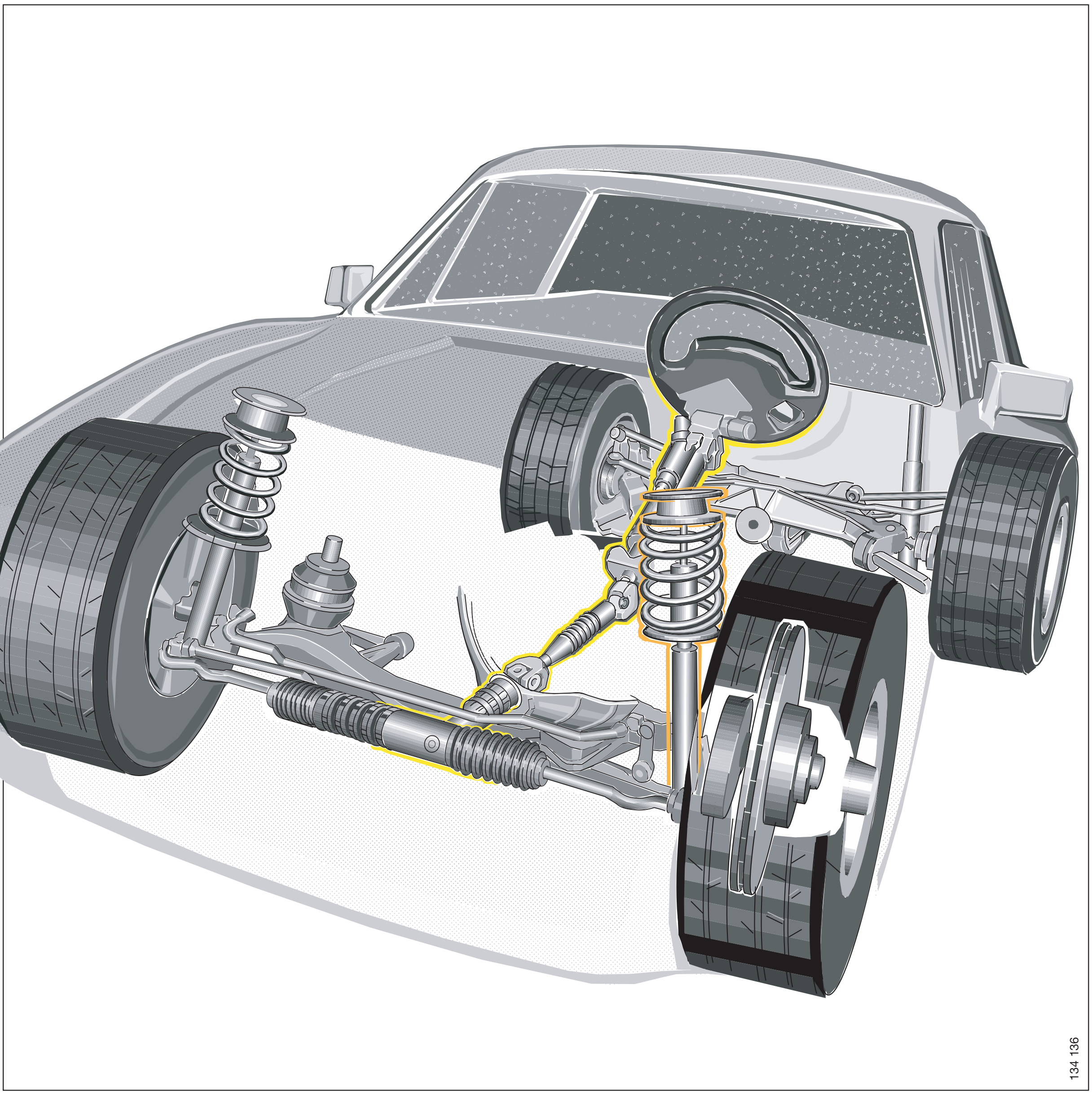

Steering Column

Rolling Bearings and Components for Passenger Car Chassis

Automotive Product Information API 04

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Aims of development

Application areas for rolling bearings

The aims of further developments and optimization in the field of passenger car chassis are primarily:

- the improvement of driving comfort by means of
  - low vibration levels,
  - more straightforward handling of components relevant to operation and
  - improved steering comfort
- the improvement of active safety to minimize the effects of emergency situations
  (see *Demands on the steering system*, page 5)
- the improvement of the passive safety by means of measures to reduce the results of accidents such as
  - safety steering columns, collapsible and energy absorbing steering wheels.

Considerable advancements have been achieved by fine adjustment of the axle kinematics and suspension, e.g. multi-link suspension and axle integrated systems.

The future belongs to “intelligent chassis” which obviously will automatically adjust themselves to the relevant driving conditions. Adjustment of the chassis is not limited to just the individual suspension and damping components but includes the associated areas of:

- drive and braking,
- driving comfort and driving safety and
- steering stability and road holding.

Current chassis regulation systems such as ABS (anti-lock systems) and ASR or ETC (traction control) improve driving comfort and safety considerably. Further developments will make increased use of electronic components, and hydraulic elements will gradually be superseded.

The increasing functionality of the complete component gives rise to increased importance of the rolling bearings. The most significant application areas for rolling bearings in the chassis are:

- the steering column,
- the steering gear,
- the suspension and the McPherson strut bearings and
- the braking system – without or with ABS.

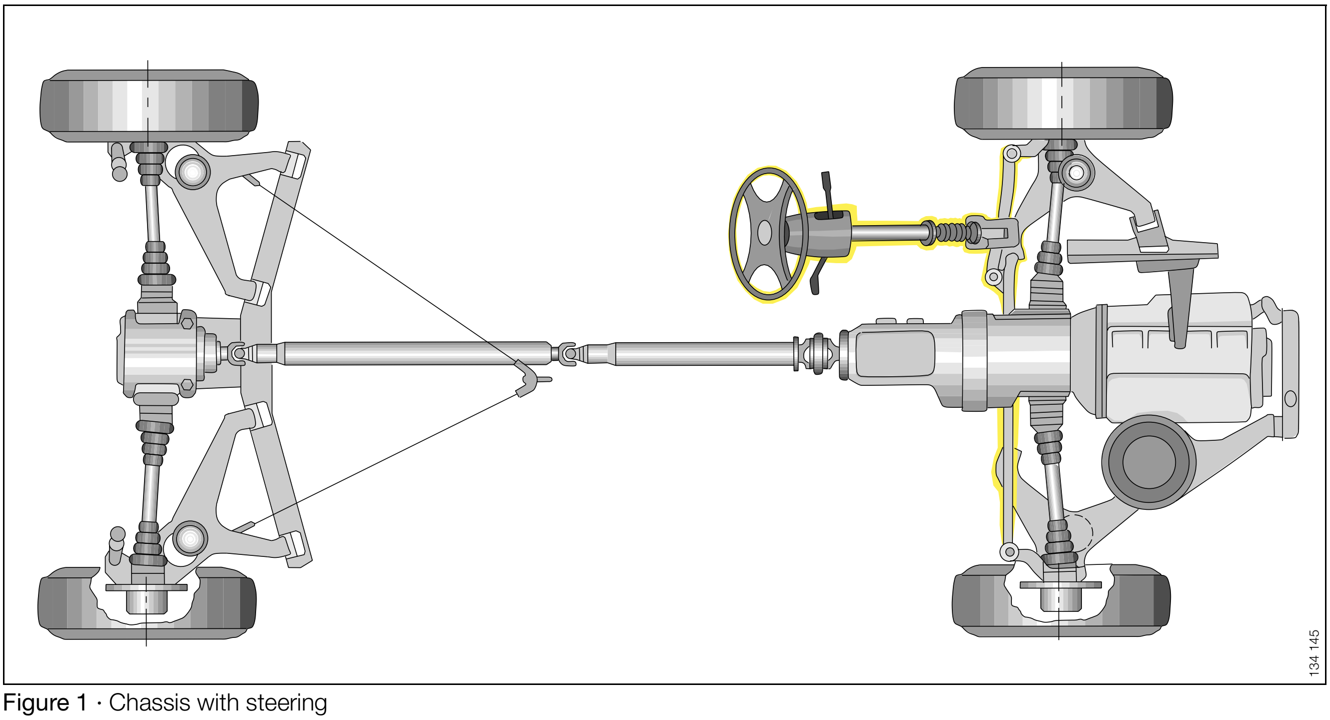

Figure 1 · Chassis with steering

Steering system

Demands on the steering system

The steering system must:

- convert the angle of the steering wheel into a specific steering angle of the wheels and
- provide the driver with information on the vehicle's condition of movement through the steering wheel.

Safety requirements

If a steering component is faulty or if it were to fail during operation, this has an effect on the function of the steering system. Compromised steering can lead to severe accidents.

In order to prevent injury to people and damage to objects, the steering system must meet extremely high safety standards. Functional safety is therefore fundamental for all steering components.

Economic requirements

Economy of design and production play a large part in determining the competitiveness of a vehicle.
Steering systems must therefore:

- comprise only a few components,
- be easy to produce and fit,
- have a low space requirement and
- be maintenance-free for the life of the vehicle.

Technical driving requirements

The technical driving requirements are influenced by the physics of driving and the steering kinematics and are also determined by the driver's demands on comfort.
The steering system must therefore:

- be easy to move and provide a high level of efficiency with a low energy requirement,
- have an acceptable steering torque but not hinder the self-centring return of the arrangement,
- damp out unevenness from the road surface and wheel oscillations and
- ensure directional stability and smooth coupling.

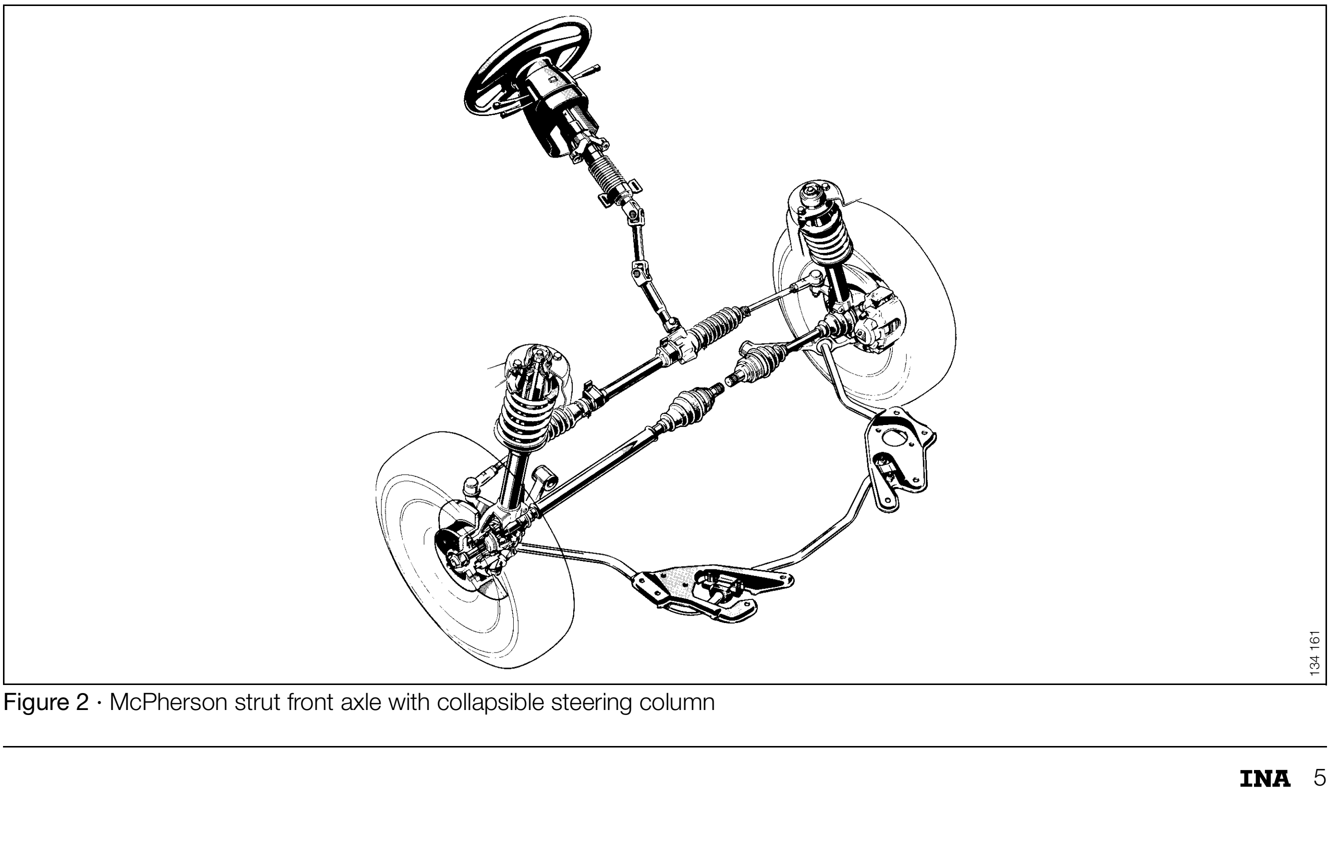

Figure 2 · McPherson strut front axle with collapsible steering column

Steering column

The steering column basically consists of:

- the outer tube which is screwed to the bodywork and
- the steering shaft.

The steering shaft connects the steering wheel to the steering gear and is supported in an outer tube. It transmits the steering torque.

Steering columns have to satisfy the following requirements:

- ensure high rotational rigidity for the steering shaft,
- ensure smooth steering,
- damp out noise,
- prevent our reduce injury to driver in the event of an accident,
- have low frictional losses and
- ensure the vehicle is safe from theft.

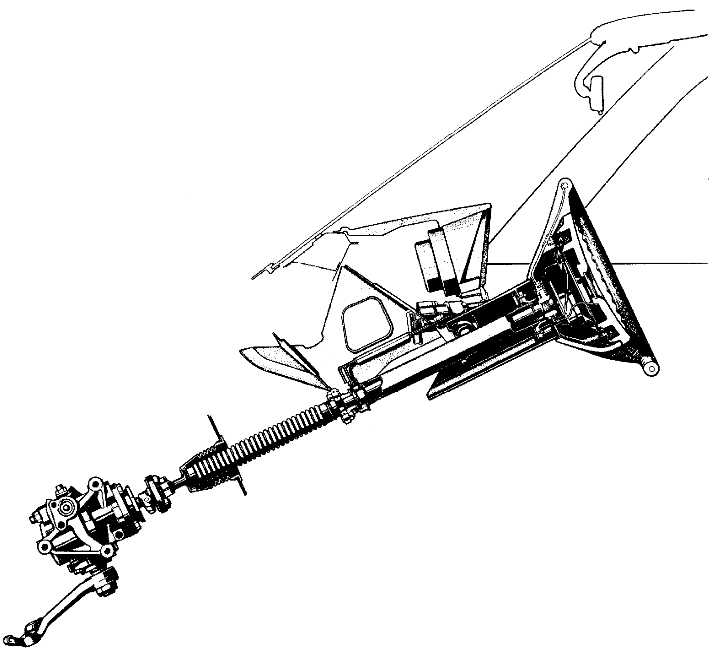

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Figure 3 · Steering column – outer tube, steering shaft, steering gear

The following design principles are used in general for steering columns.

