CARB™

A TOROIDAL ROLLER BEARING FROM SKF

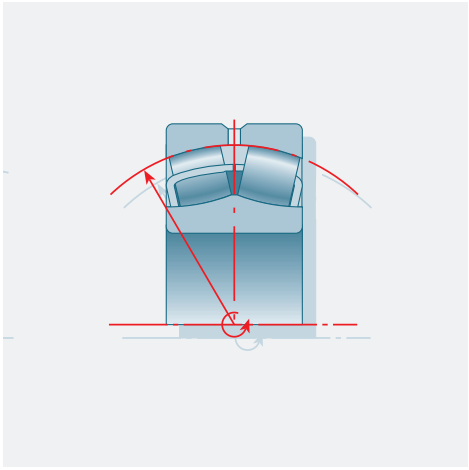
Reduce size, weight and manufacturing costs.

SKF

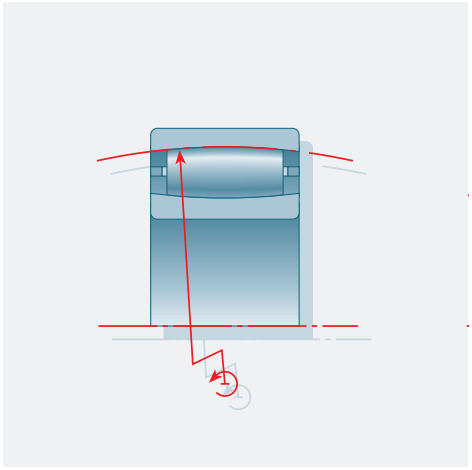
Misalign it.
Displace it. Load it.

A toroidal roller bearing can take 10 times the angular misalignment of cylindrical, taper or needle roller bearings, 100 times the axial displacement of spherical roller bearings, and up to 30 % higher load than the strongest roller bearing ever designed.

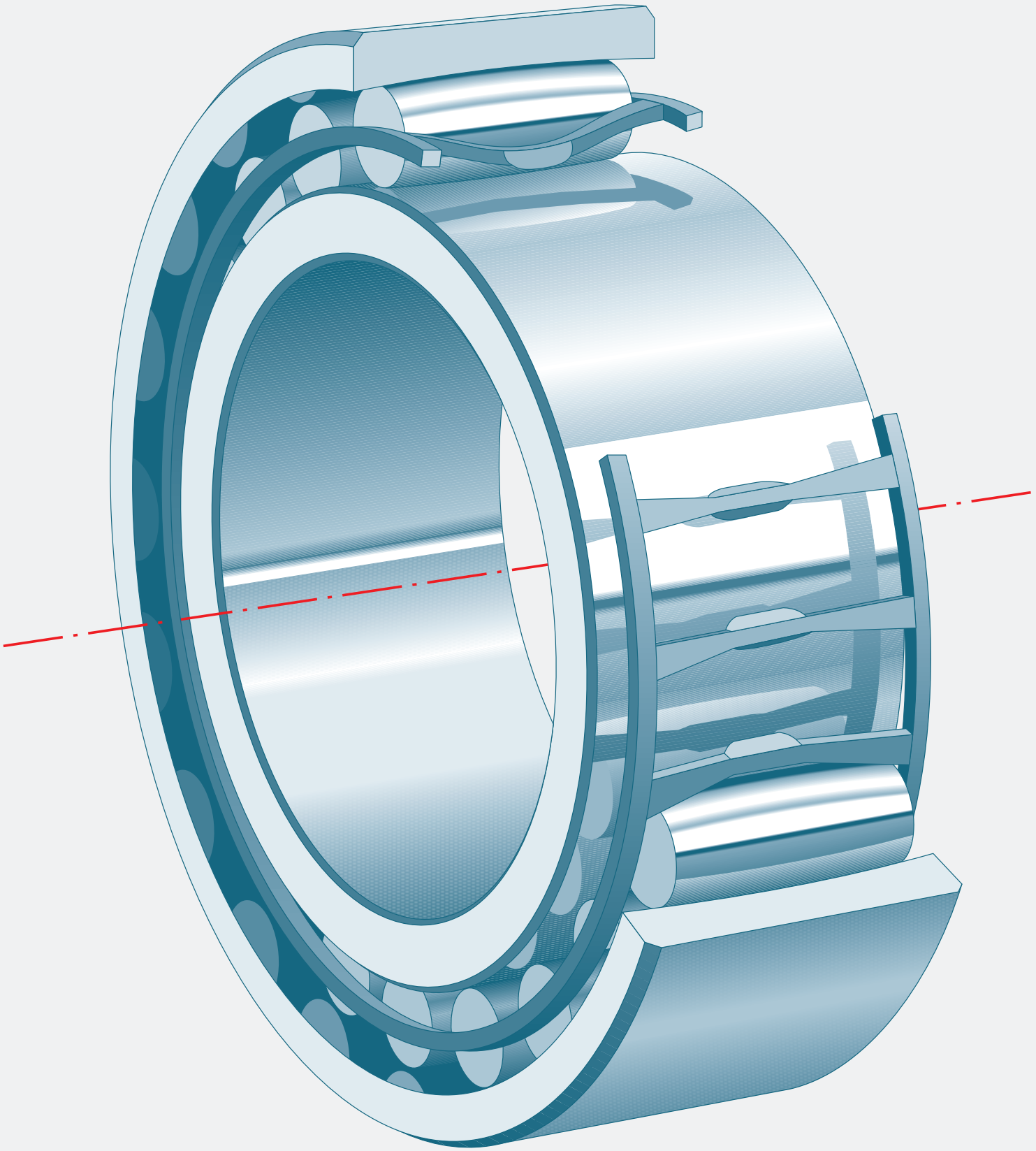
We are talking about CARB™ – the world's only toroidal roller bearing.



In a spherical roller bearing, the centre of the outer ring raceway profile coincides with the bearing centre.



In a toroidal roller bearing, the profile radius of the outer ring is much larger than that of a spherical roller bearing.



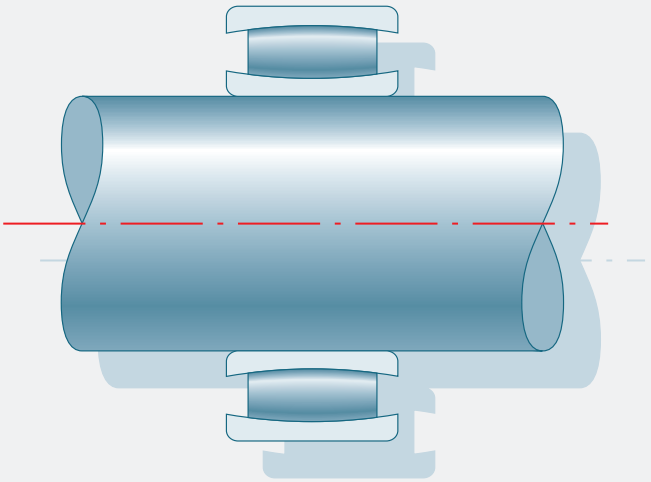
A breakthrough in bearing technology.

