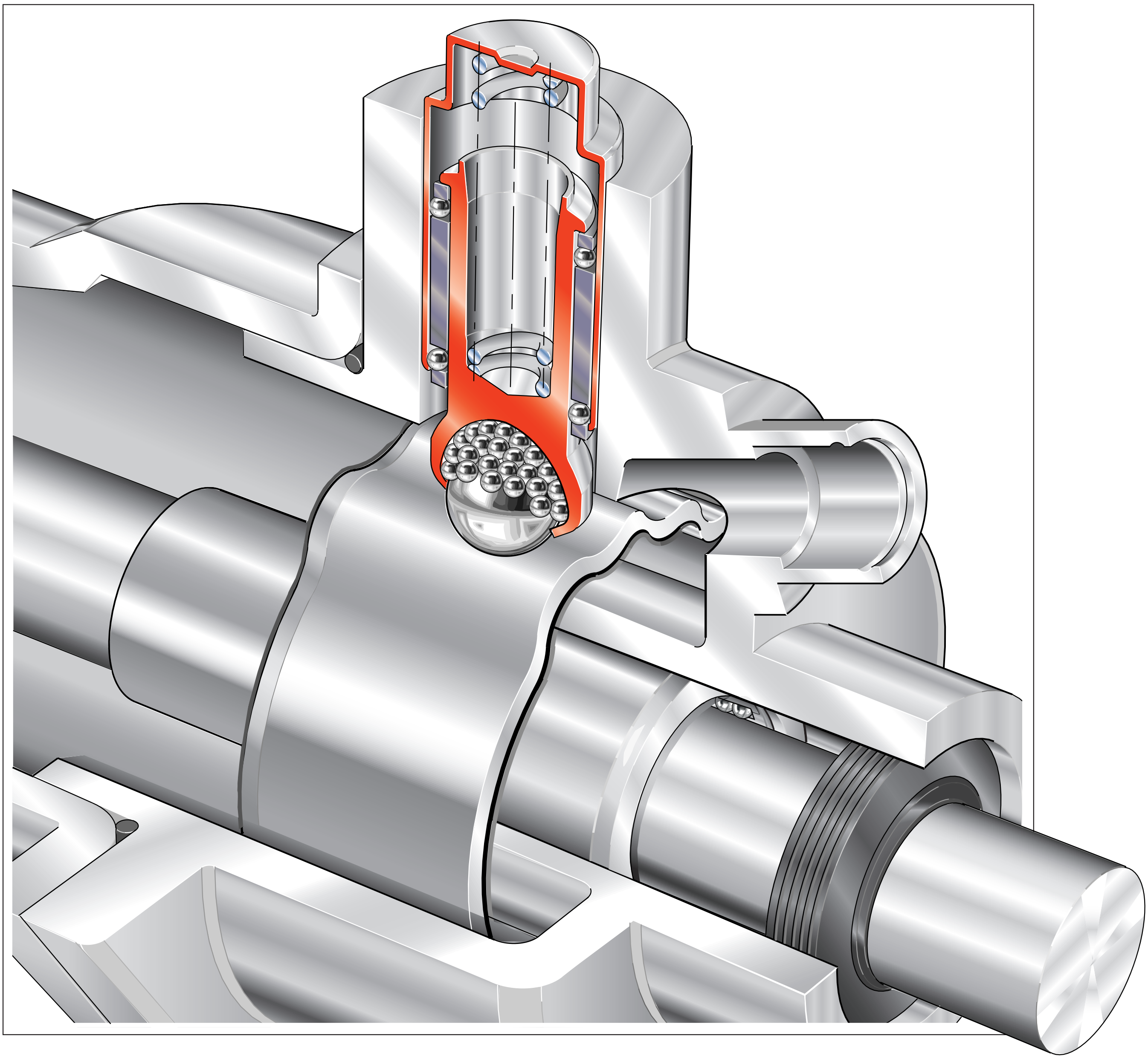


Detent Pins

for Automotive Transmissions

Automotive Product Information API 14

Contents

Function and types

Detent pins are used in gearshift systems in gearboxes. In the external gearshift system, they are normally located beneath the passenger compartment. In the internal gearshift system, they are pressed into or screw mounted in the gearbox housing or are part of lever mechanisms in the gearbox. They act on movable parts such as the input selector shaft, selector rods or selector rails.