Rigid steering column – Figure 4

The classic design is a rigid steering column. The steering wheel has a rigid connection to the steering shaft which is usually a single-piece item.

Steering column with angular adjustment – Figure 5

The angle of the steering wheel can be adjusted with this design. The tilting point is usually in the joint.

Steering column with adjustable height

Steering columns with adjustable height can be adjusted telescopically. The position of the steering wheel with respect to the driver can thus be altered in an axial direction.

Combined adjustment mechanism – Figure 6

Steering columns with only angular or height adjustment are both compromise solutions. The most favourable position of the steering wheel with respect to the driver is achieved through a combination of both angular and height adjustment.

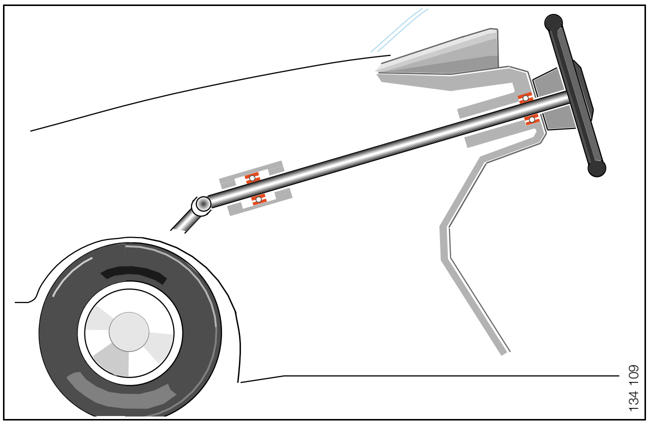


Figure 4 · Rigid steering column

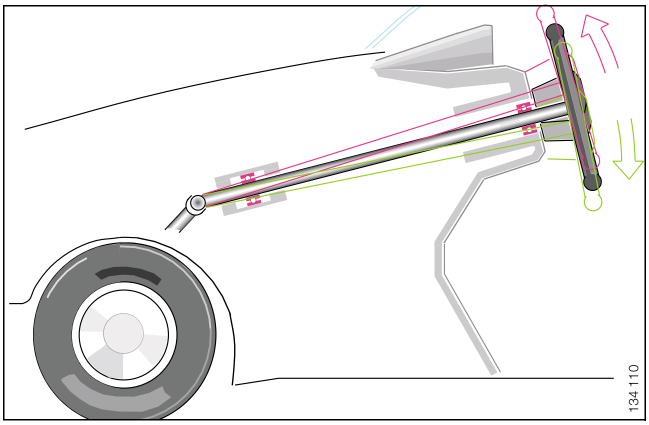


Figure 5 · Steering column with angular adjustment

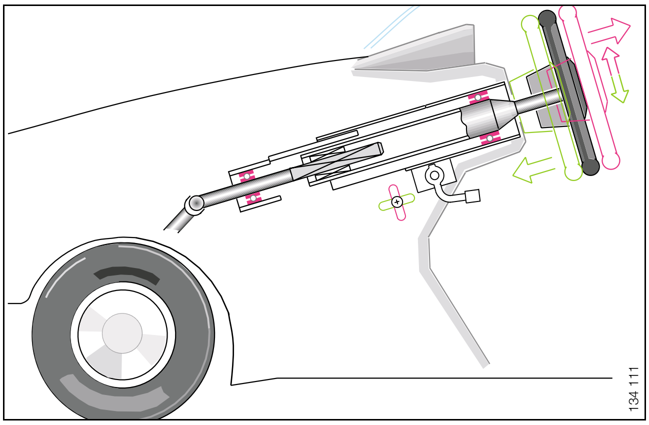


Figure 6 · Steering column with adjustable height

Demands on steering column bearings

Safety considerations

Bearings used in steering columns must satisfy the following requirements:
- clearance-free support of the steering shaft,
- effective damping of noise and oscillations,
- high rigidity and
- extremely low friction.

Body impact test – Figure 7

There is a legal specification for:
- the maximum displacement distance of the upper end of the steering column into the passenger compartment and
- the impact force of a test piece on the steering wheel.

Test conditions:
- displacement distance of 127 mm with frontal impact at a speed of 48,3 km/h
- maximum impact force of 11 000 N; impact at 24,1 km/h.

The impact force of 11 000 N is limited by:
- the design of the steering shaft (e.g. corrugated tube)
- the use of spring elements or similar energy absorbers.

The steering shaft bearings must be designed such that they take the load which occurs under specific test conditions. The shaft must display only indentations from the rolling elements and only slight deformation of the individual bearing components is permissible. The steering shaft must still be able to rotate.

Anti-theft test – Figure 8

The anti-theft test defines:
- the safety limits of the steering lock.

A torque of up to 240 Nm is applied to the steering wheel. This torque produces high residual radial forces on the upper and lower bearings via the circumferential force on the locking pin. The upper bearing on the steering wheel end is therefore subjected to high loads.

The bearings must have a high static load safety factor. Indentations in the raceways from the balls are permissible but cracks or fractures may not occur in the bearing components. The steering function of the vehicle must be unaffected. The maximum permissible effect from the indentations is a reduction in the degree of steering comfort.

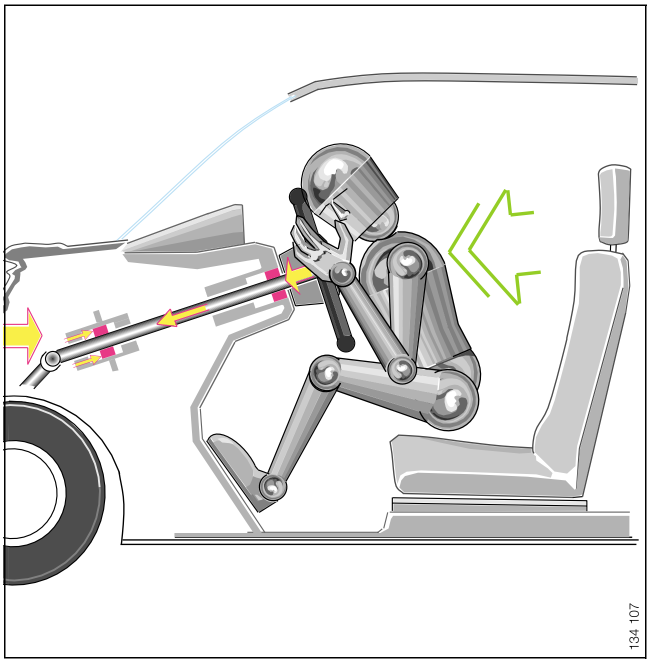


Figure 7 · Body impact test

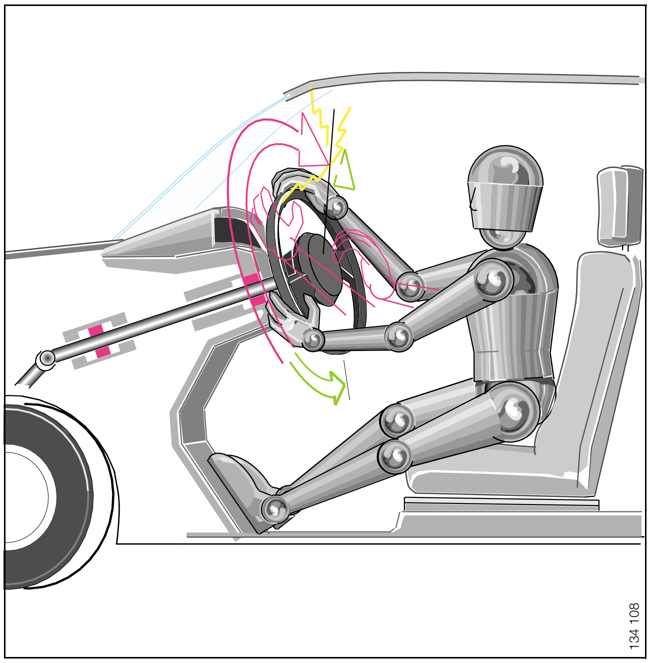


Figure 8 · Anti-theft test

Shake test – Figure 9

This test describes:

- the load on the bearing during tilting of the steering wheel caused by tensile or compressive movement.

The driver leans all his or her body weight on the steering wheel, causing a bending moment with high reaction forces on the bearings. The force on the upper bearing is normally between 1 000 N and 1 500 N.

Under these loading conditions, neither indentations nor deformations may occur in the bearings.

Other tests:

- rigidity,
- frictional moment,
- tilting strength,
- operating life,
- vibration and
- noise.

The bearing requirements and design recommendations are given on pages 18–29.

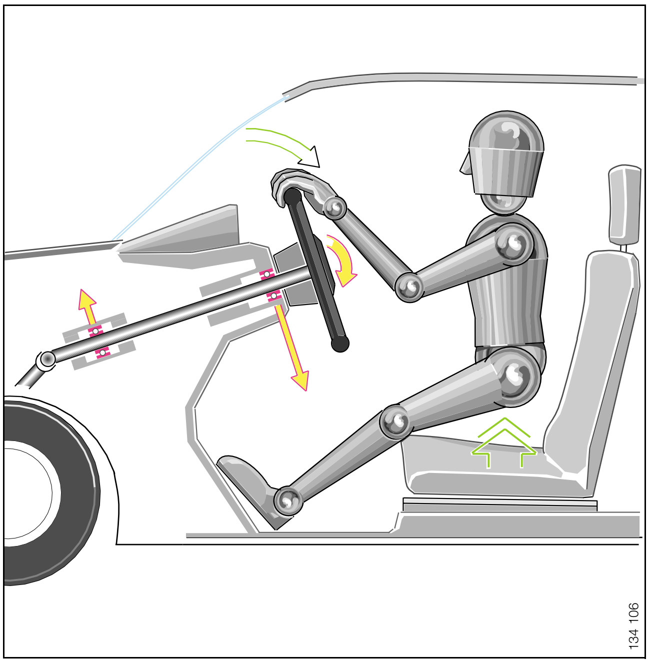


Figure 9 · Shake test

Opposed angular contact ball bearing arrangement
– Figure 10

This bearing arrangement is a proven solution.
It is used by many vehicle manufactures as it:

- has only a low frictional torque,
- has a relatively high rigidity,
- is easy to fit and economical.

The bearing are preloades clearance-free by cylindrical compression springs (variant I, ①) or wave spring washers (variant II, ①). The design and location of the springs is dependent on the bearing surroundings.

The spring force determines the rigidity of the bearing arrangement as well as the frictional torque and some of the variations in the frictional torque. Very high axial forces occur if the springs are preloaded to full compression. The bearings must support these forces. Although the drawn and induction hardened ball bearings have a very high static load safety factor, the forces must be limited so that raceway damage does not occur e.g. due to ball indentations.

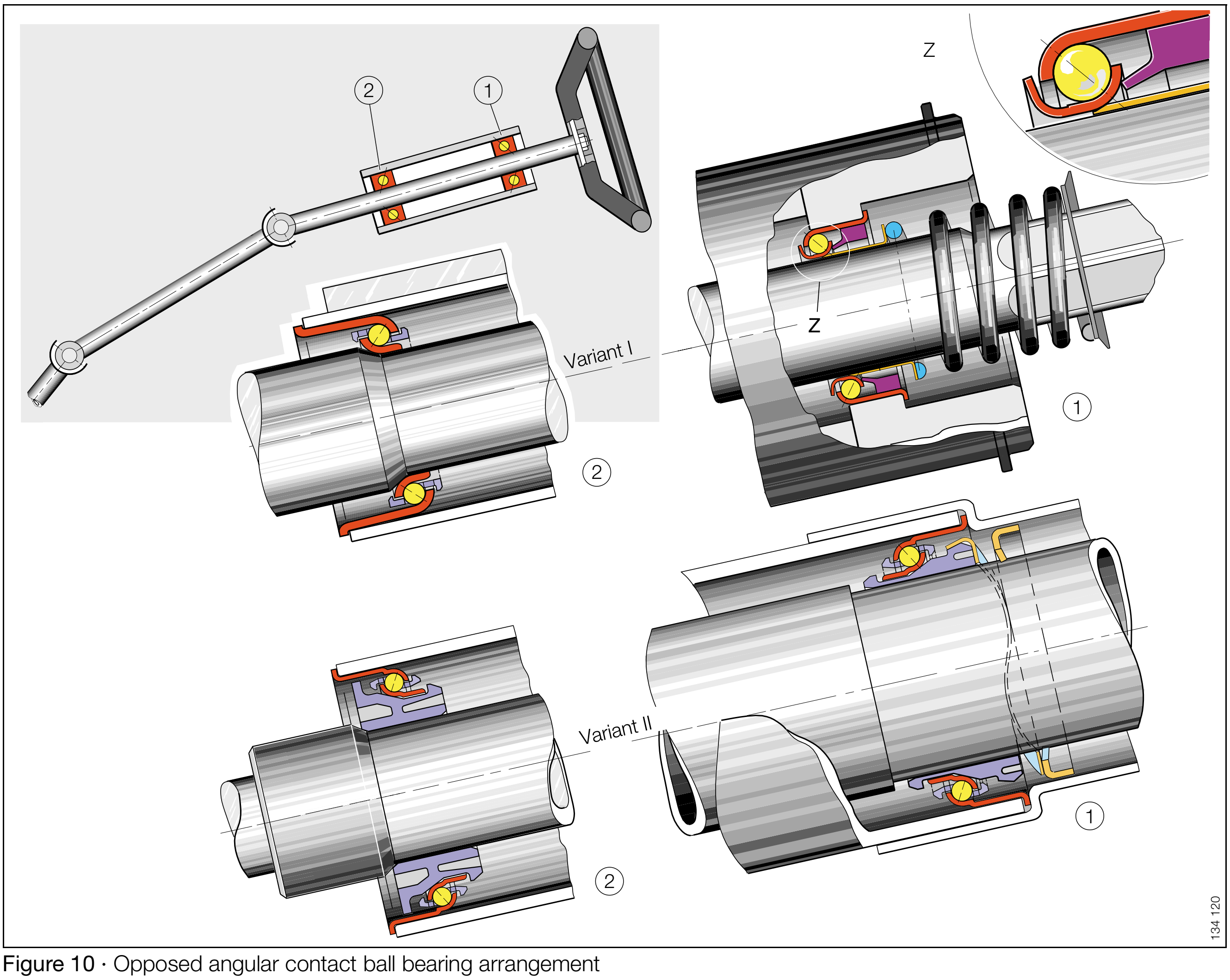


Figure 10 · Opposed angular contact ball bearing arrangement

Clamping rings – Figure 11

A push fit is required on the shaft for fitting the bearings. Clamping rings are therefore used between the bearing and the shaft. These rings centre the shaft in the bearing and provide friction locking due to the spring preload.

