brakes compared to drum brakes, which allowed using smaller motors, was one of the reasons to consider alternative brake designs. But the real changes in brake designs came about when gearless drives became more cost attractive and Kone came to market with the idea of a machine roomless elevator.
Especially the machineroom-less design, required brake performance criteria that has been irrelevant as long as there has been a machine room with plenty of space and relatively far away from the floors occupied. It soon turned out, that conventional drum brakes cannot match all these new requirements.

Drum brake - preferred choice in the past
Over the last decades, the compact design of electromagnetic disk brakes has been the preferred choice in manifold drive applications except for elevators. Large torque requirements and heavy friction work as previously prevalent in elevator applications would favour the cost effective drum brake design. However, with the introduction of inverter controlled drive systems, the brake is no longer required to take heavy friction work with every stop of the elevator, but the motor positions the elevator and the brake acts only as a parking brake. The capacity for high friction work is only required for a rare number of emergency-stops. What kept the drum brakes' attractiveness for the elevator market, were other things: Drum brakes offer an attractive cost per Nm braking torque and a drum brake can easily be checked for air gap and wear of brake linings, because of its open design. In case a lining is worn out it could be replaced easily. The most important reason for the drum brakes' attractiveness, however, was a construction that provides a simple way for dual circuit design. A conventional drum brake has two independent brake shoes, therefore malfunction of one brake shoe does not lead to catastrophic failure of the brake. But the simple design of drum brakes also has its downsides and this has invited alternative designs to the elevator market.
Drum brakes are a bulky piece of equipment. It is not easy to keep the tolerances for air gaps and temperature changes in drum brakes and this makes it necessary to operate them with relatively large strokes to release the brake completely. This results in negative impacts on reaction times and noise.

Innovative Elevator designs require advanced performance

When innovative elevator designs are mentioned, the author refers not necessarily to gearless designs or machine roomless designs. Today disk brake designs are also a common solution with gear drives. Even though innovation has been triggered by gearless designs, the benefits of these new brakes have been quickly accepted for conventional gear driven units, even with machine rooms. Following shall illustrate what the requirements of todays elevator designs are:

Current regulations require protection against upward motion

In many industrial countries, the current regulations for elevator designs, such as EN 81, 95/16EG do require that brakes have a dual circuit functionality. Dual circuit functionality is a redundancy of all critical components of the brake. In case one braking circuit fails for any reason, the other brake circuit must be capable to stop 125% of the rated max. load of the elevator. Moreover, brakes need to be installed close to the sheave, so fraction of intermediate shafts cannot cause catastrophic failure. Stawinoga reports in his findings (Stawinoga 1997) that, 50% of the unwanted movement of elevators is due to the link between brake and traction sheave. The requirement to install brakes as close to the sheave as possible introduced specific requirements in reference to space and mounting.

The accidents with unintended upward motion also caused a change of the regulation. (Schiffner 1991) There has to be a safety device to protect against this problem. This safety requirement can be met with the same brake, but in this application, the brake must be equipped with release controls, i.e. sensors that monitor the function of the brake. Those brakes, however, must also be approved by certified bodies such as TÜV etc. Besides the market for new elevators there is a huge installed base of elevators that need to be upgraded to meet the new regulations. In this case there is often very little flexibility for major changes and ideally a new brake concept shall fit into the existing space.

Parking function and emergency-stops only

Inverter controlled drives no longer need to brake the cabin at every stop the elevator makes. In regular operation the brake has only a parking function, i.e. the cabin is being positioned at the floor before the brake is being applied. Only in case of a power failure or emergency-stop the brake will experience friction work. Therefore a brake may only see a small number of demanding duty cycles. The annual safety checks should really be the most demanding duty the brake will see.