A cylindrical roller bearing tolerates axial displacement, but not angular misalignment. A spherical roller bearing tolerates angular misalignment, but not internal axial displacement. A needle roller bearing is compact, but does not tolerate misalignment.

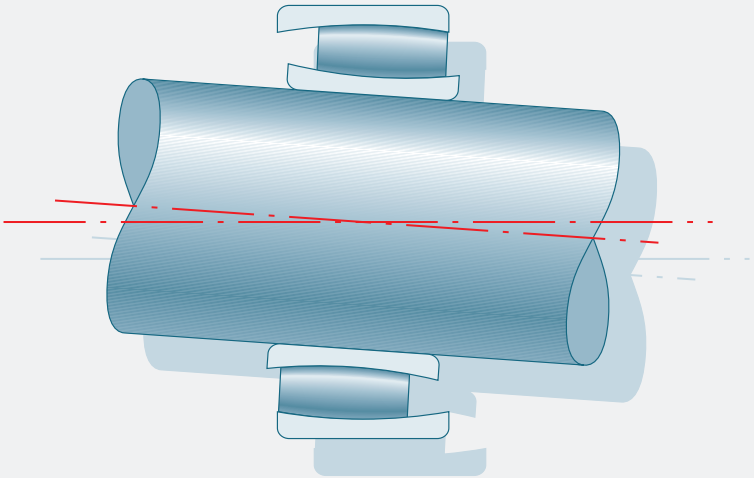
A toroidal roller bearing combines the advantages of these three bearing types and has none of their disadvantages.

It is a major breakthrough in bearing technology – the most important in over 50 years (the last being the SKF spherical roller thrust bearing in 1939).

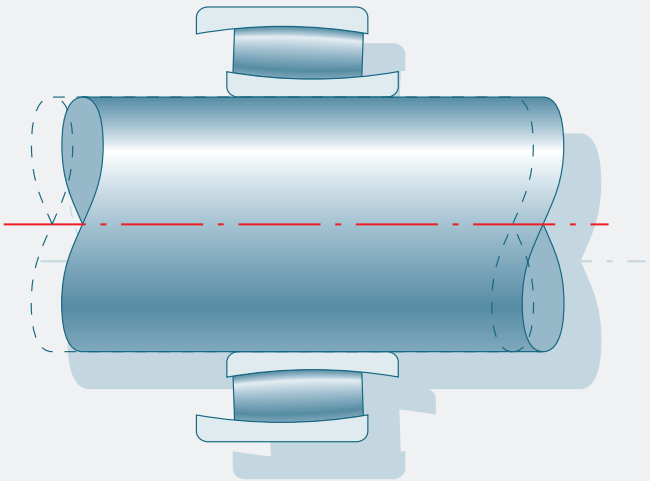
It is the beginning of a new era in mechanical design. With CARB, you can reduce machine size, weight and manufacturing costs. You can increase availability, reduce maintenance and boost performance.



No angular misalignment (=ideal working condition for cylindrical, taper and needle roller bearings). No axial displacement (=ideal working condition for spherical roller bearings).



Angular misalignment of up to 0,5° has little influence on the life of CARB. It can take misalignment of up to 1° with some life reduction.



For a typical operating clearance, the axial displacement can be up to 20 % of the bearing width.

Why CARB tolerates more than any other bearing.

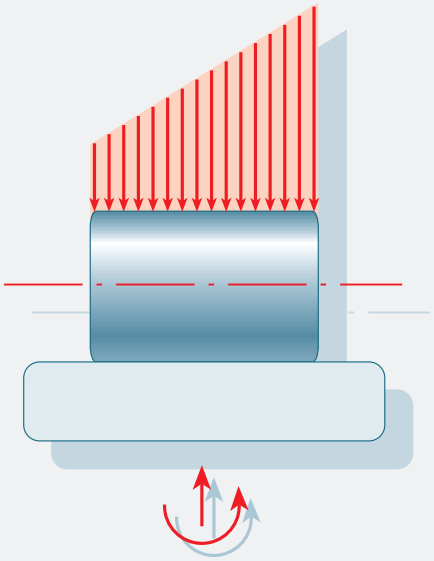
In a conventional bearing the load is often unevenly distributed along the length of the rollers. When a cylindrical, needle or taper roller bearing is misaligned, the edge stress on the rollers increases. Consequently the life of the bearing is reduced rapidly as the degree of misalignment increases.

When one of the rings of a spherical roller bearing is displaced by more than the clearance, the load on one of the rows of rollers is reduced to zero while the other row has to take the entire load – the radial load as well as the thrust load responsible for the displacement. The life of the bearing is therefore reduced rapidly as the internal displacement increases.

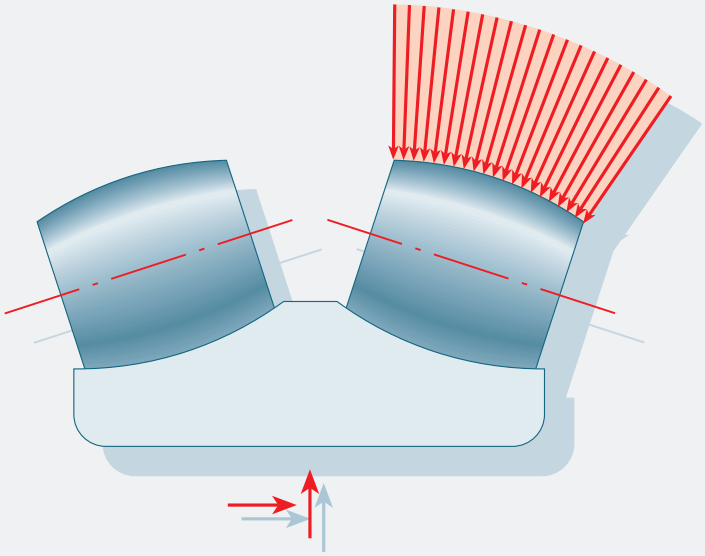
In a toroidal roller bearing the rollers always find the position at which the applied load is at a minimum. When CARB is misaligned, the inner ring becomes tilted with respect to the outer ring and the rollers slide away to take up a position where the load is evenly distributed along their length.

When CARB is displaced axially, the outer ring and inner ring move in relation to each other. The rollers move by a distance equal to one half of the axial displacement. This is the position in which the load on the rollers is at a minimum – and evenly distributed.