Due to their design and functions specially matched to the application, they have a decisive influence in the manual automotive gearbox on the technically optimum gearshift behaviour and the gearshift feel experienced by the driver.

Functions of detent pins

The detent pins fulfil primary and secondary tasks.

The primary functions are:

- location and positioning of the required gearshift position;
- locking in place once the gearshift position has been located;
- ensuring precise and secure gearshift by means of a defined gearshift resistance;
- communicating a positive gearshift feel to the driver and a clear sensation that the gear has been engaged.

The secondary functions are:

- guiding interlocking parts:
  - simultaneously locking out components not directly involved in the gearshift operation and locking in place the selected gear,
  - securing components not directly involved in the gearshift operation to prevent uncontrolled, independent movement;
- guiding gates:
  - allowing precise movement of the mechanical linkages;
- acting as carrier components to support electrical switches:
  - closing the switch contacts in integrated switch components.

Types and applications – Figure 1

In the left of the figure, types for more demanding applications are shown – the gearshift operation is controlled by linear and swivel motion. On the right, simpler types are shown – they represent applications for selector rods and rails that only perform linear motion.

① and ② detent pins ARRE, e.g. for selector shafts

③ Detent bush ARR

④ and ⑤ detent pins ARRE, e.g. for selector rods.

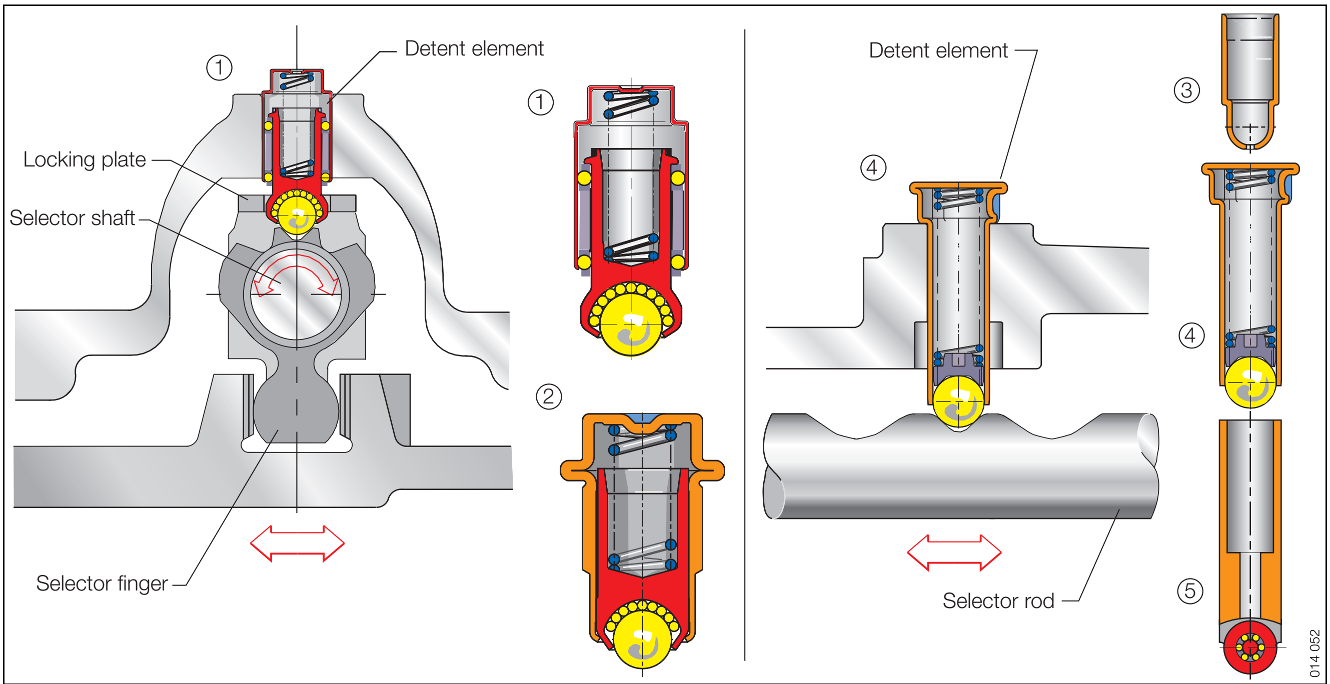