Limited space in machine roomless concepts

The fact, that the whole drive system must fit in the hoistway, located at the ceiling, the bottom or at the side of the hoistway, limits the space drive manufacturer will allow for the brake (Gröger 1998). Ideally the brake should take up only space that cannot be used otherwise. This can be in a compact way at the non-driving end of the motor, under the sheave or outside the sheave as in the Kone-Monospace or similar designs.

Inspection and Manual release for emergency release and inspection

In reference to each countries' local elevator regulations, elevators require a regular inspection. When the brake systems used to be up in the machine room, it was fairly easy for the inspector, to check the functionality. For dual circuit brakes this meant to block one brake circuit and to stop the system with only one braking system functional and then to block the other system and repeat the procedure. However, when a drive system is installed in the hoistway access to the brake may become difficult. Wire ropes, mechanical linkages or other devices are required to conduct the safety check procedures, i.e. to block one brake and test the other. Same difficulties may apply in case of a power failure, when the brake has to be released manually to release passengers from the cabin.

Reliability and maintenance

Obviously, reliability should be of key concern. Wear shall be reduced to a minimum. Even though, in inverter controlled drives the brake operates as holding brake only a fair amount of emergency stops will be applied to all elevators by the regular inspections of certified bodies, by power failure or even by passengers playing with the emergency switch. The brake must be able to accept these demands easily.

The specification for the service life of elevators may vary slightly with different manufacturers. An expected service life of 20.000 hours equivalent to 20 years (Predki 1997) has been established as a guideline at the time when worm gears have still been dominating the market. With the introduction of innovative designs this criteria has not changed much.

If the brake is used as a safety device against unintended upward motion, the functionality of both braking circuits must be monitored continuously, in order to make sure, that any malfunction can be detected immediately. This is usually done with micro switches that sense the movement of the armature disk. If the brake lining is worn out, i.e. the air gap of the brake becomes so big that the magnet is no longer capable to attract the armature and release the brake, a micro switch will report immediately that malfunction. This feature avoids the risk that the motor drives against a closed brake. Motors are usually strong enough to drive against the holding torque of the brake, however, this can be a serious problem, as this would generate heat, would wear out linings very soon and finally result in substantial reduction of braking torque that would jeopardise passenger safety.

Low noise requirements

When a drive unit is no longer placed in a nicely isolated machine room, the noise of the individual drive components suddenly will take centre stage. Just image sleeping next to an elevator in a hotel. Every dBA the elevator is too loud, may keep you from finding any sleep at night. There are not so many components in drive systems and therefore a conventional drum brake may easily be the component making most noise. Innovative brake designs are required to reliably achieve a noise level below 65 dBA. Even a requirement of 60dBA is common for some designs. One of the factors that strongly influence brake switching noise is the stroke a brake makes before contacting the friction disk. Whereas this is only around 0,3 to 0,5 mm for a disk brake, a drum brake will travel as much as 2 mm. More stroke means more noise. Therefore drum brakes have an extremely difficult basis to achieve low noise levels. Brake manufacturers apply a lot of expertise to reduce switching noise to a minimum. The maximum noise a brake will generate, often points out the difference between simple and sophisticated designs. Herefore it is important to check not only the noise levels of a new brake, but to check it after it has experienced some wear.

Different Electromagnetic Brake Designs

Over the last years, several designs have been introduced to the market and established themselves as the most common choice for dual circuit brakes. All of the concepts introduced below comply with the elevator requirement of two independent brake circuits and offer a possibility to monitor both brake circuits for applications when the brake has to provide protection for unintended upward motion.

Electromagnetic Brakes in a drum brake style

This concepts utilises the compact design of disk brakes radially to a brake drum, with a brake shoe instead a parallel friction lining.