Clamping rings are produced in three design variants:

- solid ring made from deep drawn steel ①
  - these rings require a very high preload force and are used predominantly in trucks
- coiled rings made from thin-walled sheet steel ②
- plastic ring – TN clamping rings ③.

Variants ② and ③ are used in preference in passenger cars.

In the production of the steel clamping rings, a blunt point is formed on the end of the wedge “s”. The gap between the shaft and the bearing inner ring must be greater than the dimension “s” in order to ensure shaft centring.

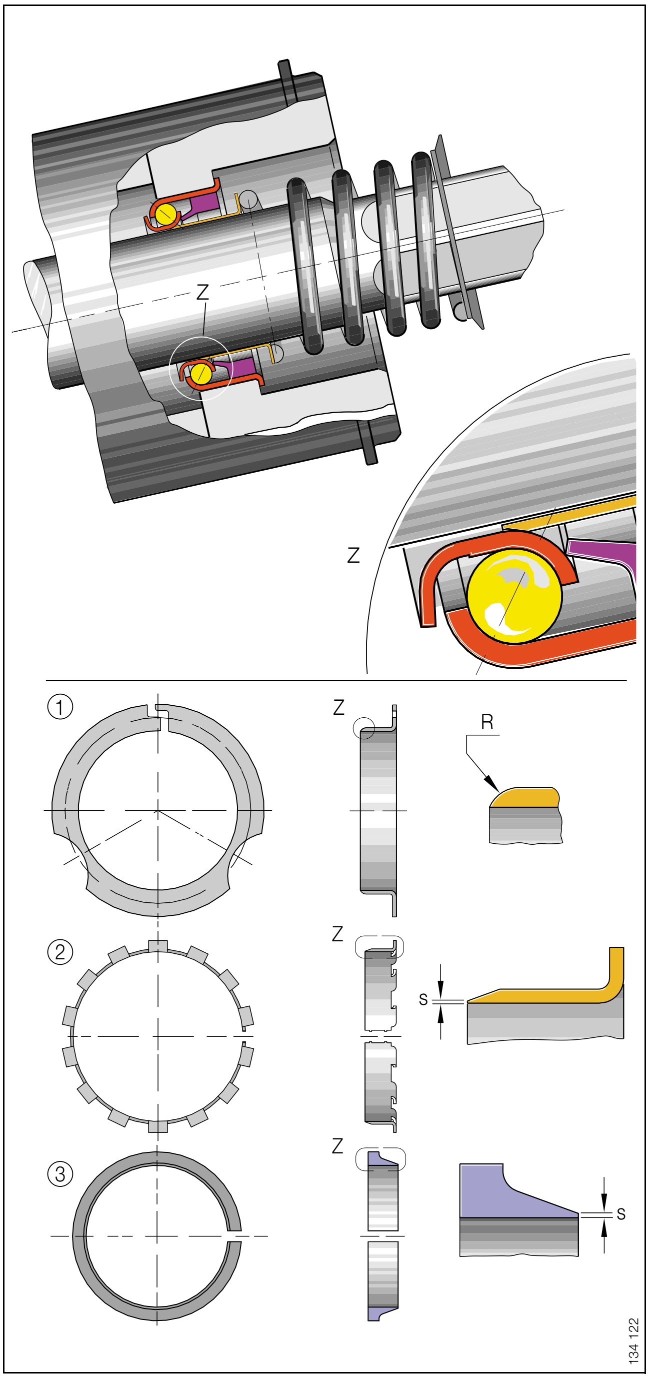


Figure 11 · Clamping rings

Angular contact ball bearings SKL – Figure 12

Angular contact ball bearings SKL are drawn i.e. non-machined bearings which are subdivided by the type of rolling element guidance – full complement or cage guided ball set.

Full complement angular contact ball bearings

The full complement ball set provides rolling characteristics with greater variations in the frictional torque. This design is therefore not suitable for steering systems with high comfort requirements.

Cage guided angular contact ball bearings

Cages retain the rolling elements at a distance from each other as well as guiding them, thus reducing friction.

The raceways can be honed in order to improve steering comfort.

Angular contact ball bearing variants

INA produces angular contact ball bearings SKL in the following variants:

- basic design ⑤
- with integral seals ④
  – these protect the bearings from contamination,
- with integral tolerance rings ①, ②, ③
  – these damp out noise and vibrations and bridge larger tolerances and
- with integral spring ②
  – these simplify steering column assembly.

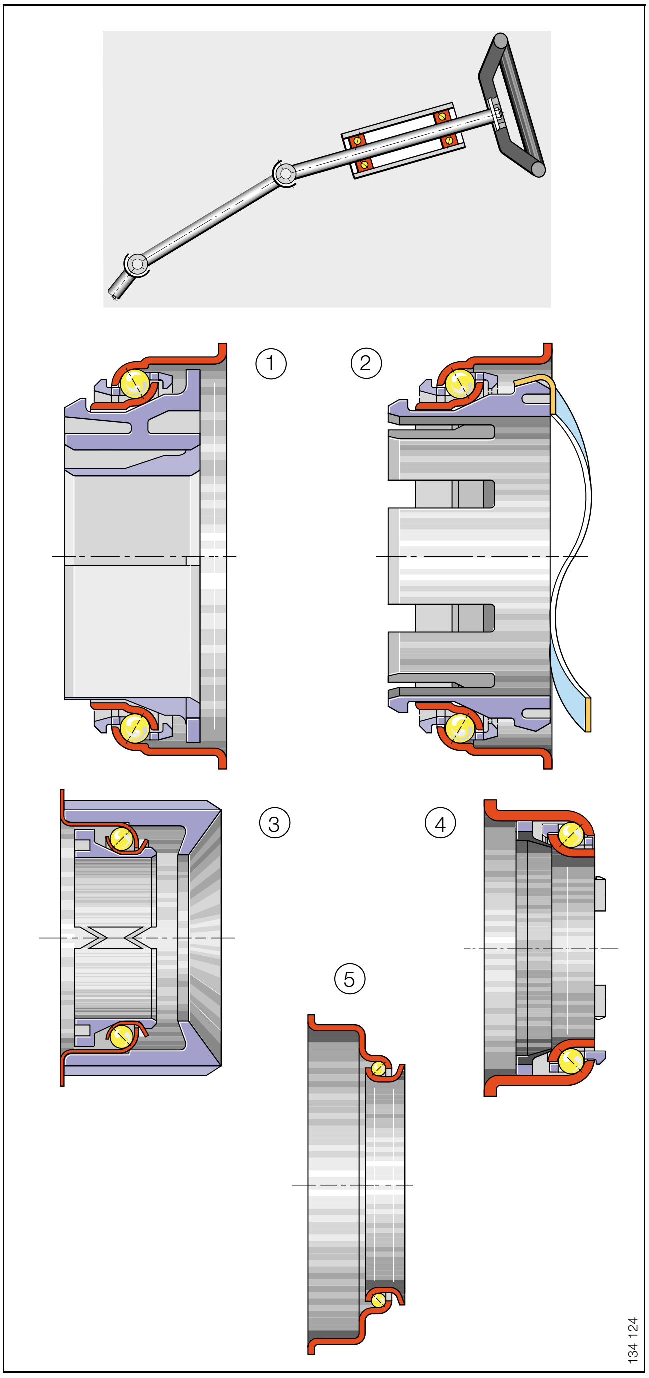


Figure 12 · Angular contact ball bearings SKL – selection

Opposed needle roller bearing arrangement – Figure 13

For rigid steering systems with angular adjustment, the steering shaft can be axially fixed in the steering gear. Needle roller bearings of type LEN ① are frequently used in this instance.

These bearings:

- do not have an inner ring – the needle rollers run directly on the steering shaft,
- provide clearance-free support for the steering shaft,
- damp out noise and vibrations,
- compensate tolerances in the surrounding structure – the steering shaft and the outer tube are usually cold-formed, are not remachined and are therefore economical components,
- have low friction and
- are easy to fit.

Preloading

The rubber tolerance ring provides the preload in the needle roller bearings. When the bearings are pressed into the outer tube, the split outer ring and the rolling elements are subjected to a defined preload by the tolerance ring.

The preload is set such that:

- sufficient rigidity is achieved and
- the displacement force for the shaft is not too high.

The limiting of displacement force is particularly necessary if the position of the steering shaft has to be adjusted during assembly.

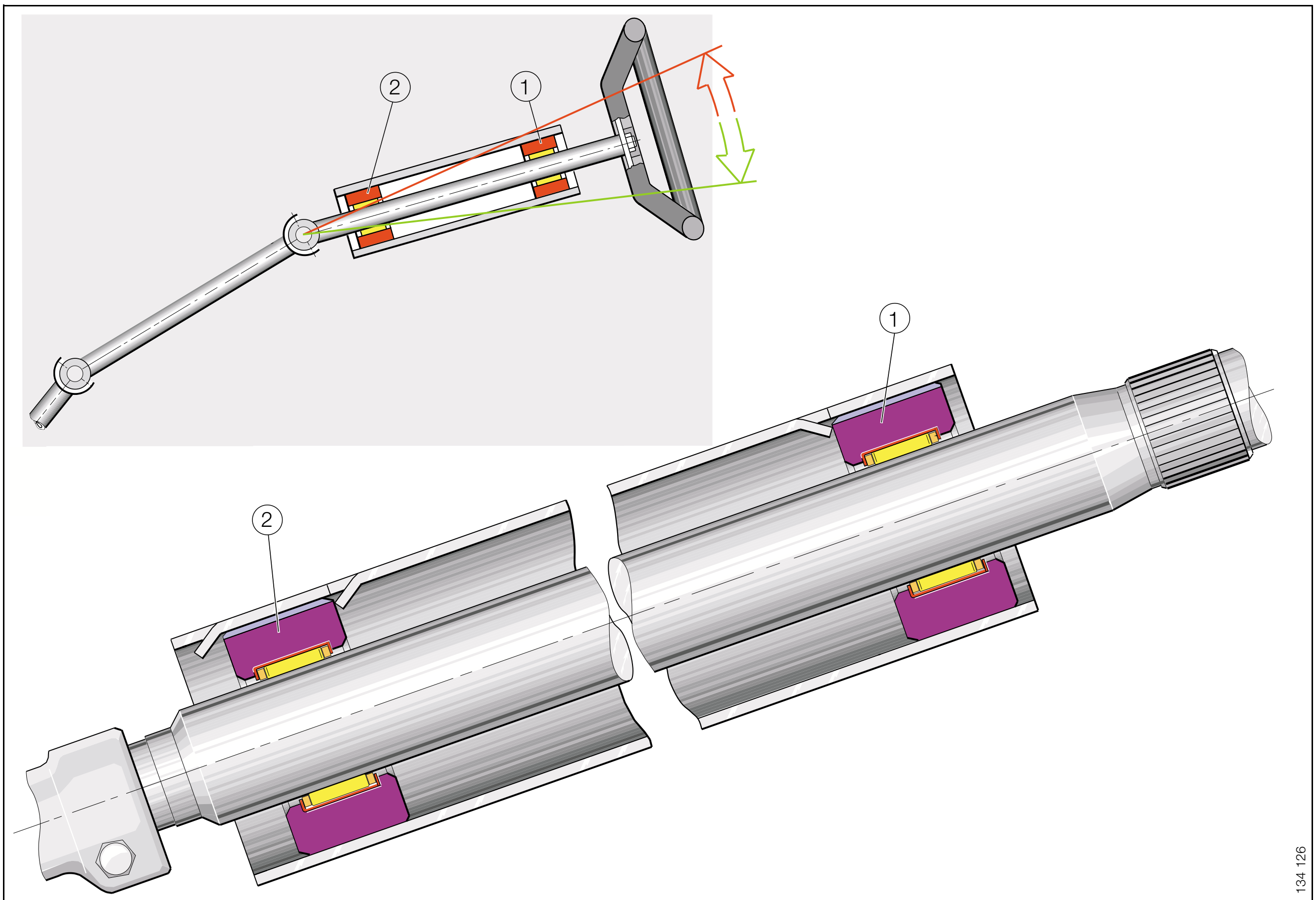


Figure 13 · Opposed needle roller bearing arrangement

Needle roller bearings LEN – Figure 14

A single bearing of this series consists of:

- a rubber tolerance ring,
- a split outer ring,
- a needle roller and cage assembly (cage with rolling elements) and
- a thrust washer.

The NBR hardness of the rubber tolerance rings is 65 to 80 Shore A (matched to the required rigidity).

The precisely specified rubber mixture and the derived technical delivery conditions ensure uniform NBR quality throughout the operating life of the bearings. The comfort characteristics of the steering system are therefore the same throughout the operating life.

The split outer ring and rolling element set are matched to each other. The raceways are thus protected from deformation and damage whilst under load. The split is set at an angle to the shaft axis and is staggered. The rolling elements can therefore overroll the split without any detriment to their function.

Needle roller bearing variants

INA produces needle roller bearings of series LEN with:

- single ① or double lip ② seals
  – this protects the bearings from contamination
- plain or serrated tolerance ring.

If misalignment errors are to be compensated (maximum shaft tilting ±3°) INA matches the dimensions and hardness of the tolerance ring. By doing this, the sealing lip remains on the running surface even during tilting. This is particularly important in adjustable steering systems as an additional adjustment element is no longer necessary here.