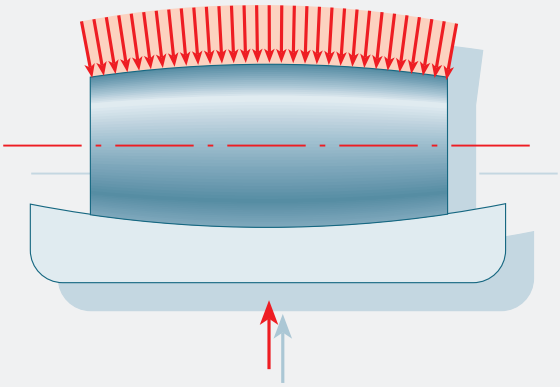
This is the reason why CARB tolerates more than any other bearing.



Cylindrical roller bearing: angular misalignment creates considerable edge stresses and reduces the life of the bearing.



Spherical roller bearing: axial displacement in excess of the clearance causes one of the rows of rollers to carry the whole load, both axial and radial. This shortens the life of the bearing.



Toroidal roller bearing: under angular misalignment and axial displacement, the rollers take up a position in which the load is evenly distributed over the length of the roller.

Until now, you have had to adapt your design to the bearing.

Most shafts are supported by a locating and a non-locating bearing. The bearing at the free end is subjected to both axial displacement and angular misalignment to a greater extent than many imagine.

Until now, no bearing has been able to tolerate internal axial displacement and misalignment at the same time. For heavy loads, there have been two main alternatives for attaining the desired service life of the bearing at the free end: allow axial displacement using a cylindrical or a needle roller bearing, or allow misalignment using a spherical roller bearing.

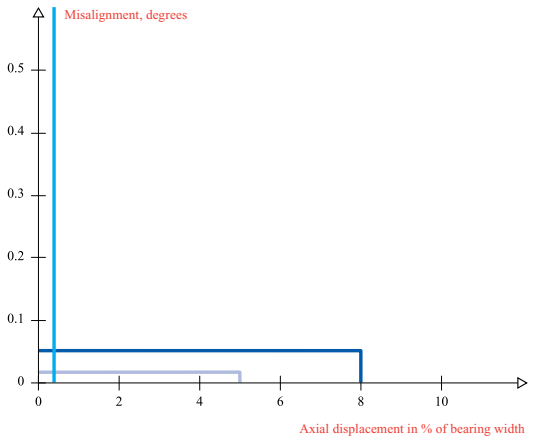
Cylindrical and needle roller bearings.

These bearings permit axial displacement, but misalignment between inner and outer rings should not exceed 0,05° for cylindrical roller bearings (much less for needle roller bearings) because the bearing life is then reduced dramatically. To reduce misalignment to acceptable levels, you have to make a more rigid design or use closer manufacturing tolerances.

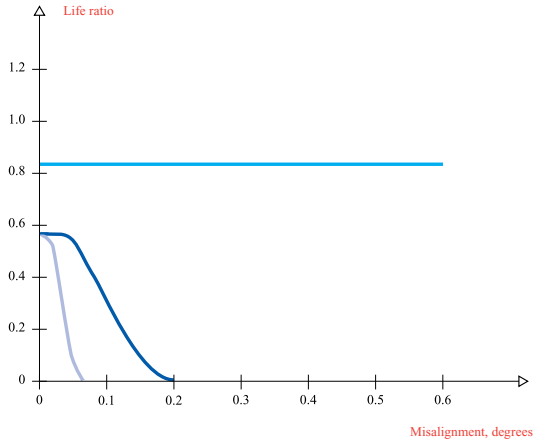
Spherical roller bearings.

These bearings tolerate misalignment. Axial displacement is handled by allowing the entire bearing to slide in the housing. The friction that must be overcome to make the bearing slide in the housing increases as the surfaces become worn. This reduces bearing life. If a spherical roller bearing on a 100 mm (4 in), one-metre-long (3 ft) shaft can no longer move in its housing, a temperature increase of only 10 °C (50 °F) is sufficient to reduce bearing life to below 50 %.

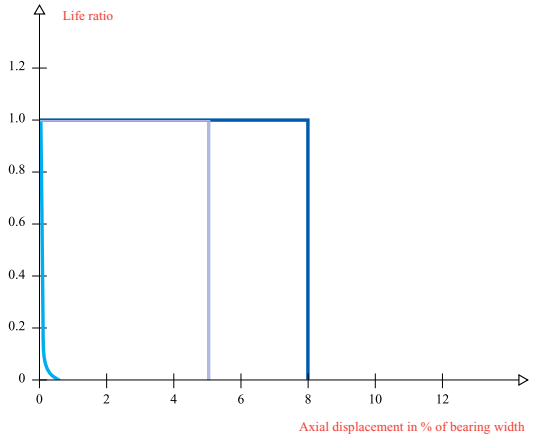
So cylindrical, needle and spherical roller bearings require that you adapt your entire design either to avoid misalignment or to handle axial displacement.



Cylindrical roller bearing
Needle roller bearing
Spherical roller bearing



Cylindrical roller bearing
Needle roller bearing
Spherical roller bearing



Cylindrical roller bearing
Needle roller bearing
Spherical roller bearing

Now the bearing will adapt to your design.

A toroidal roller bearing adapts to both angular misalignment and axial displacement, pushing design limits further than anyone thought possible. At the same time, a toroidal roller bearing can support up to 30 % higher load than the strongest roller bearing ever designed.

At least 10 % displacement.

During axial displacement, the radial clearance in CARB decreases. A typical CARB can tolerate axial displacement of 10 % of the bearing width without life reduction. The permissible axial displacement for a corresponding cylindrical bearing is about 8 %.

Tolerates asymmetrical deformation.

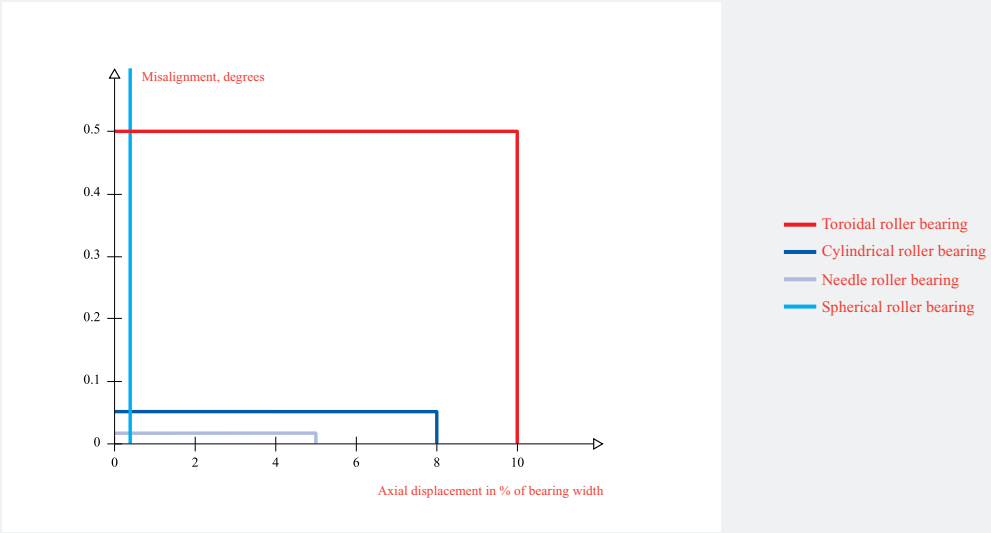
When a bearing seating is machined (in a gearbox casing, for example), the side of the casing may deflect, resulting in a slightly tapered bearing seating. When the bearing is mounted, the outer ring may therefore become deformed. CARB, however, can tolerate deformation, either symmetrically around the periphery or asymmetrically due to angular misalignment (see illustrations on page 15). No other roller bearing can tolerate this.