(Figure 3) In this design the frame is constructed in a way that the brake can be mounted easily. The bulky magnets and jaws of traditional drum brakes can be eliminated. The design is very cost effective and requires no additional space. However, traditional drum brakes have the disadvantage of rather large brake strokes to release the brake completely. The brake shoe needs to release completely, in order to avoid that contacting surfaces will heat up and wear, or noise develops from a brake shoe contacting the drum. To assure an air gap between brake shoe and drum the brake needs to release a relatively far distance, and this is counter productive for reducing noise to a minimum. The hard switching impacts will limit the low noise capability of this design. Moreover, Kone's tight patent protection limits manufacturers possibilities to use this concept for their design.

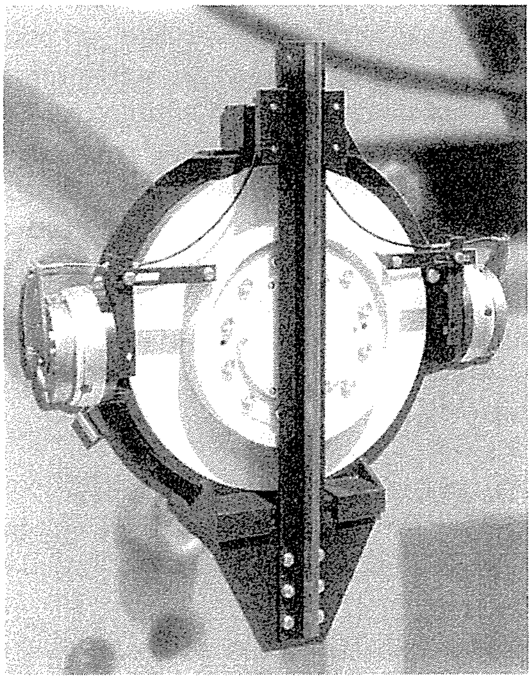


Figure 3. (Special disk brakes used in a drum arrangement)

The ROBA-stop®-disk-Electromagnetic caliper brakes

Electromagnetic caliper brakes merge the benefits of easy external fitting of drum brakes with the low noise performance of disk brakes. ***(Figure 4 a+b)*** As with the drum brakes, braking torque strongly depends on the diameter where the centre of the calipers are applied. In this design, tolerances can be kept much tighter, as heat extension is less a problem. Moreover, with the modular design of this concept, several calipers can be fitted to one disk and therefore relatively high braking torques can be achieved with no additional space required.

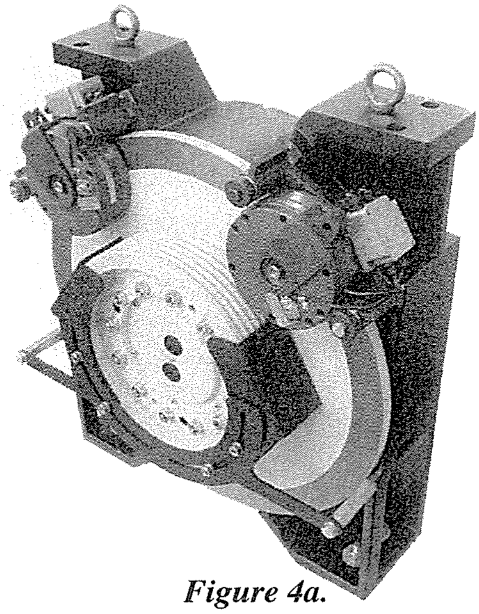


Figure 4a.
(Gearless drive with caliper brakes)

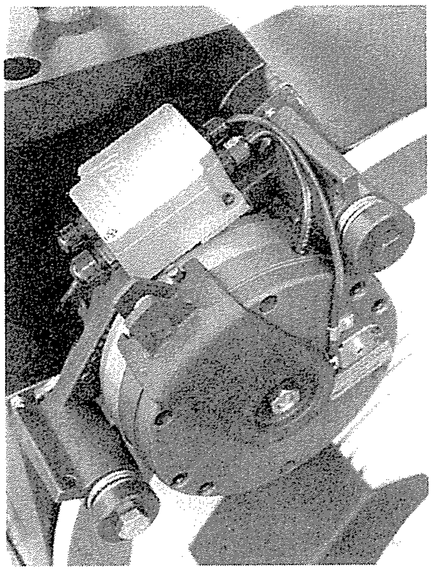


Figure 4b.
(ROBA-stop®-disk caliber brake)

The unique ROBA-stop® Z, dual circuit brake.