Figure 1 · Detent pin – types and application

Design

Design features – Figure 2

The basic design of a detent pin comprises a pressure spring and a spring-loaded ball. This design allows not only axial motion – the stroke – but also horizontal motion – travel across the ramps.

In order to improve the function – see section *Gearshift force curve* – and at the same time reduce the frictional value, the components are supported depending on their design

- by plain or rolling bearings for the stroke,
- by plain or rolling bearings for travel of the detent ball across the ramps.

Special product characteristics

The formed detent bush ① gives uniform sliding friction behaviour.

In the design ②, the plain bearing travel function is taken over by a narrow ring containing a needle roller bearing.

The detent pins ③, ④, ⑤ and ⑥ are complete, ready-to-fit units. In these cases, the detent ball is supported such that it is free to rotate in any direction or is held in a pin or piston. It is preloaded against the housing by means of a pressure spring. The detent pin ③ is fitted with a guide piece that supports a detent ball by sliding contact and with sliding guidance during the stroke.

In the designs ④, ⑤ and ⑥, the detent ball is supported by rolling contact on approximately 60 small support balls. In the particularly low-friction detent pins ⑤ and ⑥, the stroke motion is also supported by rolling contact.

The housing bodies of the detent pins are:

- pressed into the gearbox housing ③, ⑥ or
- screw mounted ④, ⑤ or
- fixed to internal gearshift mechanisms in the gearbox.

Types ③ and ⑥ have the most favourable price/performance ratio.