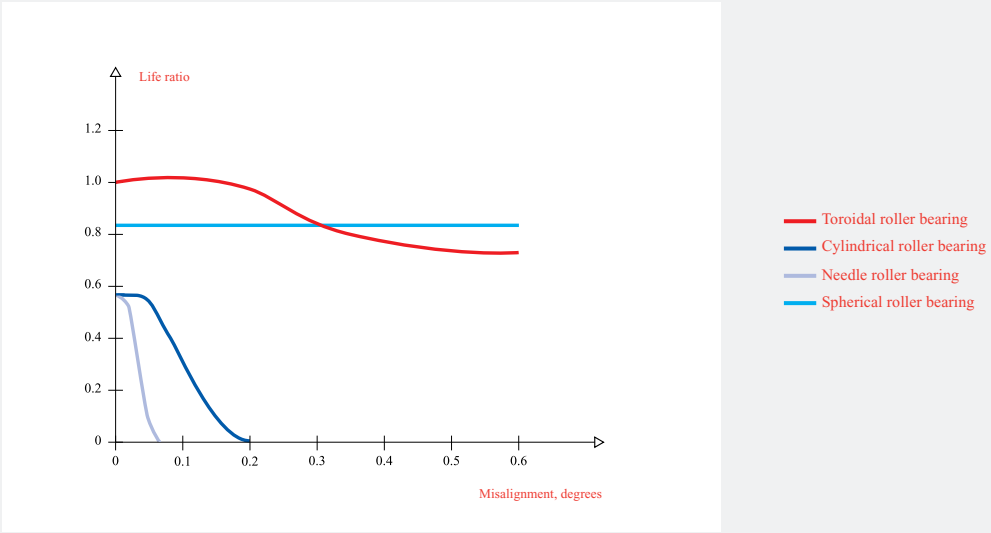
Low friction.

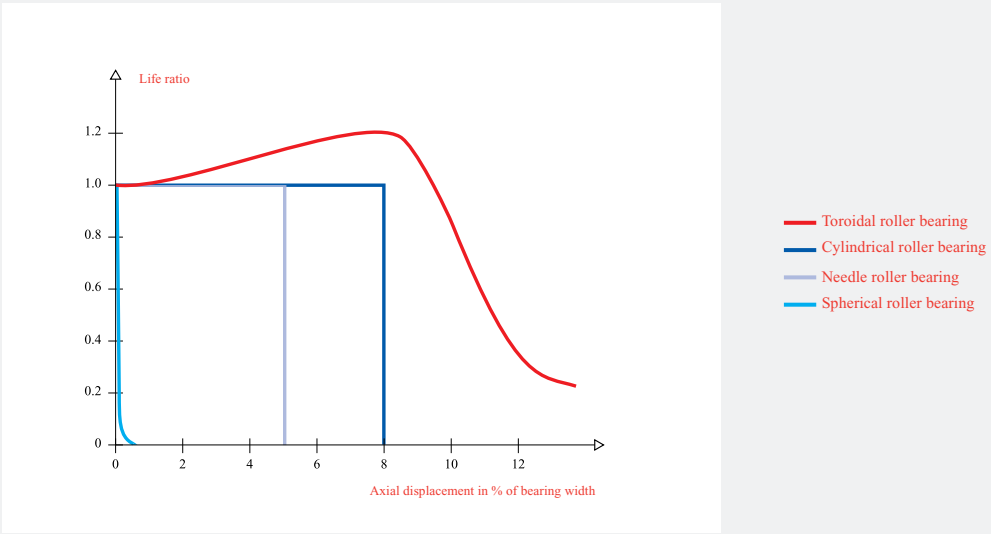
A toroidal roller bearing has only half to one-third the friction of a single row spherical roller bearing, and about the same as that of double row spherical and cylindrical roller bearings.

What's the catch?

These diagrams show how far you can push CARB. In addition to these limitations, keep in mind that CARB is not designed to accept axial load, and that both the inner and the outer ring must be located.


Misalignment, degrees
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
Axial displacement in % of bearing width
Toroidal roller bearing
Cylindrical roller bearing
Needle roller bearing
Spherical roller bearing


Life ratio
1.2
1.0
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Misalignment, degrees
Toroidal roller bearing
Cylindrical roller bearing
Needle roller bearing
Spherical roller bearing


Life ratio
1.2
1.0
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Axial displacement in % of bearing width
Toroidal roller bearing
Cylindrical roller bearing
Needle roller bearing
Spherical roller bearing

Reduce size, weight and manufacturing costs.

CARB permits smaller and lighter designs where bearing size has previously prohibited downsizing. In some cases, CARB enables the entire machine design to be downsized. In other cases, CARB will only allow downsizing of the bearing and its arrangement.

For example, in a design using a cylindrical roller bearing subjected to misalignment of more than 0,1°, you can use a toroidal roller bearing that is two bore sizes smaller. You then reduce the bearing weight by 40 %. If you have to maintain the shaft diameter, you can use a toroidal roller bearing with the same load carrying capacity as the cylindrical roller bearing. You can then halve the sectional height (the difference between the bearing's outside and bore diameters).