This design is unique in design as it utilises one coil carrier with two brake linings. Alternative designs work with split armatures and only one lining. Obviously, the additional rotor of the Z-brake , an essential component of a brake, adds substantial reliability and safety to this concept compared with alternative designs (Mayr 2001). This patented unit, is a very compact design with extremely low noise and is also frequently used in stage technology applications where there is an obvious high requirement for extremely low noise. The switching impact of the Z-Brake is quite soft. Obviously, physical size of the brake is a strong factor for minimum noise levels. The compact design of the Z-Brake offers an ideal basis for this. ***(Figure 5)***

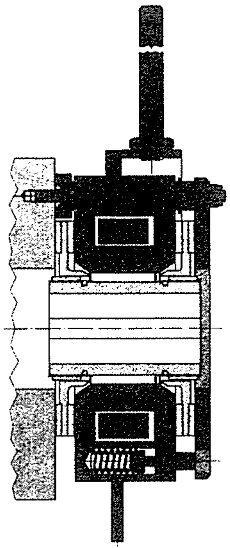


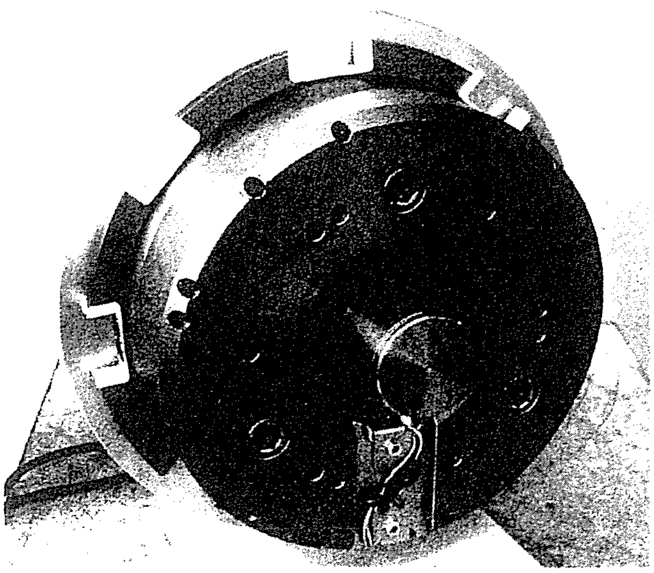
Figure 5. (ROBA-stop®-Z, dual circuit brake)

The ROBA-stop® twin Coil Brake

Roba-stop® twin coil brakes are the latest design that have been introduced to the elevator market. This brake design, has two concentric coils and armatures in an extremely compact space.

When only one coil is powered, only one of the concentric armatures will be attracted and therefore the brake releases 50% of the brake torque. The design, provides both, a dual circuit functionality and the feature of independent release of the two circuits. This offers a substantial benefit when manual release is no longer done mechanically, but electrically with a back-up battery system. In the unlikely event of a power failure, the elevator will be driven or lowered to the next floor with the back-up power system. More often than this, the benefit of the comfortable remote control will be used by the inspector, who regularly has to check the proper function of the individual brake circuits. For the safety check a brake can be used with one magnet continuously energised and one brake circuit operating regularly. When the cabin is stopped only one brake operates to proof the reliable function of each circuit.