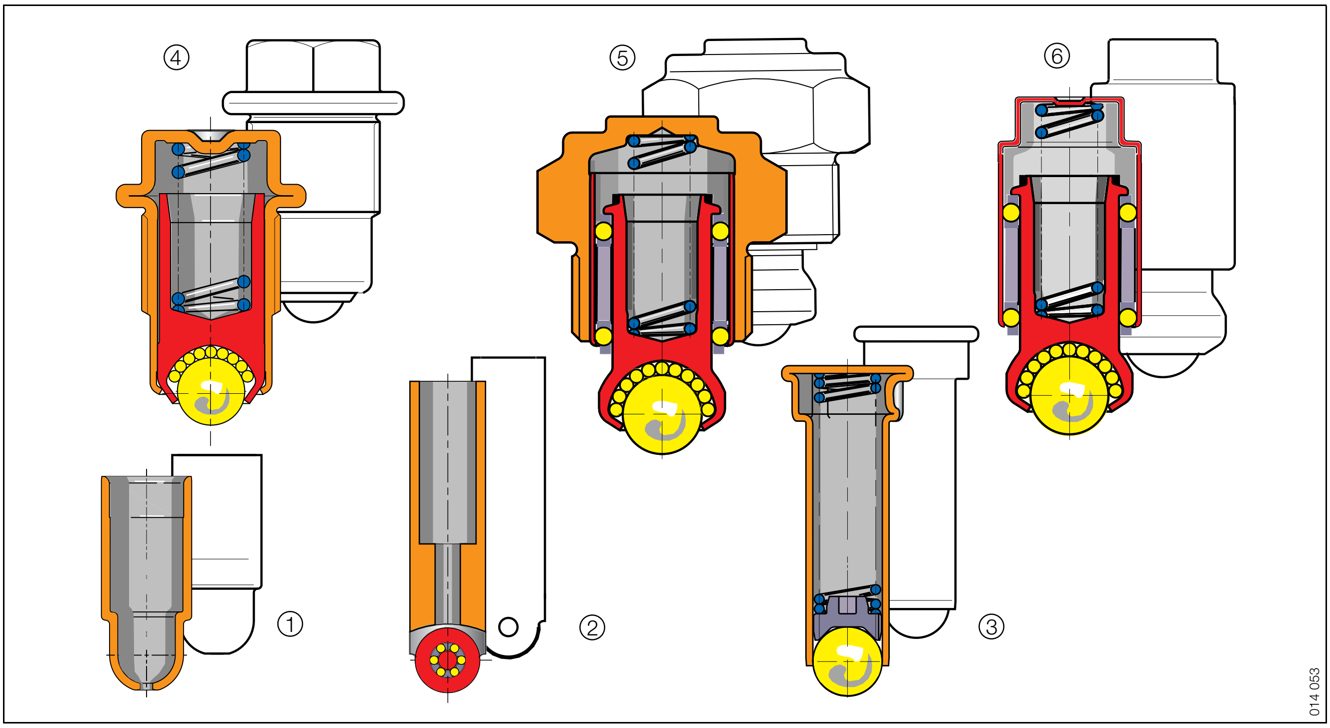


Figure 2 · Product design

Types – Figure 3

The objectives in optimising detent pins include reducing the frictional value. In this way, the gearshift forces required to roll over the ramp profile of a selector shaft can be significantly reduced.

The magnitude of the frictional value is influenced by

- the ramp geometry.
- the type of detent pin.

Figure 3 shows the relationship between the spring preload force F_F and the gearshift force required F_S for various types. The angle of the ramp geometry – at the reference point of the spring force – is between 38° and 42°.

Even the type without support balls behind the detent ball ② reduces the gearshift force by 40%. The movable detent ball and the stroke motion of the plunger give significantly improved frictional value behaviour in comparison with the rigid design.

The frictional value is also influenced by the bearing arrangement or type of bearing arrangement of the plunger and detent ball. In order to further reduce the frictional value, the detent ball was therefore also supported by rolling contact in the design ③.

The lowest frictional value occurs in the design ④. In this case, the detent ball and the plunger for stroke motion are supported by rolling contact.