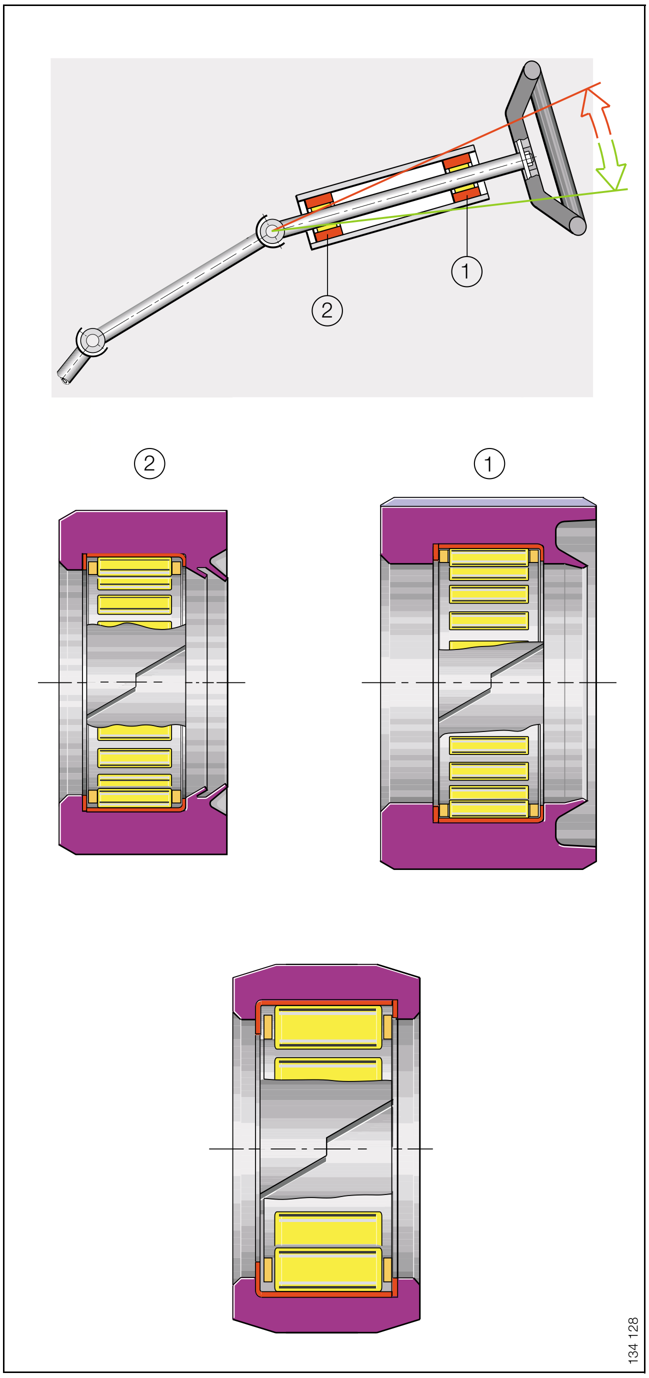


Figure 14 · Needle roller bearings LEN – selection

Opposed four point contact ball bearing arrangement

Increasing demands for comfortable steering systems with telescopic height adjustment mean bearing arrangements with four point contact ball bearings are gaining in significance.

These steering systems consist of two steering shafts which can displaced within each other. Each shaft is supported axially and radially by a locating bearing KLX. The guidance in the displacement area, usually a plastic/steel sliding pairing, is sufficient as the third bearing position:

The locating bearing must:

- be clearance-free, rigid and have low friction and
- compensate housing and shaft tolerances.

In order to keep costs to a minimum, the functionality of the bearings is increased by means of design improvements.

Installation example – Figure 15

The upper locating bearing ① – on the steering wheel:

- provides clearance-free axial and radial fixing for the shaft,
- compensates the length tolerances in the steering column by means of the integral spring and spacer ring and
- serves as an assembly aid due to the retaining lugs on the tolerance ring – locates the shaft during transportation.

The tolerance ring on the lower locating bearing ② provides axial fixing by locating the snap lug in the shaft recess.

The bearing arrangement is set clearance-free by the spring elements in the bearing. These place the bearing outer ring and the ball set under preload.

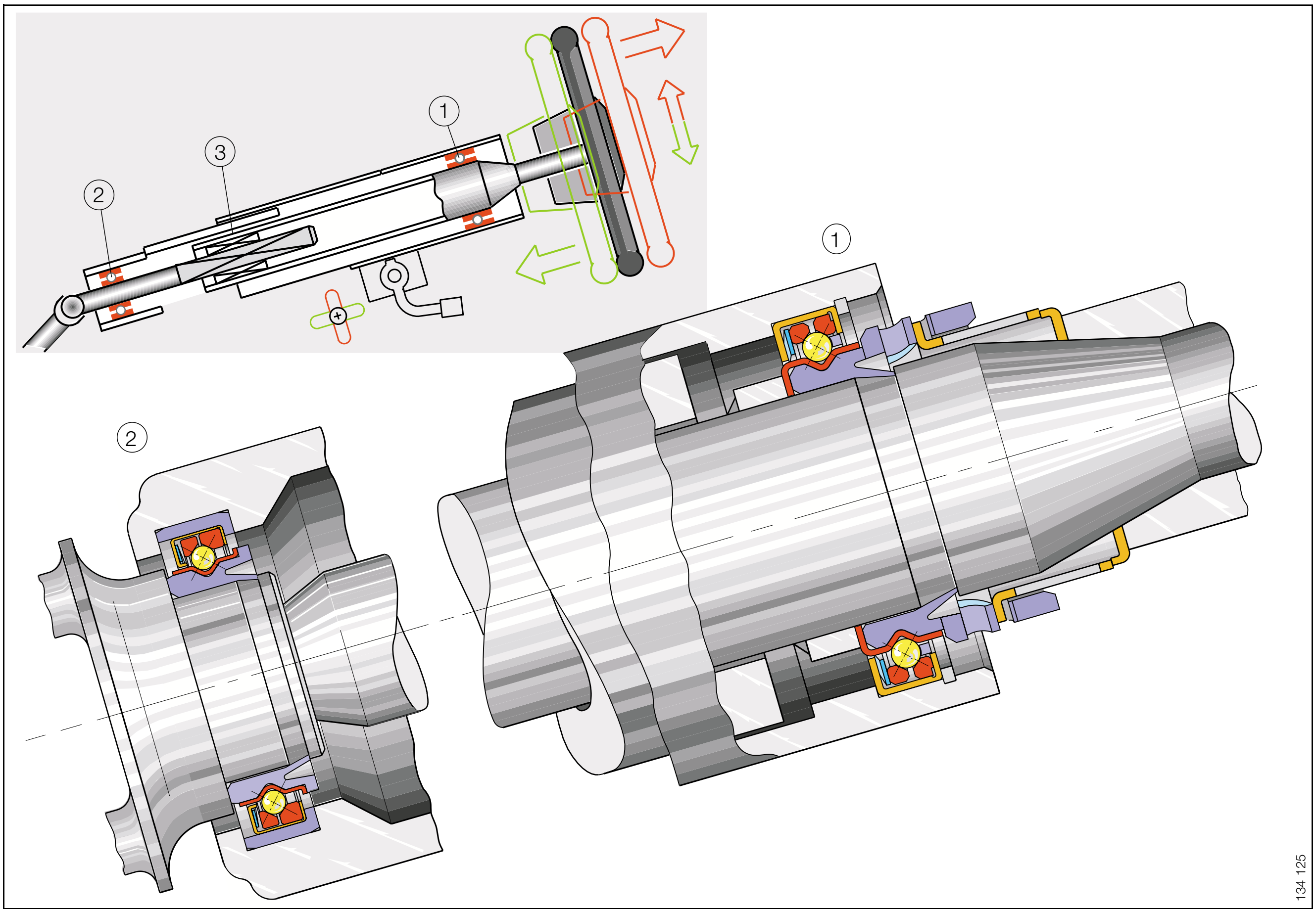


Figure 15 · Opposed four point contact ball bearing arrangement

Four point contact ball bearings KLX – Figure 16

The initial bearing was a simple four point contact bearing without spring preloading. Demands for more comfort and greater functionality lead to design variants:

- clearance-free four point contact bearing KLX with wave spring washer ③
- clearance-free four point contact bearing KLX with two rubber elements ④
- clearance-free four point contact bearing KLX with one rubber elements ⑤.

Variant ⑤ ist the most reasonable solution with respect to production costs and function as:

- all bearing rings are produced as drawn components,
- only one rubber element is required,
- the outer sleeve can also be used as the outer ring and
- the inner ring has a reinforcement for a press fit with defined press-out force.

However, tooling costs are high and bulk production must therefore be justified by economical quantities.

Clearance-free four point contact bearings are rigid and have a defined friction. However, as these values have a mutual influence on each other, the design of the bearing arrangement and production of the bearings must be carefully matched to each other (see sections *Rigidity* and *Friction*).

Four point contact bearings KLX are locating bearings. They must support the axial forces which occur, even during vehicle crashes. The following are therefore particularly important:

- the staic load safety factor and
- the strength of the bearing components.

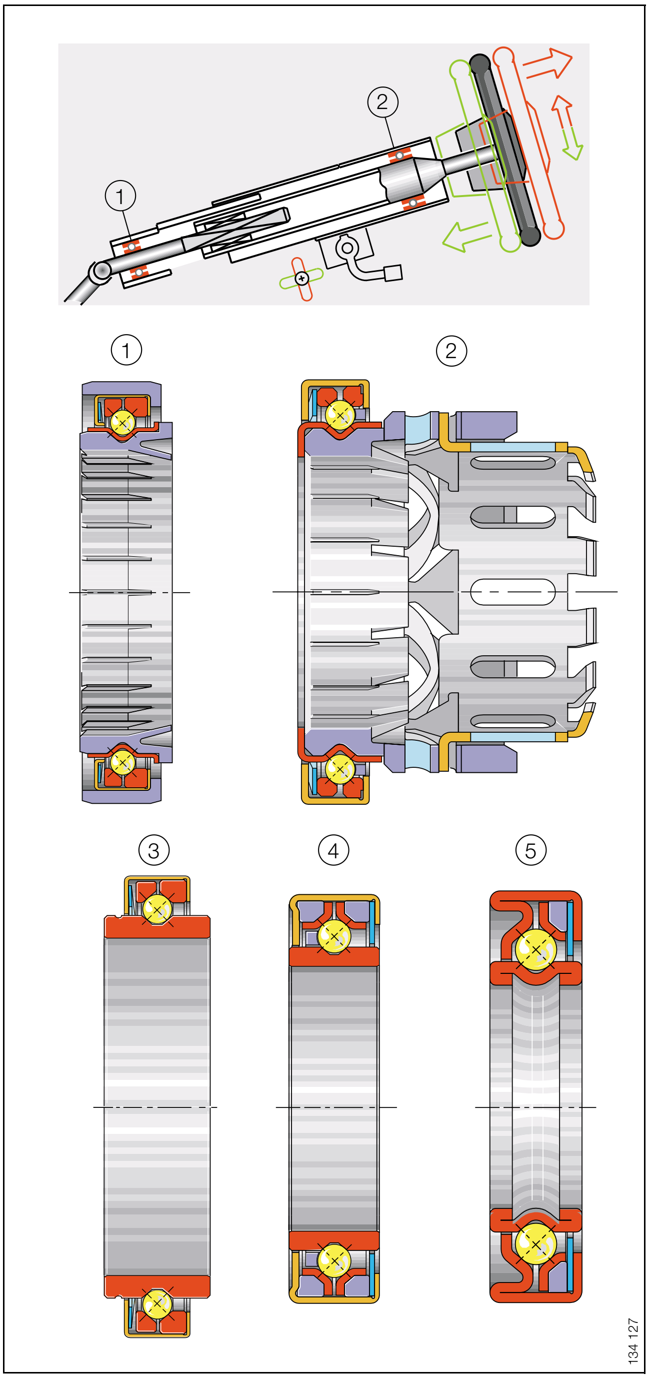


Figure 16 · Four point contact bearings KLX – selection

Four point contact ball bearing and needle roller bearing arrangement

Installation example – Figure 17

The combination of a four point contact bearing KLX ① and a needle roller bearing LEN ② is frequently used for rigid steering columns with angular adjustment if:

- the steering shaft cannot be axially fixed in the steering gear and
- fixing is not a viable technical solution.

This combination is considerably more rigid than, for example, an opposed needle roller bearing arrangement LEN/LEN. The icreased rigidity is achieved by the four point contact bearing and its positioning at the point where the highest forces occur (the steering wheel).

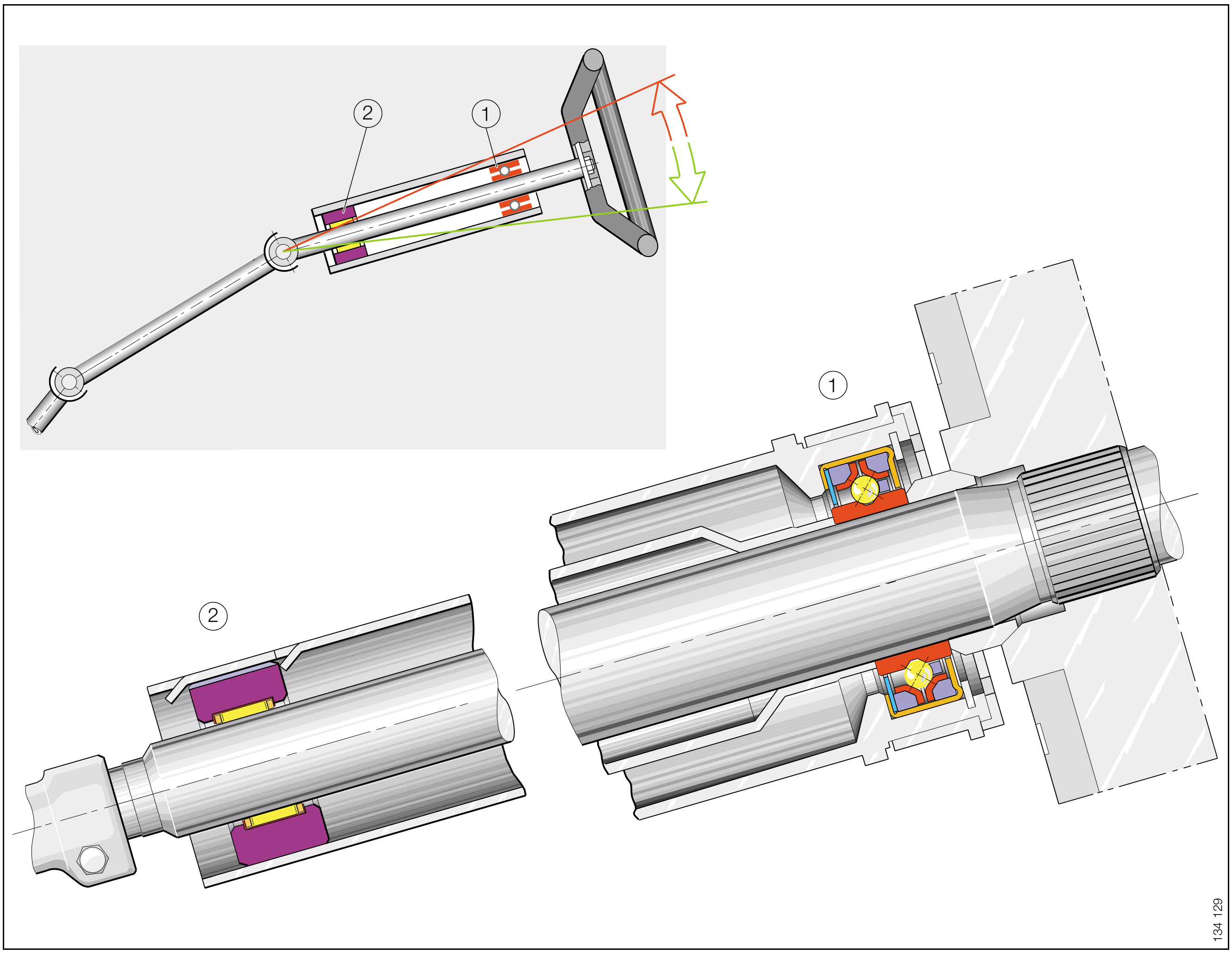


Figure 17 · Arrangement with four point contact bearing and needle roller bearing

Rigidity

With increasing demands on driving comfort and passive safety, there is a similar rise in the steering column rigidity requirements; for example, the airbag increases the weight of the steering wheel considerably.