A further benefit of the twin brake is the possibility to integrate it in the sheave. This will limit additional space requirements and makes it an ideal choice for upgrading existing elevators to meet new safety regulations. ***(Figure 6 a+b)***



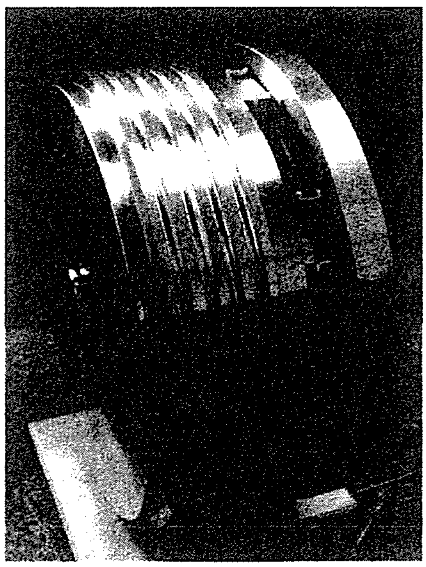


Figure 6a+6b. (ROBA-stop®-twin integreated in a sheave)

Selecting the right brake

Summarising above options of different brake systems, following questions should be raised when selecting a brake for an elevator drive system:

- Is the brake performing a holding function only with requirements for emergency stops or may it also be used with uncontrolled drives for regular braking actions
- Does the brake have to comply with the safety requirements to avoid unintended upward motion, i.e. monitoring of both circuits ?
- Is the drive system a gear drive or gearless drive ?
- What is the location of the drive? - machine room, or which part of the hoistway – and how much space is available ?
- What access is given to inspect and maintain the brake ?
- What noise requirements are set ?

As a matter of fact, whereas there is a wide market for drum brakes, there are actually not many established companies world-wide, who manufacture disk brakes for elevators applications. Most of these manufacturers have a good reputation as brake manufacturers in general applications. As brakes for elevators often have very individual requirements, most projects need customised solutions to optimise a basic design to the specific needs of the customers. Moreover, individual features as reducing noise to a minimum to give you some leeway against competitors, requires not only excellent skills but detailed knowledge of the elevator requirements at the brake manufacturers side. Current market situation shows, that very few manufacturers can master these skills. Often patent protection limits the OEMs choice to one supplier only. However, if more than one supplier is in the evaluation process, the selection process should go far beyond purely technical matters. Cost is certainly a dominant factor in todays business world, but following should be considered, too:

- Competence - Is the supplier a specialist in elevator brakes ?
- Does the manufacturer have generic technical competence with the design of elevator brakes or is he just following other designs ?
- Are the brakes designed to the specific needs for the elevator market ?
- Do the products meet the specification of the applicable elevator regulations ?
- Are the products approved by certified bodies such as TÜV etc.
- What are the confirmed specs such as noise level, service life, and reaction times?
- Can the potential supplier present any references for applications in elevators ?
- Does the supplier have all quality routines in place necessary for reliable manufacturing of safety critical components ?

Quite often it seems that cost of the components in elevators is the most important factor.
We all know that reducing cost in elevators is an extremely strong driver, however it shall not be top priority. Safety and reliability shall be it. It should be considered, that over many decades there have been very little changes in the basic design of the elevator drives. The drastic changes in the drive systems over the last couple of years have taken place in a very short time and it is our duty to continuously raise the high level of passenger safety in elevators.
Brakes play a the centre role with this and the selection of the most reliable product and the most reliable partner shall be given utmost attention.

CONCLUSION

The article shows, that the innovation with new elevator drives has triggered innovations for new brake concepts. The different designs all need to meet latest elevator regulations and need to optimise space and noise requirements alike. Applications for this cannot only be found in new installations but also in elevators that are being refurbished to meet latest specifications. In selection the right brake, the author argues, that not only technical specs should be considered, but also the reliability, the experience, the quality procedures and references should be looked at before a supplier is being selected.

ACKNOWLEDGEMENT

The author thanks companies Thyssen, Stuttgart-Neuhausen and Ziehl-Abegg, Künzelsau for providing photographs and other information.

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BIOGRAPHICAL DETAILS

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