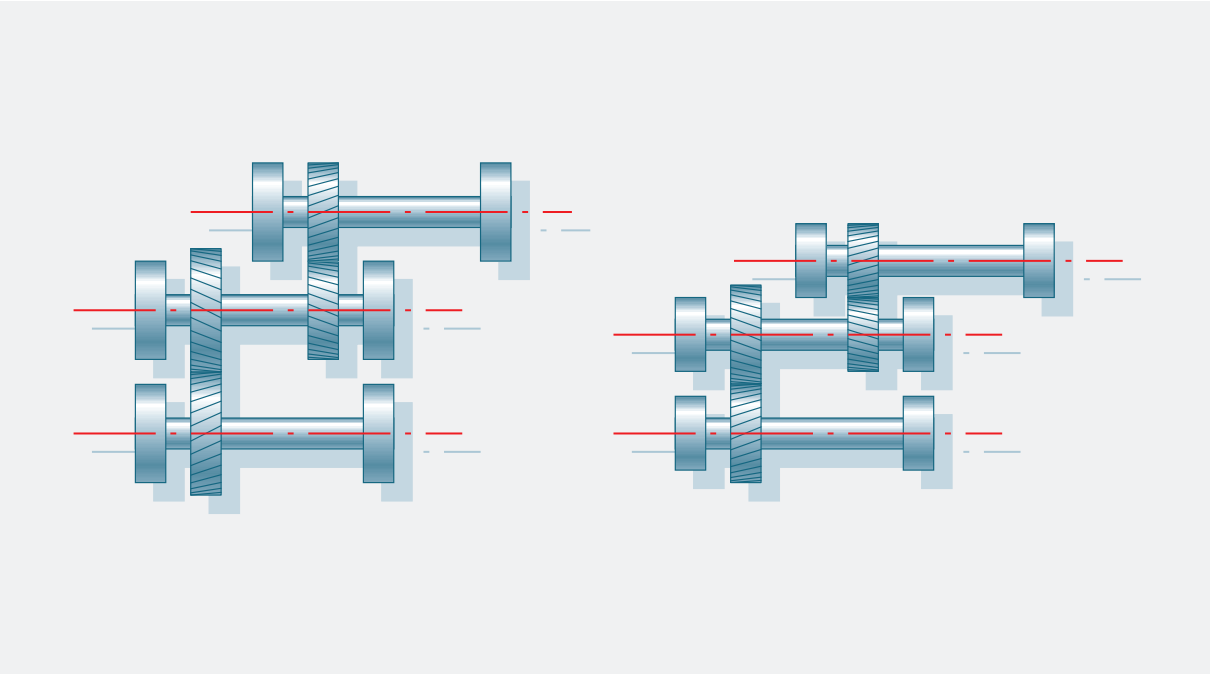
Manufacturing costs for most machines are related to size and weight. So CARB can help you not only to design more competitive products, but also to reduce manufacturing costs by downsizing.

Reduce cost even more.

CARB can help reduce manufacturing costs even beyond the reductions gained by downsizing. In certain designs, close tolerances are required for crucial operations, for example machining a bearing seating, aligning a housing or adjusting axial clearance.

In such designs, CARB may allow wider tolerances. Since manufacturing costs decrease logarithmically as you widen tolerances, CARB can drastically reduce the cost of some manufacturing operations. Or even eliminate them.

If you want to reduce machine size, weight or manufacturing costs, CARB will bring you closer to your goal.



Toroidal roller bearings may enable downsizing of the entire design. A gearbox with conventional bearings (left), may be scaled down substantially by using CARB to allow shafts to be moved closer together (right).

GOAL	PROBLEM	OPPORTUNITY
To reduce size and weight	Design must be oversized to limit misalignment	Downsize the entire design until material properties set the limit, and let CARB handle misalignment
	Shaft diameter must be maintained to handle torque	Use a smaller CARB to allow shafts to be moved closer together and downsize the entire design
	Distance between two shafts must be maintained for the design to work	Use a smaller CARB and downsize the housing
	Complex bearing arrangement to cope with deflection or axial expansion	Downsize the bearing arrangement and let CARB handle misalignment and axial displacement
To reduce manufacturing costs	Any of the four problems above	Downsize and reduce manufacturing costs
	Expensive machining of seating	Relax tolerances and reduce machining costs
	Expensive alignment of housing	Relax alignment requirements
	Expensive adjustment of axial clearance	Relax axial adjustment requirements

Increase availability, cut maintenance and boost performance.

CARB can help you increase machine availability and reduce maintenance where conventional bearings now experience premature failure.

Manufacturing deviations and deformation in operation cause uneven load on rollers in conventional roller bearings (see pages 6–7). This is often the main cause of premature bearing failure.

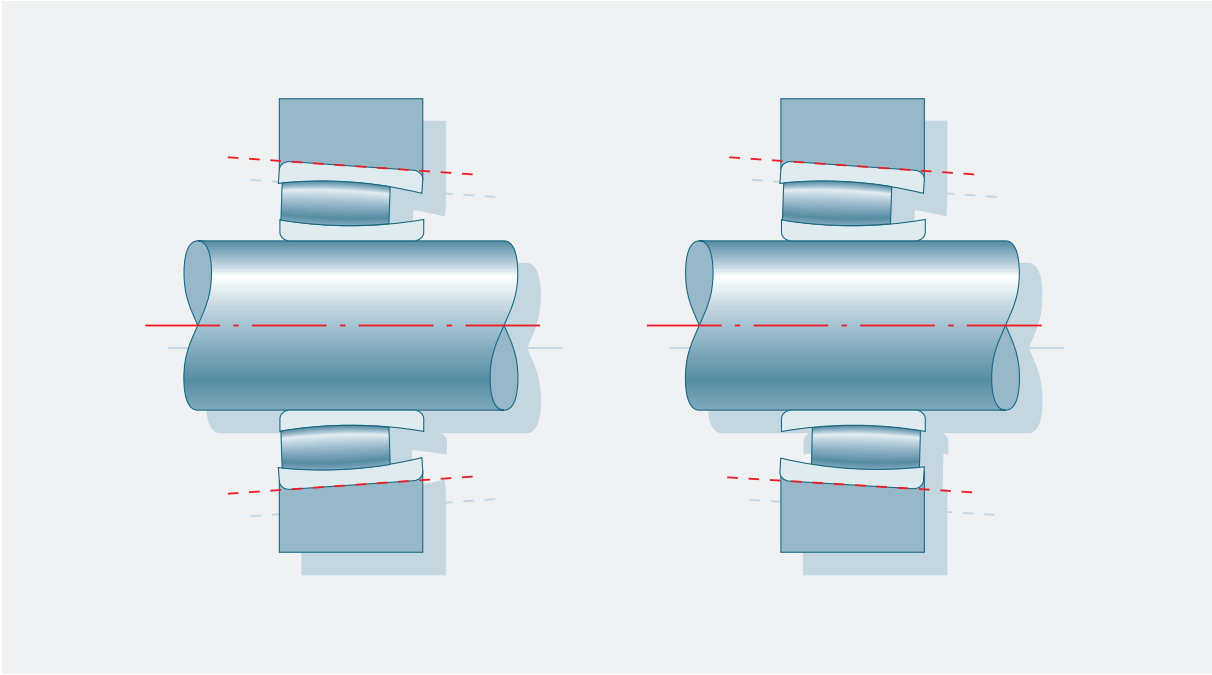
In a toroidal roller bearing the rollers take up a position where the load is evenly distributed over the roller length. CARB thus not only accommodates axial displacement and angular misalignment but also slight taper errors – including those which vary around the circumference (see illustration opposite).

For this reason a toroidal roller bearing will run for its full life where others fail prematurely.

Boost performance, too.