In order to ensure steering wheel deflections from load or vibrations due to irregularities in the road are not transmitted to the driver, the steering shaft bearing arrangement must have a correspondingly rigid design.

The rigidity values in the following bearing arrangements are guides for orientation. They have been determined either empirically or calculated.

Opposed angular contact ball bearings SKL/SKL
– Figure 18

The rigidity is largely dependent on:

- the spring preload,
- the contact angle in the bearing and
- the rigidity of the shaft (middle diagram, Figure 18).

The lower diagram shows the bearing arrangement rigidity as radial displacement of the steering shaft with bearings:

- at the upper bearing position and
- at the load point "F".

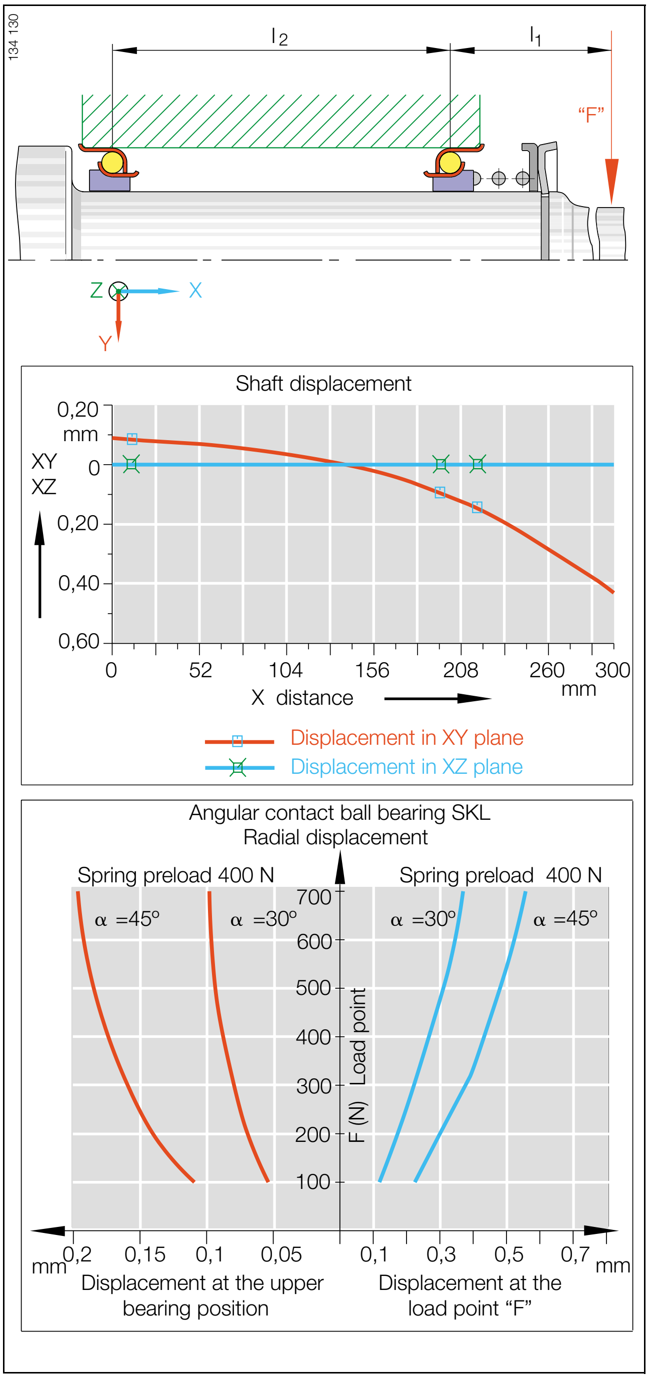


Figure 18 · Opposed angular contact ball bearings SKL/SKL

Opposed needle roller bearings LEN/LEN – Figure 19

The rigidity is lower in this arrangement.

The displacement of the shaft is largely dependent on:

- the hardness of the rubber tolerance ring and
- the force F.

The figure shows the displacement at:

- the upper bearing position and
- the load point “F”.

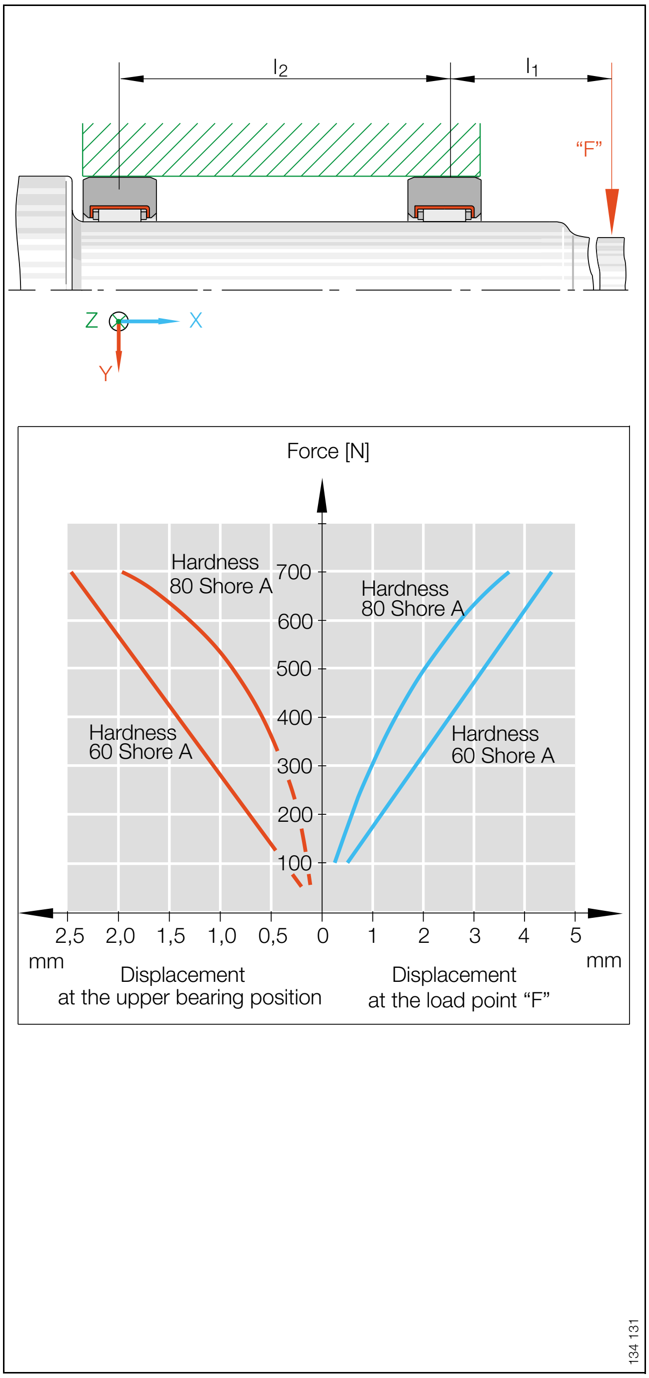


Figure 19 · Opposed needle roller bearings LEN/LEN

Opposed four point contact ball bearings KLX/KLX
– Figure 20

Increased rigidity is achieved with clearance-free or preloaded four point contact bearings.

Relatively high rigidity values are achieved by the defined preload which correspond approximately to the values for the SKL/SKL combination.

The figure shows the displacement at:

- the upper bearing position and
- the load point "F".

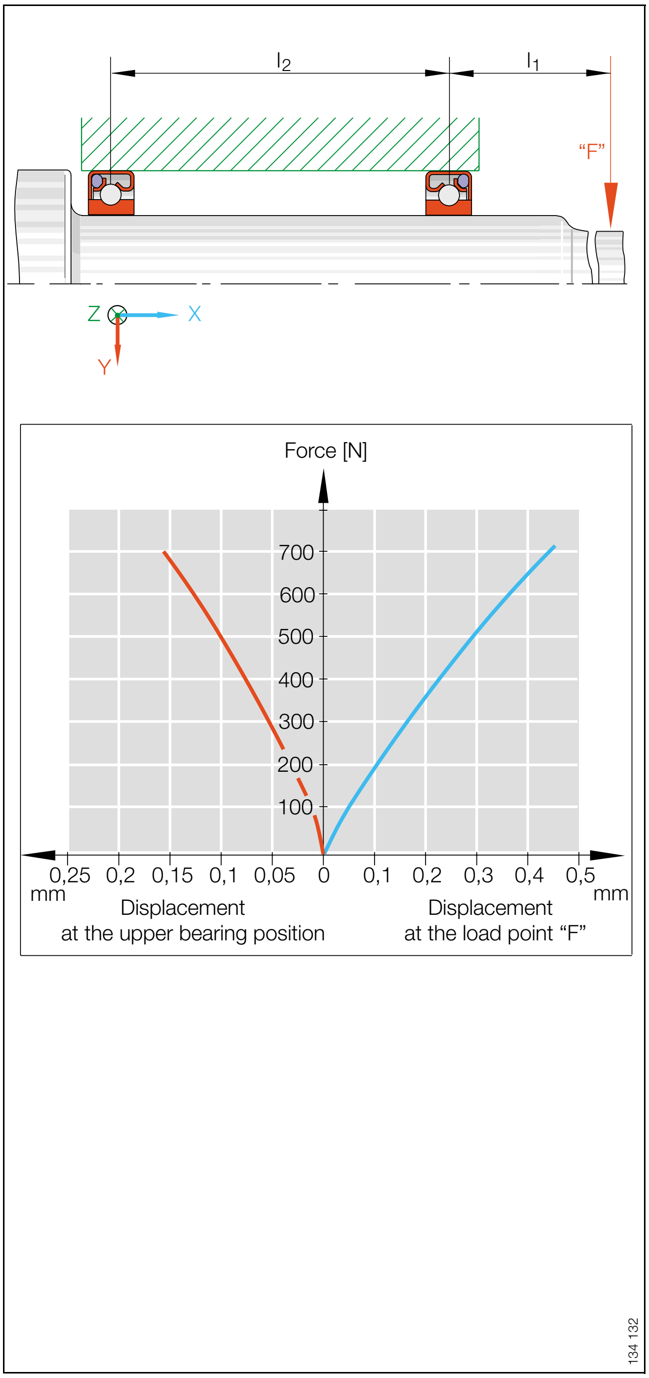


Figure 20 · Opposed four point contact bearings KLX/KLX

Four point contact ball bearing KLX and needle roller bearing LEN – Figure 21

This combination is a compromise with respect to the permissible displacement of the shaft.

The rigidity of the upper bearing (at the steering wheel) is decisive for the total rigidity. The hardness of the rubber tolerance ring on the lower bearing is not significant.

The figure shows the displacement at:

- the upper bearing position and
- the load point “F”.

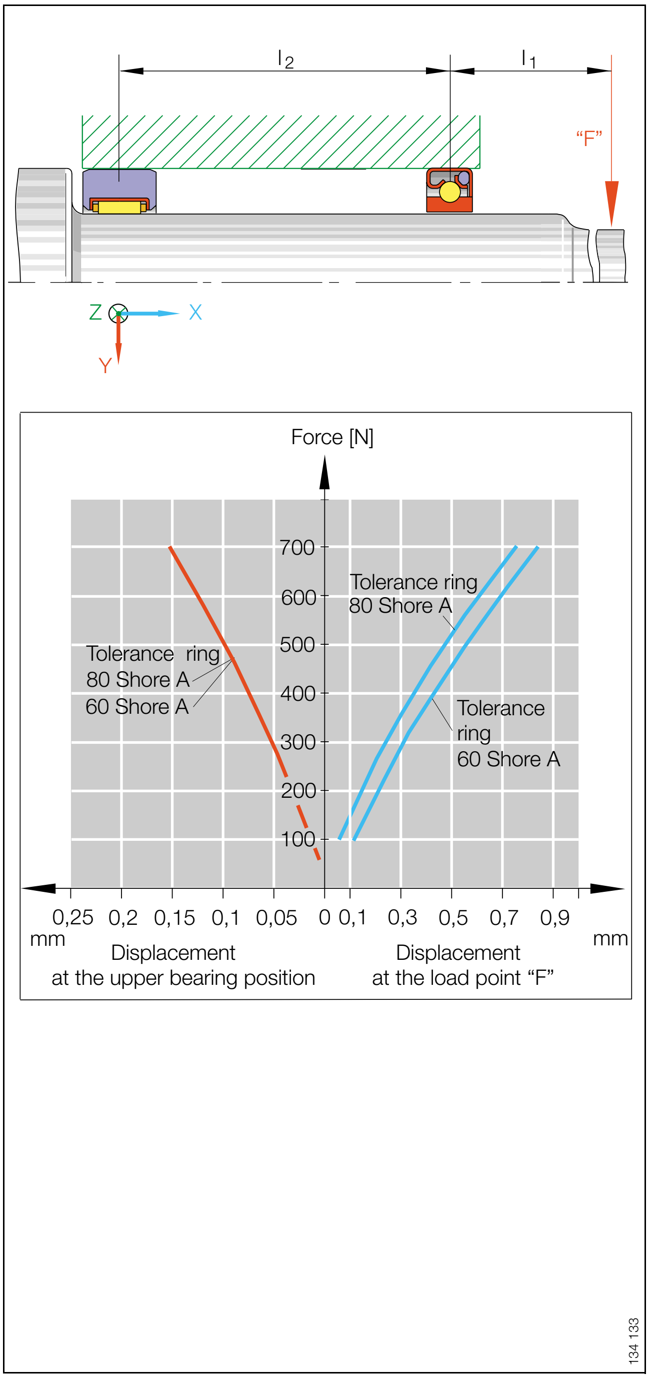


Figure 21 · Four point contact bearing and needle roller bearing KLX/LEN

Comparison of rigidity values

The comparison shows the rigidity values at the load point "F" – Figure 22

If a high rigidity is required, the following should be used:

- KLX/KLX combination or
- SKL/SKL combination.

The bearing geometry and preload must be set such that good friction values are achieved as well as high rigidity.