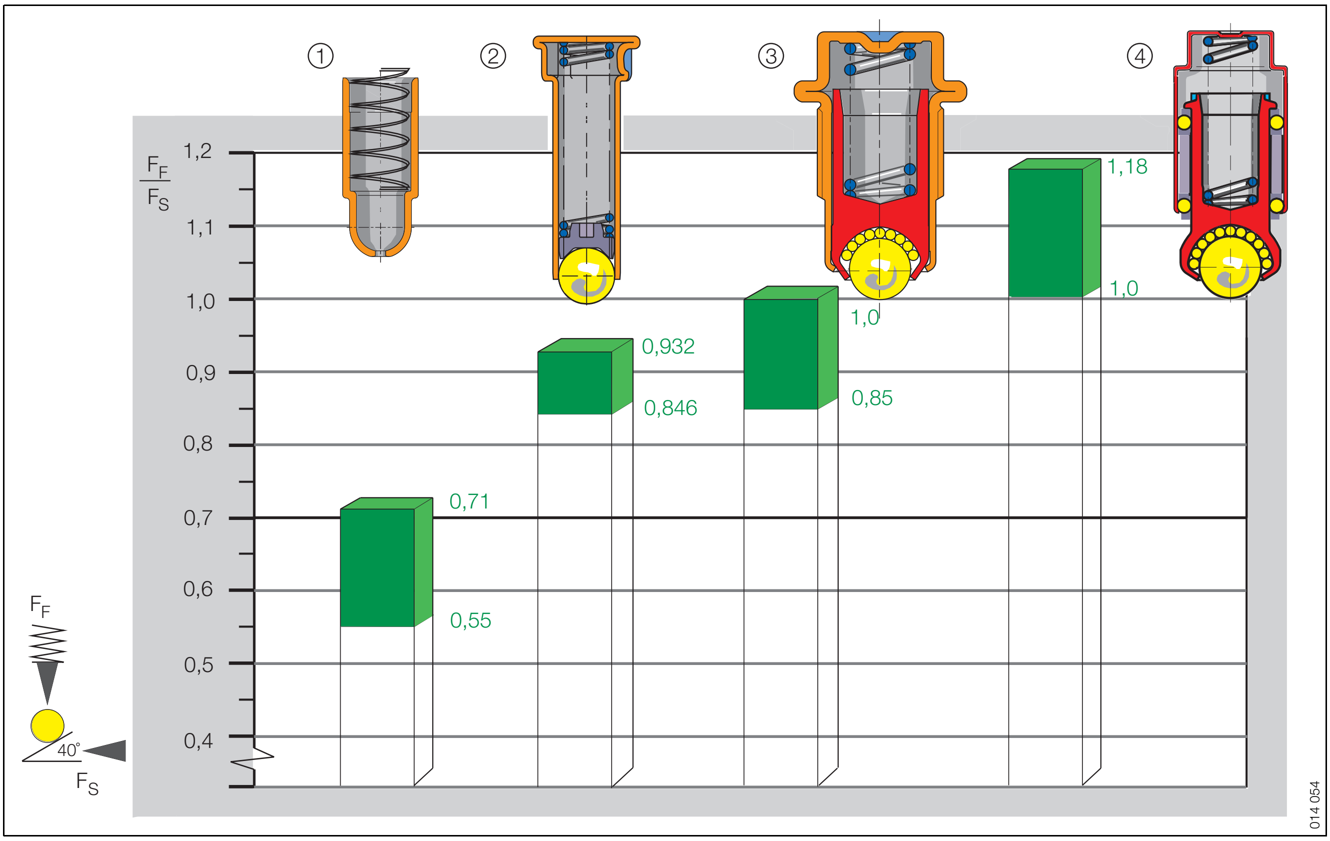


Figure 3 · Types

Gearshift force curve

The type and position of the detent pin have a decisive influence on the force curve occurring during the gearshift operation. In order to determine the necessary design measures for the detent pins, the following aspects of the overall gearshift curve are considered:

- the stroke characteristics
  - displacement of the plunger in the housing body
- the displacement resistance
  - dependent on the type of detent pin
  - dependent on the mounting position of the detent pin
- travel characteristics
  - travel of the detent ball/plunger across a ramp.

Stroke characteristics – Figure 4

Various detent pins in volume production are compared with each other on a test rig – see section *Test methods*.
The diameter of the detent balls was 8,731 mm, the balls are supported by rolling contact.

The stroke motion of the plunger is supported:
① by plain contact in the housing,
② by rolling contact by means of a ball cage.

The tilting clearance of the plunger is between 0,05 mm and 0,3 mm, depending on the type of detent pin. The force is applied at less than 45°. The tilting can thus be described in approximate terms.

Interpretation of the force curve

The following are marked in the figure:

- the actual working range in the functional condition in order to overcome the relevant ramp profile,
- the tolerance scatter occurring as a result of volume production.

The irregularities at the start of the curve result from the necessary operating clearance of the stroke motion bearing arrangement. The increase in force at the end of the hysteresis curve is caused by the impact of the plunger on the base of the housing.