In designs where bearings are mounted with a loose fit for the outer ring to allow axial displacement, corrosion or thermal gradients may prevent the bearing outer ring from moving. This can create thrust loads that damage the bearing. As CARB handles axial displacement internally, it permits a tight fit of the outer ring and a firmly fixed housing. This reduces vibration and allows higher machine speed.

For heavy duty machines (for example in the paper and steel industries) CARB means more savings, less maintenance and higher productivity. For consumer products (for example car gearboxes and motorcycle engines) CARB means lower service and repair costs and increased customer satisfaction.



CARB easily adapts to a tapered housing bore and the resulting deformation of the outer ring (left). CARB also adapts to a misaligned housing bore – even if the outer ring cannot move in the housing (right).

GOAL	PROBLEM	POSSIBLE CAUSES	OPPORTUNITY
To increase availability and reduce maintenance	Premature bearing failure	Manufacturing deviations: • tapered housing bore ⇒ outer ring deformation • housing bore misaligned • bearing positions misaligned Deformation in service: • long/heavy shaft ⇒ shaft bending ⇒ bearing misalignment • shaft or housing seating deformed ⇒ deformation of bearing rings • thermal gradient ⇒ outer ring unable to move ⇒ axial load • uneven temperature ⇒ deformation of rings	Let CARB handle deformation, misalignment, axial displacement; achieve full bearing life and lower maintenance costs
To improve performance	Vibration limits machine performance	Loose outer ring fit/displaceable housing: • fretting ⇒ outer ring unable to move ⇒ axial load • thermal gradient ⇒ outer ring unable to move ⇒ axial load	Use CARB, fixed housing, interference fit for outer ring and reduce vibration

Challenges for an experienced mechanical designer.

How can you take advantage of CARB in your designs? Can you make them smaller? Lighter? Less costly to manufacture? Can you increase reliability? Reduce maintenance? Increase performance?

In the following pages you will find some designs for which we believe CARB will make a contribution. Who will be the first in your industry to take advantage of CARB?

Our intuition tells us that CARB can do more than improve existing designs. Perhaps CARB will enable the design of entirely new products? Would it be possible to design machines whose function is based on their ability to handle rotating load? Machines based on the fact that the radial clearance of CARB diminishes slowly and non-linearly as axial displacement increases? Machines with shafts that slowly pulsate axially and at the same time rotate?

Contact our application engineers – whether your are planning to improve an existing design or aiming towards the *perpetuum mobile*.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SKF
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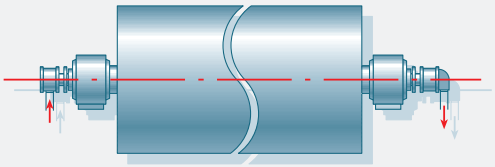
Drying cylinders in papermaking machines.

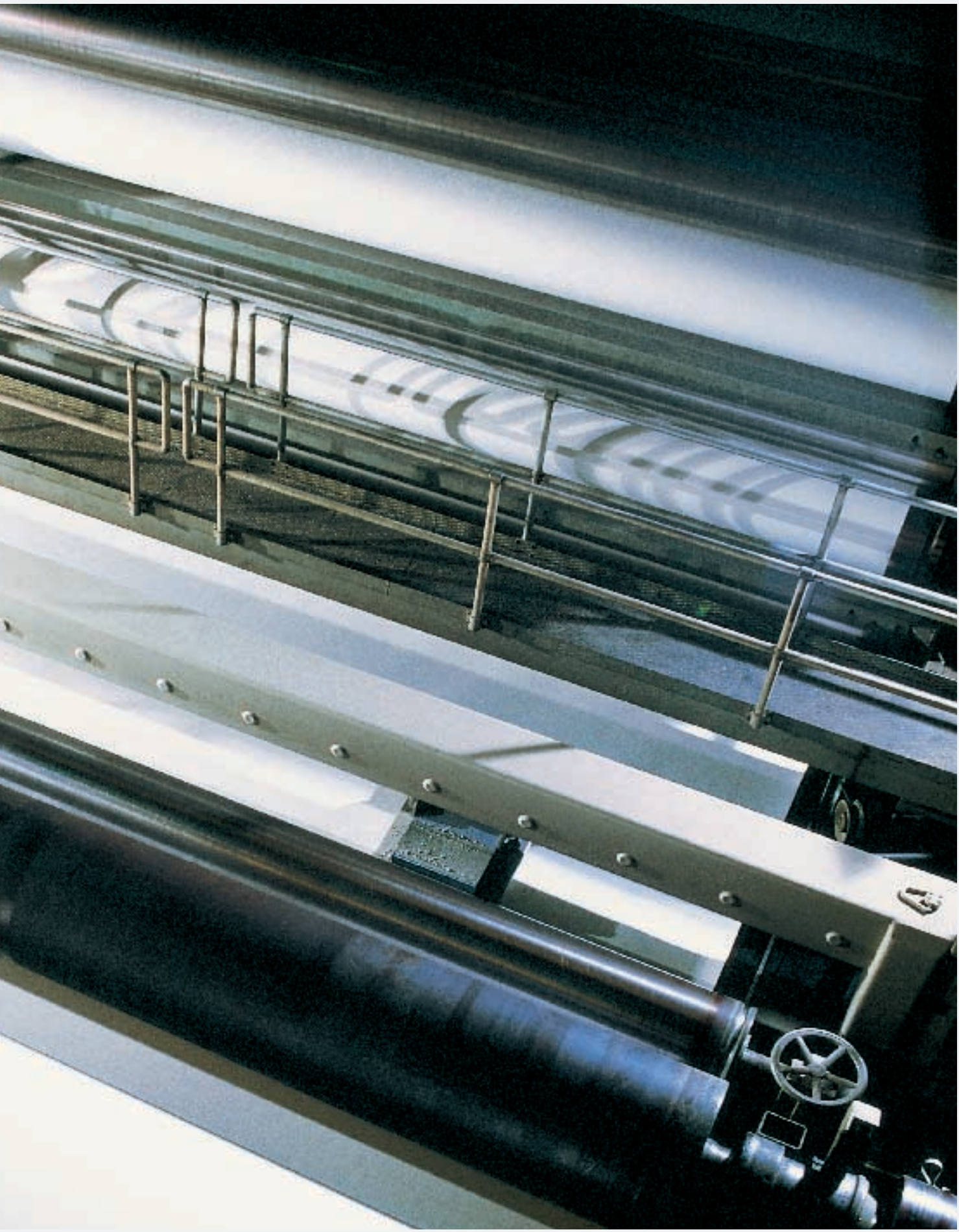
The dryer section in a papermaking machine consists of 30 to 100 rotating, steam-heated drying cylinders, covered by a hood. Steam of up to 200 °C (400 °F) is blown into the drying cylinder through the hollow shaft. Because of the thermal expansion of the cylinders, the bearings at the free side must be able to take up axial displacement, often more than 10 mm (0,4 in).