The LEN/LEN arrangement has the lowest rigidity. If the rigidity of the tolerance ring cannot be substantially increased (e.g. by a plastic ring), the arrangement is replaced by a better combination.

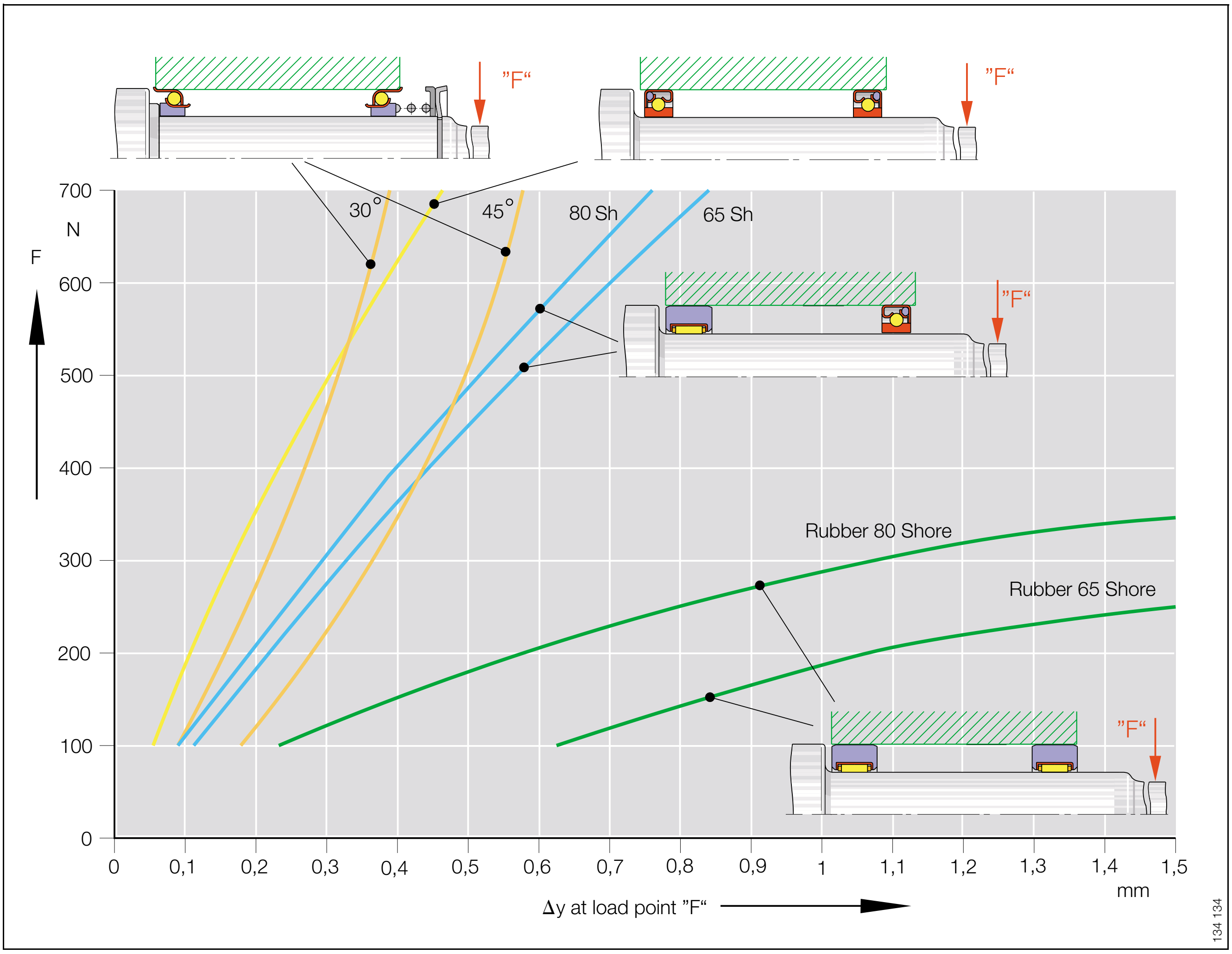


Figure 22 · Comparison of rigidity values at load point "F"

Friction

Apart from rigidity, friction is one of the most important physical factors influencing the degree of comfort as well as quality and customer acceptance of the steering.

The friction in the steering column comprises:

- the friction in the steering shaft bearings and
- the friction in the joints (universal joint bearings).

The frictional component in the steering shaft/steering bearings is approximately 70% to 80%. It is dependent on:

- the quality of the bearing raceways,
- the quality and geometrical accuracy of the bearing seating and
- the type of bearing, the bearing preload and the centring.

Figure 23 shows the installation of angular contact ball bearings SKL in a standard steering column with the usual geometrical errors in the bearing seating.

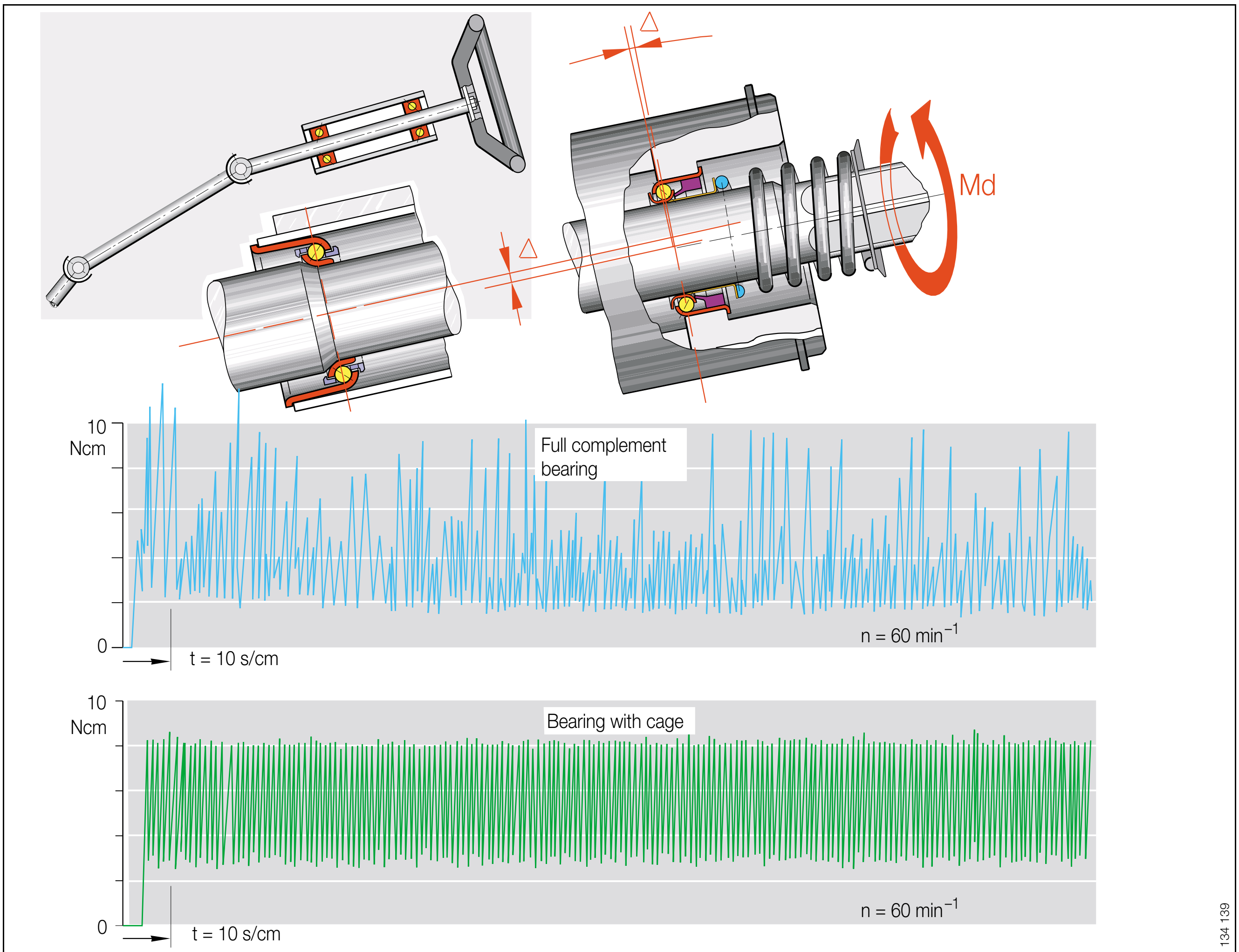


Figure 23 · Frictional torque in a standard steering column – comparison between full complement bearing and bearing with cage

In contrast to Figure 23, Figure 24 shows an installation of angular contact ball bearings SKL in a steering column or a housing with precision bearing seating surfaces.

The frictional torque is considerably lower in this instance.

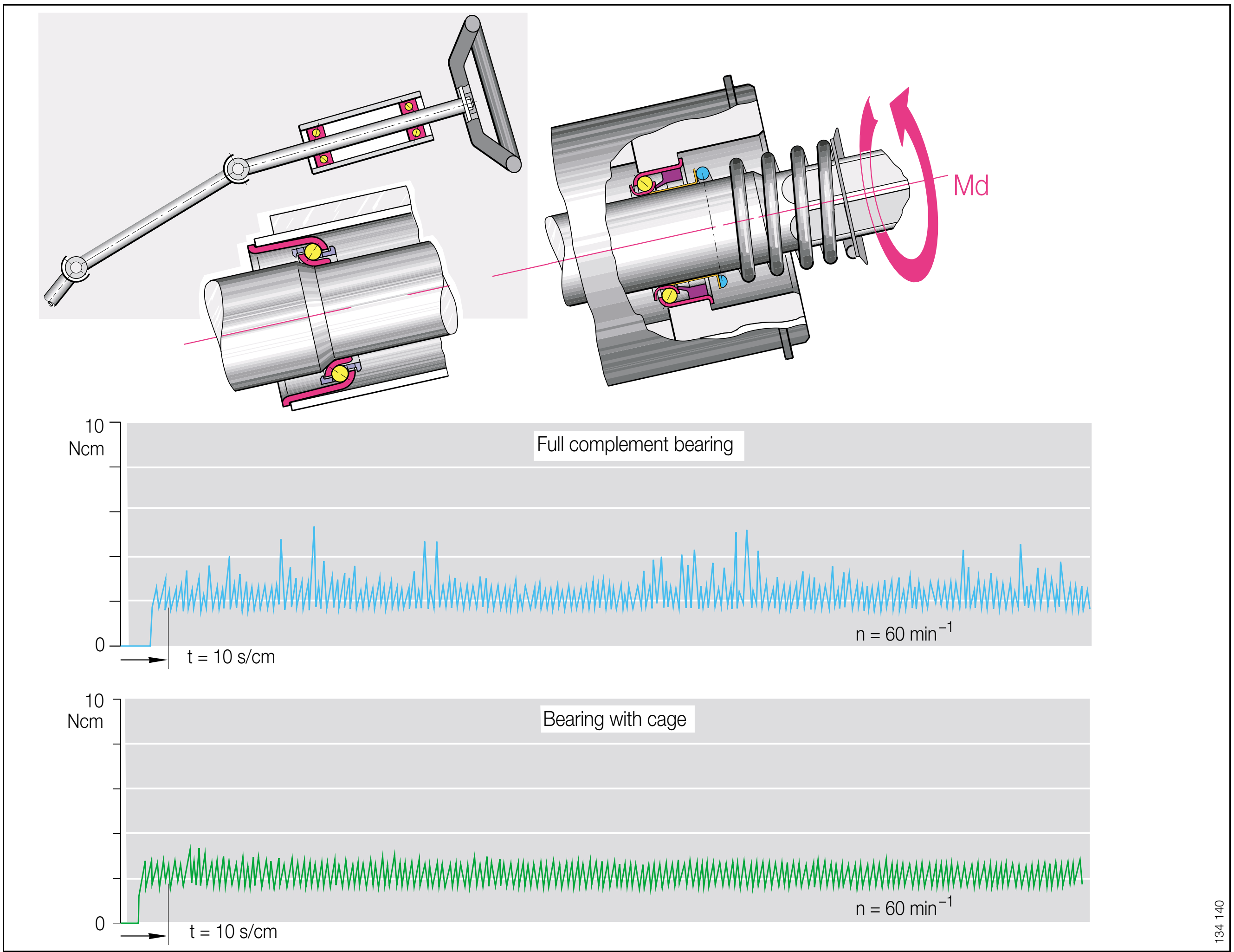


Figure 24 · Frictional torque in a steering column with precision bearing seating surfaces – comparison between full complement bearing and bearing with cage

Test procedures

INA has developed test rigs and procedures taking customer specifications into consideration (see Figure 25 as example and the table below) for the following measurements and tests:

- frictional torque,
- operating life,
- axial and radial rigidity,
- angular misalignment,
- breaking load and
- noise.

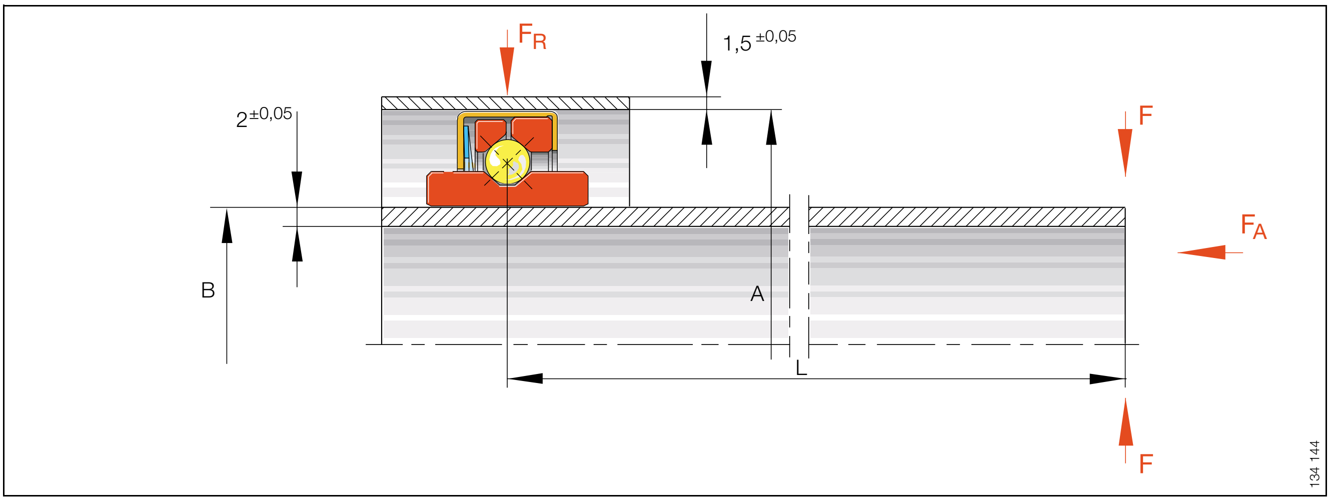


Figure 25 · Test sketch, test specification – example

Bearing test specification		Ring gauge A	Plug gauge B	Comments
Frictional torque		Loose	Loose	Measurement after 3 revolutions at $n = 60\ min^{-1}$
Frictional torque deviation				
Maximum frictional torque		Minimum value	Maximum value	
Frictional torque deviation				
Axial rigidity		Maximum value	Minimum value	Ball indentations permissible
Load F_A ±1 000 N/±3 500 N	Maximum displacement			
Radial rigidity		Maximum value	Minimum value	No contact between inner ring and sleeve under radial load F_R
Load F_R ±200 N/±1 000 N	Maximum displacement			
Radial load 15 000 N		Maximum value	Minimum value	Ball indentations and deformation of individual components permissible, maximum frictional torque Ncm ...
Maximum displacement Maximum permanent deformation				
Minimum axial breaking load		Maximum value	Minimum value	–
Minimum shaft retention force		Maximum value	Minimum value	–
Angular displacement under radial load F = ±100 N		Maximum value	Minimum value	Load applied L = ... mm away from the bearing axis

Frictional torque in four point contact bearings KLX
– Figure 26 and 27

The frictional torque is measured on four point contact bearings with spring preload in order to ensure quality.