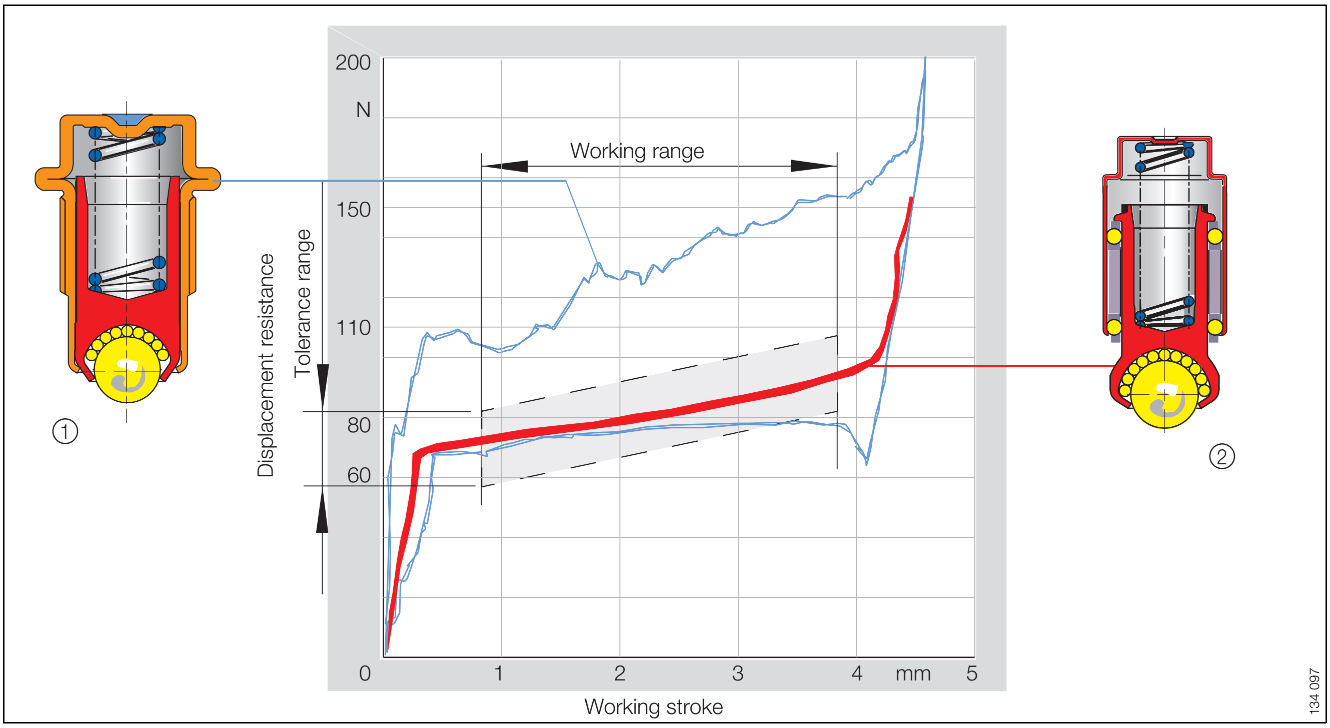


Figure 4 · Stroke characteristics

Gearshift force curve

Displacement resistance – dependent on the type of detent pin

Various types in volume production are compared with each other on a test rig – see section *Test methods*.

The detent ball has a diameter of 8,731 mm. The detent pins ①, ③, ④, ⑤ are preloaded by springs to 70 N, while the detent pin ② is preloaded to 55 N.

The ball is supported as follows (Figure 5):

① rigidly integrated in a plain sleeve

② supported by sliding contact in a specially formed plastic cup

③ supported by sliding contact in plastic

④ supported by sliding contact in a cup lined with Teflon®

⑤ supported by rolling contact on approx. 60 support balls.

Interpretation of the force curve

The displacement resistance in the plain bush is up to 10 times higher than with the ball supported by rolling contact. Since mixed friction is present, the sliding friction can be reduced by up to 40%, for example in the detent pin ④, depending on adjustment.