The distance between the two bearing positions of a drying cylinder is sometimes more than 10 m (30 ft). Misalignment of 0,2° is common as a result of deflection of cylinder and frame and improper alignment of the housings. Even greater misalignment can arise through the settling of the machine foundation.

CARB mounted in a fixed housing tolerates axial displacement and misalignment simultaneously. This reduces vibration, allows higher running speed and provides longer bearing service life.

Paper mills in Sweden and Germany are using the new bearing. A Swedish mill found that the vibration decreased by up to 85 % when CARB in a fixed housing replaced the conventional bearing arrangement.



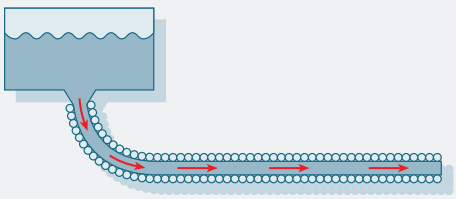


Guides in continuous casters.

The temperature is about 500 °C (900 °F) at the top of a continuous caster. Molten steel is poured from a container through a cooling chamber. The steel starts to solidify on the surface and runs between roller guides. Bearing damage can have serious consequences. If many bearings fail and the roller guides stop rolling, they can easily tear a hole on the cooled outer surface. The molten steel then runs out onto the shop floor.

Today's continuous casters utilise various designs incorporating cylindrical roller bearings, needle roller bearings, spherical roller bearings or plain bearings.

CARB has been tested in the top segment of continuous casters. CARB enables the design to be more compact and the guides more reliable.



Automotive gearboxes.

Gearboxes are designed to be as small, light and reliable as possible within the given demands on torque transmission. The greater the torque, the larger the bearing misalignment.

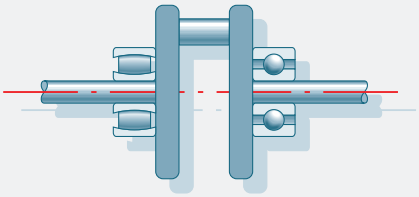
An automotive gearbox can be exposed to internal temperatures between –35 °C (–30 °F) and +150 °C (+300 °F). This creates large thermal expansion and contraction of steel shafts and aluminum casing, and, consequently, axial displacement of the bearings.

CARB has been tested on the output shaft of automotive gearboxes. CARB makes it possible to either position the shafts closer to one another and make the gearbox smaller, or increase the torque without making the gearbox larger or heavier.

Crankshaft in racing motorcycles.

In a racing motorcycle, the engine works at full capacity almost all the time. The crankshaft bends, the crank housing deforms, and the bearings on the crankshaft misalign.

CARB might make it unnecessary to oversize the crankshaft and crank housing. Or, for given dimensions of crankshaft and crank housing, CARB might increase bearing life.



Industrial gearboxes.

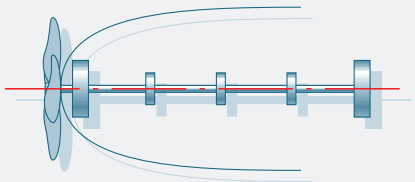
One goal of the designer is to achieve the maximum torque transmission per unit weight. The weight can be reduced by making the gearbox casing thinner. Thinner casings, however, tend to deflect under load, resulting in misalignment and change in clearance of the bearings.

Could CARB help you downsize your next gearbox design? Could CARB help increase reliability and reduce maintenance?

Support bearings for a ship's propeller shaft.

The propeller shaft of a ship can be more than 10 m (30 ft) long and up to some 600 mm (24 in) in diameter. Two or three support bearings keep deflection within reasonable limits. Self-aligning bearings with a loose outer ring fit are used for most ships. Wear, friction, corrosion or thermal gradients can prevent the bearings from moving, creating large thrust loads that can damage the bearings.

Why not use CARB to eliminate this risk?

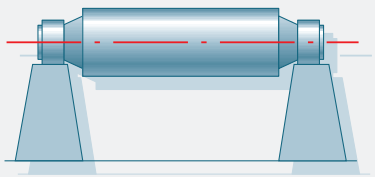


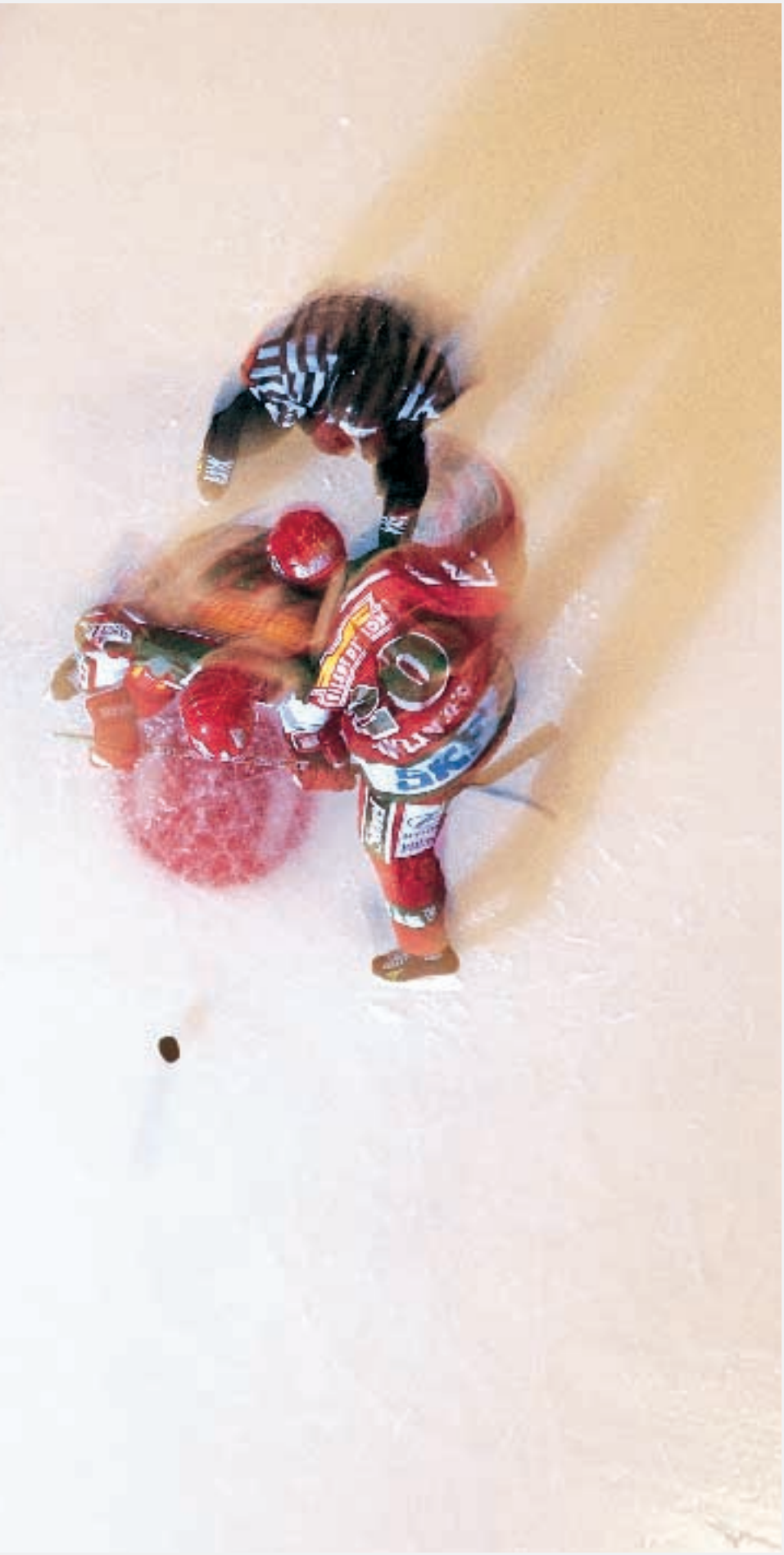
Support bearings in large grinding mills.