INA has developed specific processes and quality standards (QN 4.65) in order to measure and display the frictional torque and variation in the frictional torque.

Figure 27 shows the design of the measuring rig and a typical frictional torque trace. The outer ring is connected to the sensor by means of a chuck and the inner ring to the drive shaft by a similar means. The measurement is thus carried out free of axial loads.

After running in (approximately 3 revolutions), the values for the subsequent three revolutions are determined.

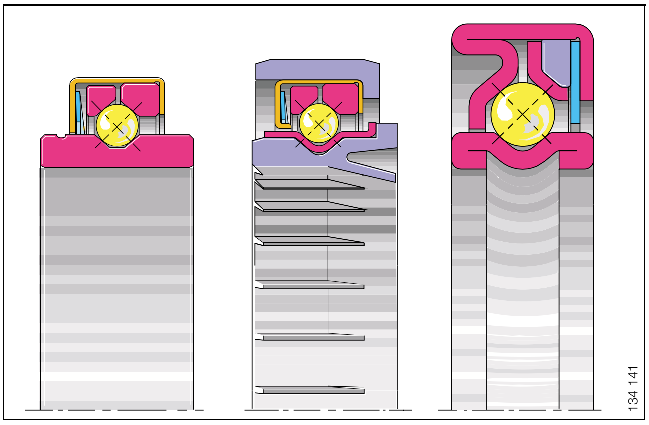


Figure 26 · Four point contact bearings KLX – design variations

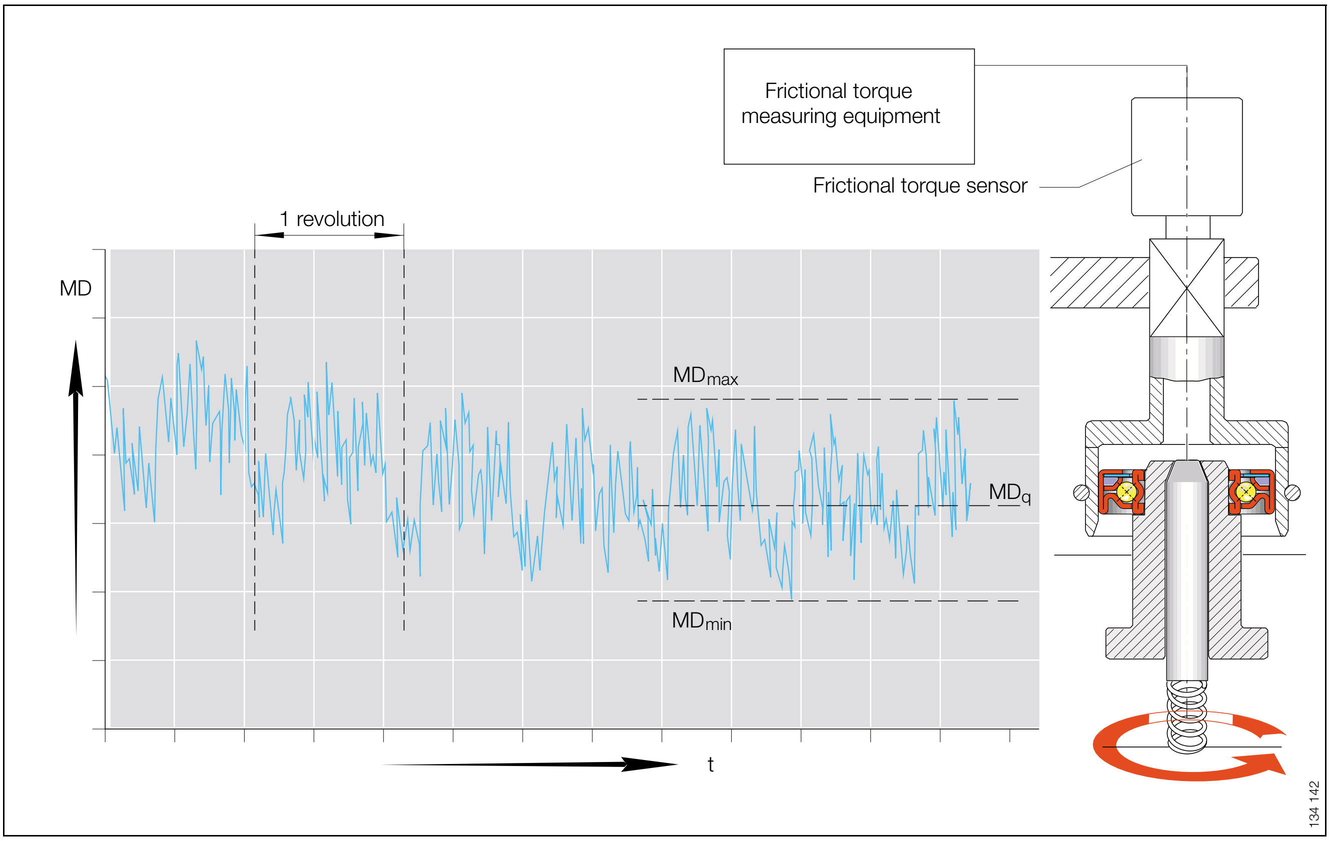


Figure 27 · Measuring equipment and frictional torque trace

Frictional torque –
example with angular contact ball bearings SKL

Test conditions

- test rig as shown in Figure 28
- axial load per bearing: 250 N
- bearing speed: 60 min^{-1}.

Approval criteria

- maximum frictional torque per bearing: 0,1 ±0,03 Nm
- no disruptive rolling noise.

Rating life – example with angular contact ball bearings SKL

Test conditions

- test rig as shown in Figure 28
- radial and axial load per bearing: 250 N
- number of revolutions: 100 000 min^{-1}
- bearing speed: 120 min^{-1}.

Approval criteria

- maximum frictional torque per bearing: 0,1 ±0,03 Nm
- bearing fully frictional: no ball indentations, cracks or fractures permissible.

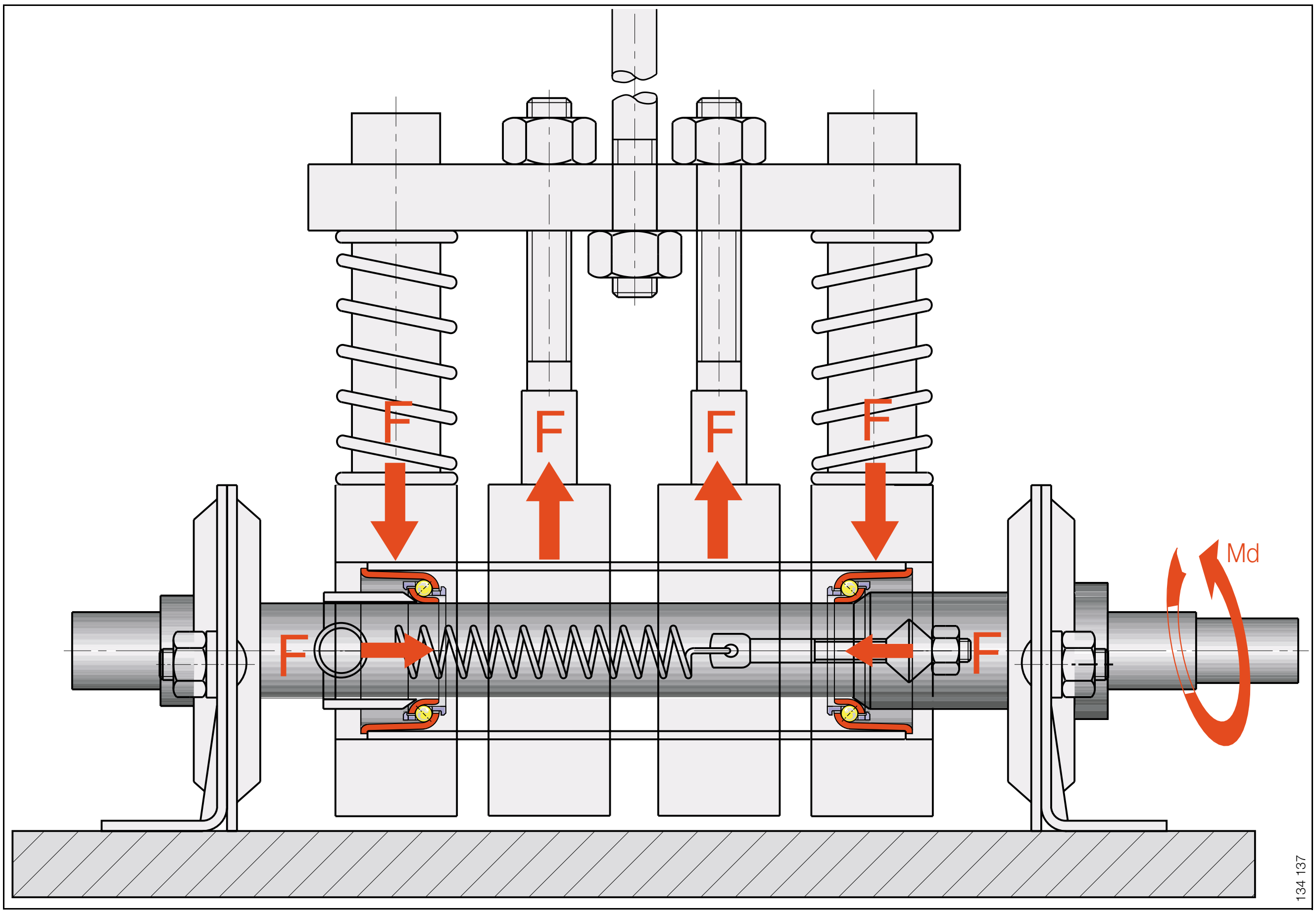


Figure 28 · Test rig

Breaking load – Figure 29

Test conditions

- test rig as shown in Figure 29
- axial load: 4 500 N.
  The load is applied and maintained for 3 seconds.

Approval criteria

- the inner ring must remain an integral part of the bearing
- no cracks or fractures.

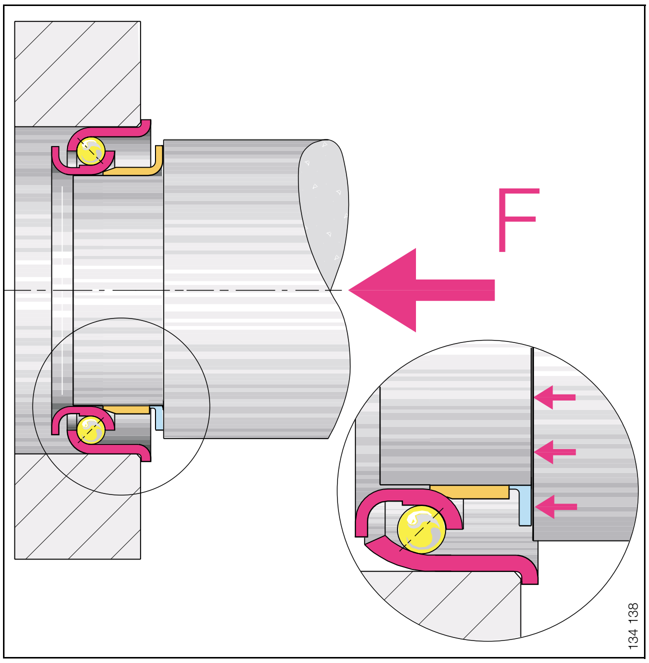


Figure 29 · Test rig

Noise

Test conditions

- measurement rig as shown in Figure 30.

Influences on the cause of noise

- raceway quality
  - roughness
  - geometrical accuracy
- from/design of the steering column
- rigidity of the steering column and
- position of the bearings.

The bearing raceways are usually made from drawn material. The quality can only be improved by grinding or honing.

If the demands on the noise characteristics are particularly high, noise damping measures are essential for the bearing/bearing tube and the bearing tube/bodywork.

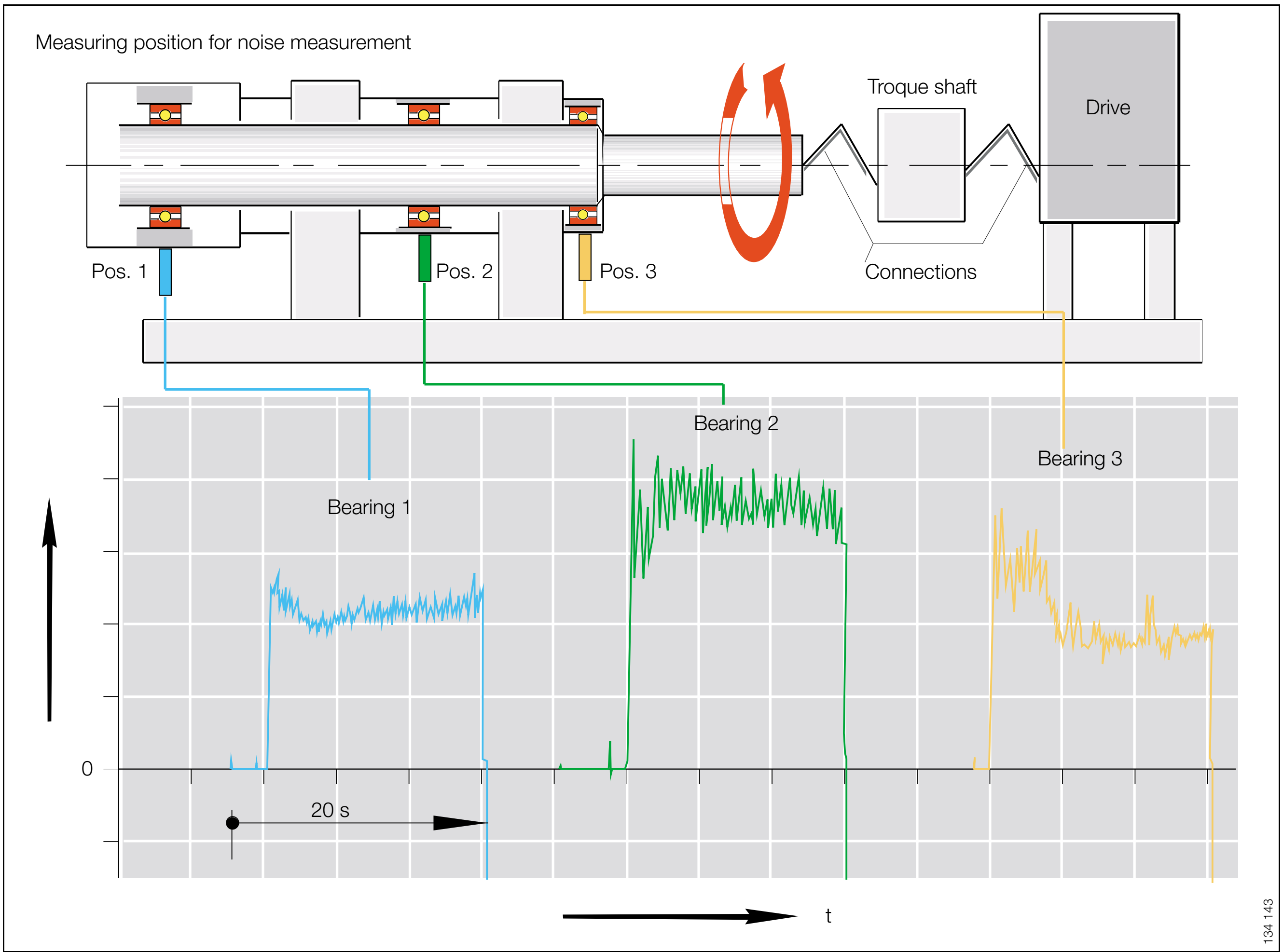


Figure 30 · Noise measurement test rig

Fitting dimensions

Design of bearing seating surfaces

The bearing seating surface quality has a decisive influence on the frictional torque, the rigidity and the noise characteristics of the steering column.

The following examples for the design of the seating surfaces are recommendations and can be modified to suit requirements and budget.

Preloaded angular contact ball bearing SKL – Figure 31

- Housing
  - bearing with press fit in housing
  - interference outer ring/housing, minimum 0,02 mm
- Shaft
  - inner ring with loose fit on the shaft centring with steel tolerance ring, minimum gap 0,2 mm
- spring preload
  - for passenger cars, minimum 300 N
  - for commercial vehicles, minimum 500 N.

The geometrical accuracy of the bearing seating surface should be within the given diameter tolerance and the coaxiality should be as small as possible.

The following must be taken into consideration in the design:

- bearing type,
- distance between bearings,
- type of clamping and tolerance rings and
- spring design and magnitude of spring preload.

The specific maximum permissible values for new steering column developments are determined in tests using these facors. INA has a comprehensive service to offer in this area.

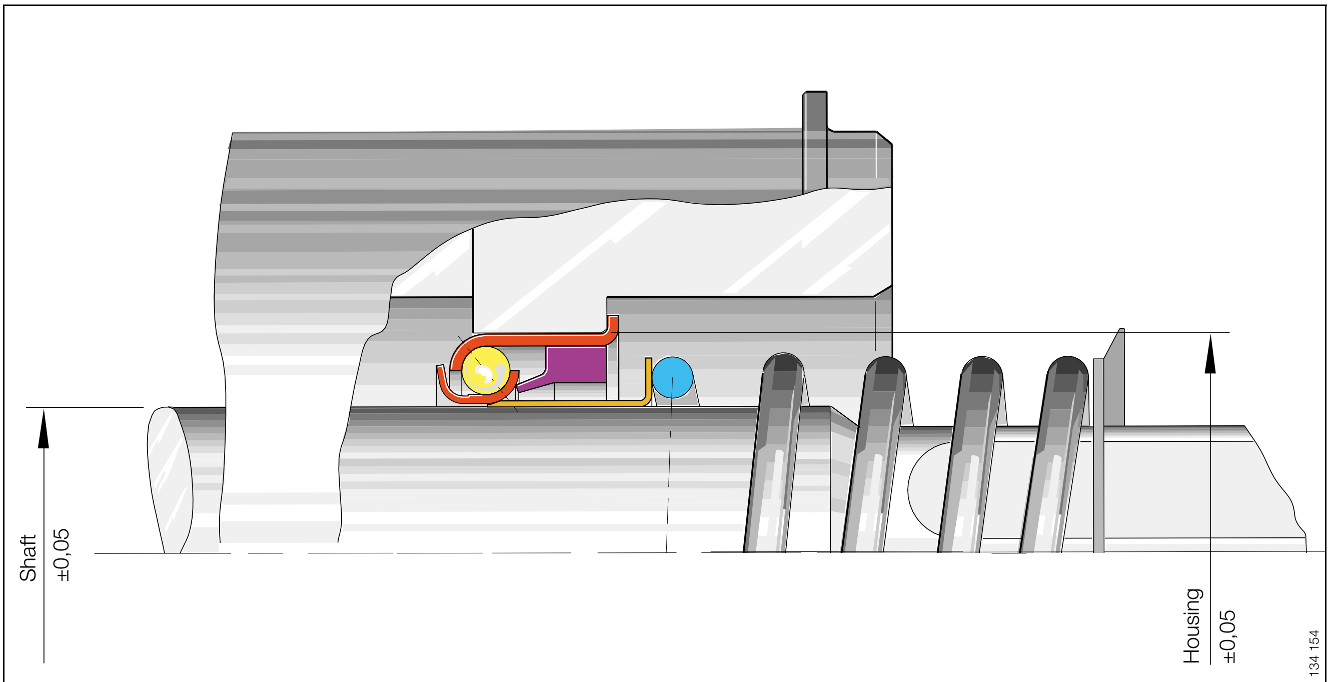


Figure 31 · Design of bearing seating surfaces

Clearance-free needle roller bearings LEN – Figure 32

Bearings of this type allow relatively large housing and shaft tolerances without any deterioration of function.

The rolling elements roll directly on a work-hardened shaft which has not been heat treated. The rolling element raceways must have a minimum hardness of 200 HV.

Lugs or crimping are usually used to locate the bearing in the housing.

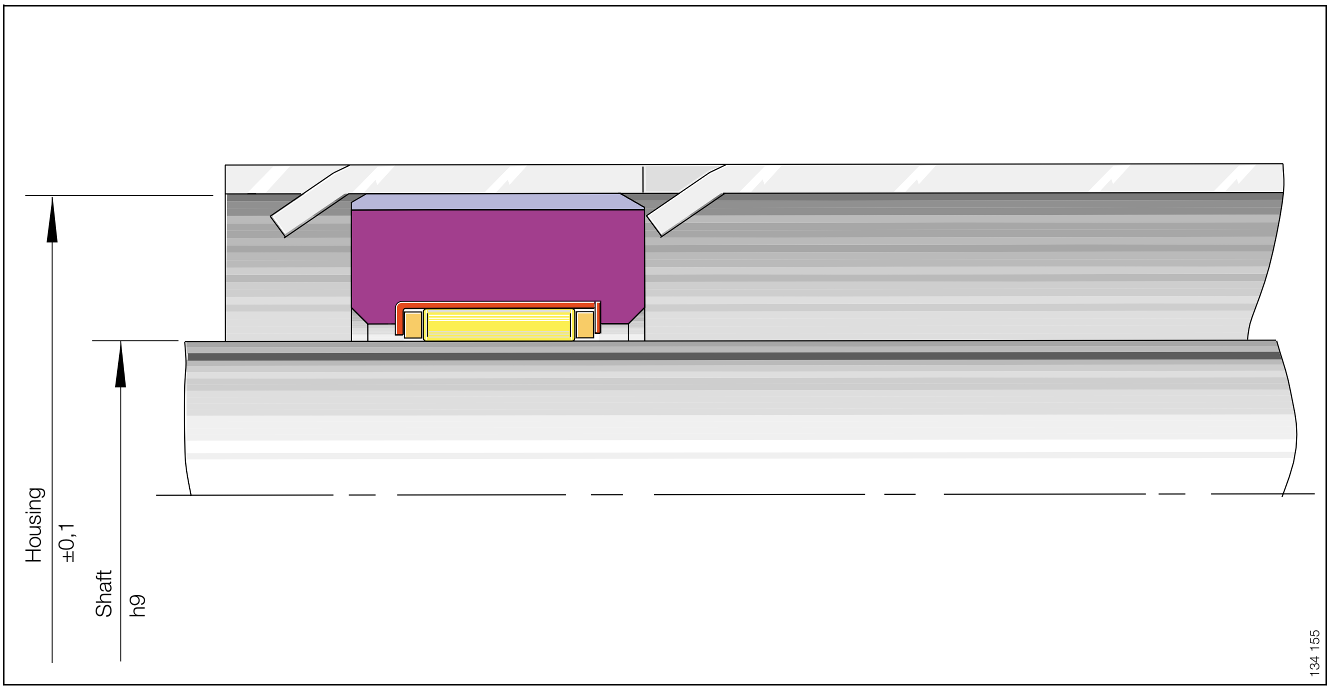


Figure 32 · Design of bearing seating surfaces – bearing location with lugs in the housing

Clearance-free four point contact bearings KLX
– Figure 33

The design of the bearing seating surface for bearings of this type depends on:

- a defined press fit being provided in the housing and on the shaft with a defined displacement force to take axial forces or
- the axial forces being taken by snap rings, distance rings or similar additional components.

The retaining forces for the inner ring are very high for bearings with a press fit – up to 3 000 N. As the shaft is often cold formed for reasons of cost (h9), large interference values result from the tolerance zones.

The inner rings must have an adequate cross section in order to avoid excessive stresses in the inner ring.
Through hardened rings should be more strongly annealed if a higher toughness is required.

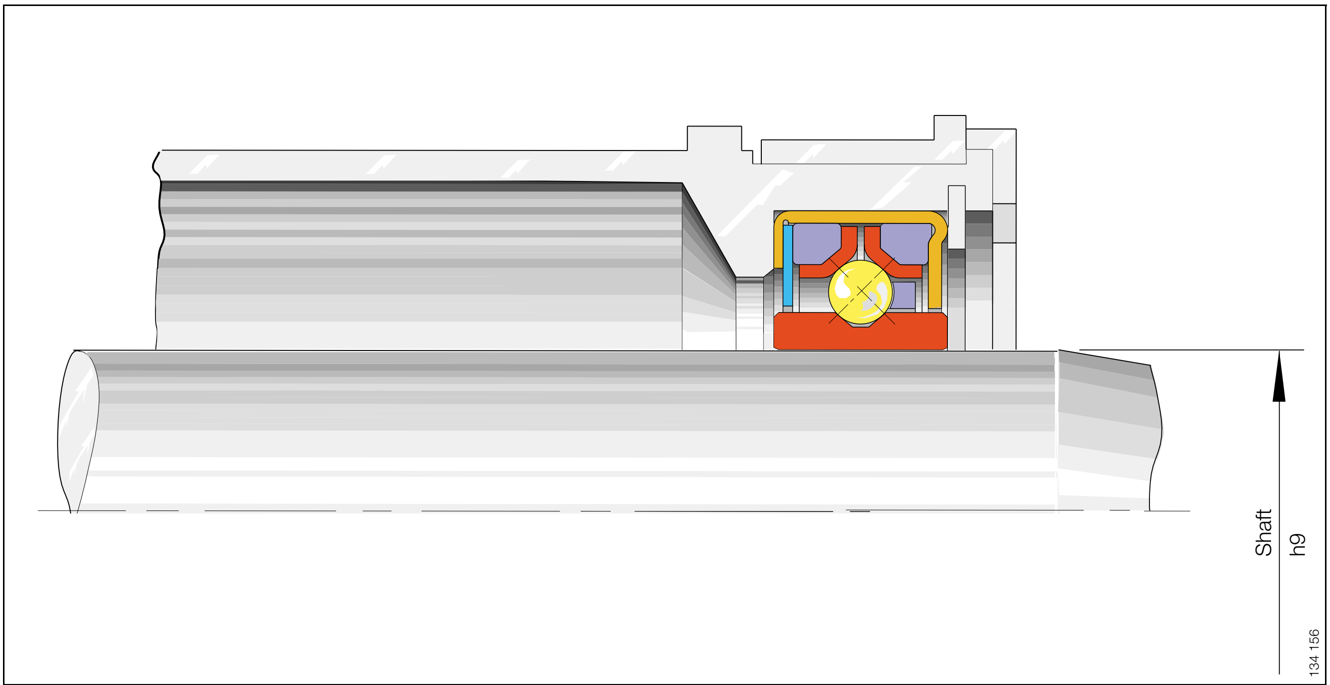


Figure 33 · Design of bearing seating surfaces – press fit on the shaft

Bearing selection matrix

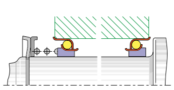
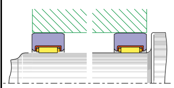
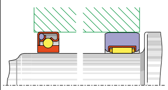
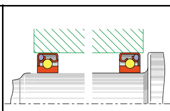
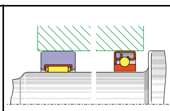
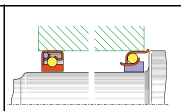
The table below is a recommendation only. It provides a simplified means of selecting bearings and contains engineering/qualitative and economic criteria.

Assessment is based on many years of experience and tried and tested theoretical know-how. However, it does not provide any information on the weighting of the individual factors and criteria. Simple addition of the individual points does not thereforce provide a total assessment of each bearing type.

Based on the given specification, the responsible designer deside:

- which criteria are important for the design of the bearing arrangement and
- which bearing arrangement best meets the requirements.

Only the most common bearing types for steering columns and the most important assessment criteria are taken into consideration.

Bearing arrangement Assessment criteria	 SKL/SKL	 LEN/LEN	 KLX/LEN	 KLX/KLX	 LEN/KLX	 KLX/SKL
Costs	+++	+++	+	–	+	+
Rigidity	+++	–	++	+++	–	+++
Frictional torque	++	+++	++	+/–	++	++
Noise damping	–	+++	++	++	++	+
Operating life	+++	+++	+++	+++	+++	+++
Fitting	+/–	+++	++	+/–	++	+/–
Market penetration	+++	++	++	+/–	–	–

Assessment key:
+++ = very good
++ = good
+ = average
– = poor

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