Many grinding mills are located in the desert, and are exposed to wide temperature changes from day to night. Such environments are amongst the worst imaginable for bearings.

The drum weight and span between the housings deform the end faces of the mill, causing the bearings to misalign. That is why the most common bearing used is the spherical roller bearing. One of the bearings is either mounted with a loose outer ring fit, or one of the housings is put on rockers.

With CARB at the free end in a fixed housing, you would not have to worry about premature bearing failure. It is also reasonable to expect that CARB would reduce vibration.





Screw compressors.

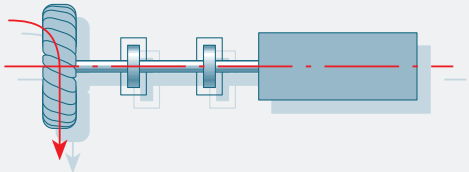
Screw compressors are used, for instance, in refrigeration plants to compress refrigerant. The bearing sectional height determines how small the compressor can be made. If the screws can be located close to one another, the efficiency of the compressor increases.

Smaller screw compressors often incorporate needle roller bearings due to their low sectional height. In larger compressors, cylindrical roller bearings are used.

Would CARB make it possible to position the screws closer to one another and increase the compressor efficiency? Would CARB reduce unplanned downtime? Lower maintenance costs?

Rotor shafts in fans.

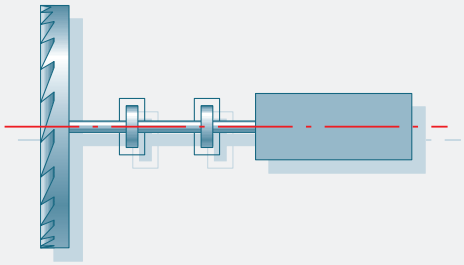
Fans are vital to keep production going in many industries (in power generation plants and paper mills, for example). If the fan system breaks down, the entire plant may have to be shut down. For every operating hour, more dirt particles in the air adhere to the fan blades. After a while the dirt builds up and loosens in chunks. The bearing load will then rotate with the fan. This, in combination with loose outer ring fits, may cause wear of the housing and reduce the bearing life. CARB with interference fitted rings would make the fan less sensitive to imbalance.

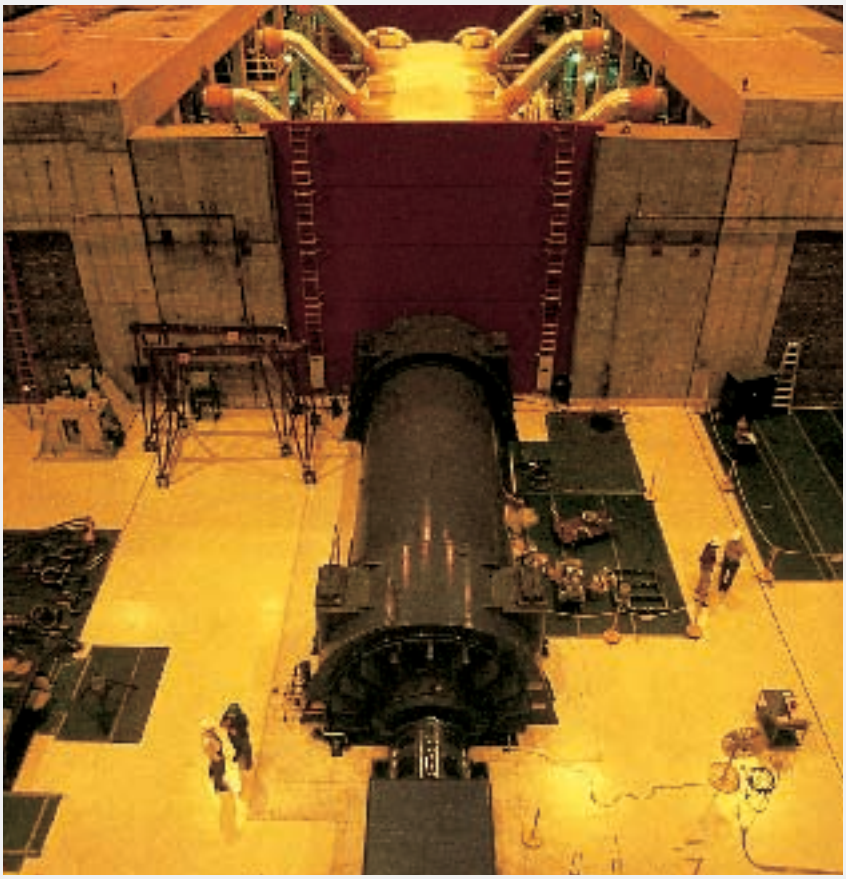


Wood chippers.

A large chipper processes a three-metre-tall tree trunk with a diameter of 80 cm (2,5 ft) in three seconds. When logs are put into the chipper, tremendous and uneven forces are exerted on the knife wheel. Knife blades may be broken off, causing a rotating load on the bearings at the free end where the knife wheel sits. Most chippers today use self-aligning bearings to cope with deflection and housing misalignment. The rotating load tends either to cause the bearing to wear the housing, or to lose its freedom of movement. In both cases, the bearing will be damaged.

CARB lets you use fixed bearing housings. Would that put an end to discussions about how to allow axial displacement in the bearing on the knife wheel?





Rotor shaft in electric machines.

The sheer size of large electric machines makes it virtually impossible to avoid bearing misalignment.

Today, spherical roller bearings or plain bearings are commonly used. Spherical roller bearings are mounted with a loose fit in the housing, and there is some risk of premature bearing failure due to uncontrolled thrust load. Plain bearings sometimes demand special equipment and monitoring because the oil must be pumped in between the sliding surfaces before the machine is started.

With CARB, both bearing rings can have an interference fit. What benefits would that mean?

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