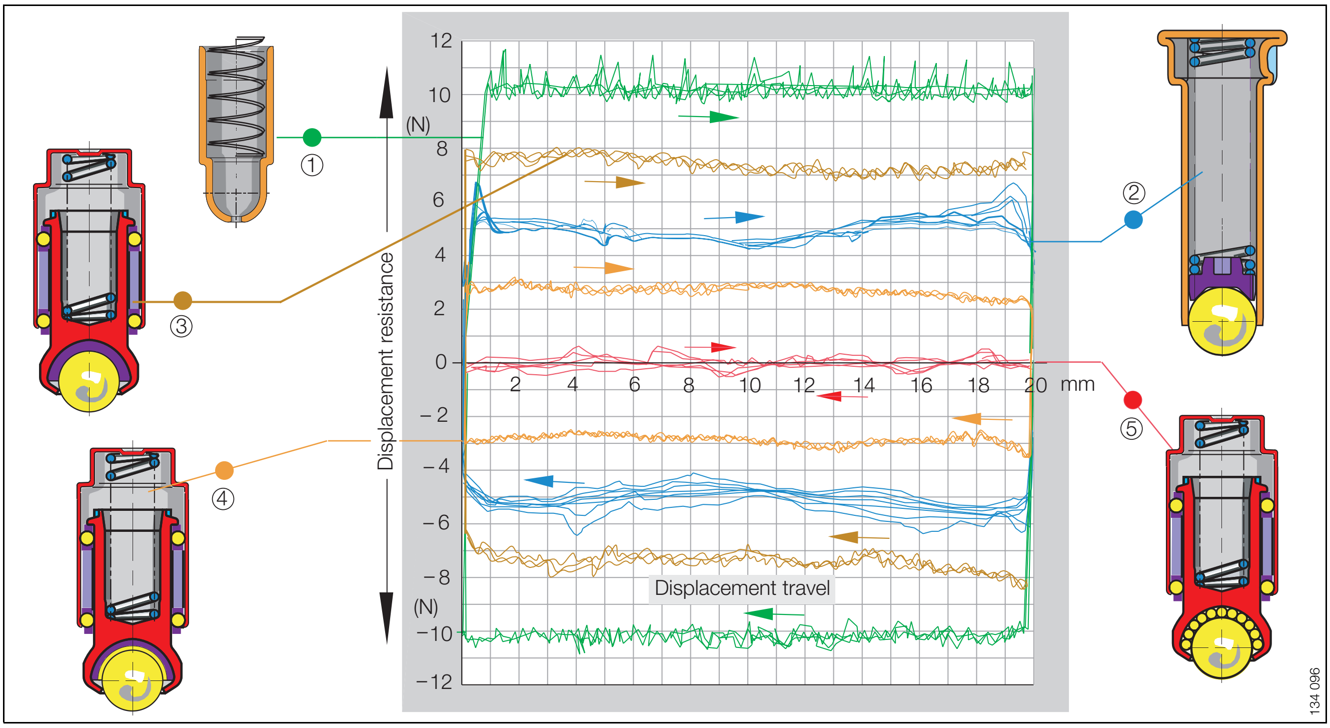


Figure 5 · Displacement resistance – dependent on the type of detent pin

Displacement resistance –
dependent on the mounting position of the detent pin

The displacement resistance of a detent pin in the following mounting positions is measured on a test rig – see section *Test methods*.

The detent ball is positioned (Figure 6):

- vertically downwards
- horizontally
- vertically upwards.

The detent ball has a diameter of 8,731 mm. It is supported by rolling contact on approx. 60 support balls and preloaded to 55 N by a spring.

The detent ball is moved across a flat surface.

Interpretation of the force curve

The displacement resistance is at its highest with the detent ball facing vertically downwards and at its lowest with the detent ball facing vertically upwards (Figure 6). The cause lies in the degree of freedom of the "chaotically" circulating support balls.

In the case of the detent ball facing vertically downwards, all the support balls collect in the largest free space, i.e. just behind the retention mechanism for the ball. The free space in the centre of the pin is not sufficient, however, for ideal movement of the support balls. The balls are in contact under load and sliding friction occurs between the rolling elements.

The movement conditions are optimum in the case of the detent ball located at the top.

In this case:

- the support balls collect in the centre of the pin and form the largest arc around the detent ball
- the free space for crimping of the pin is at its largest.

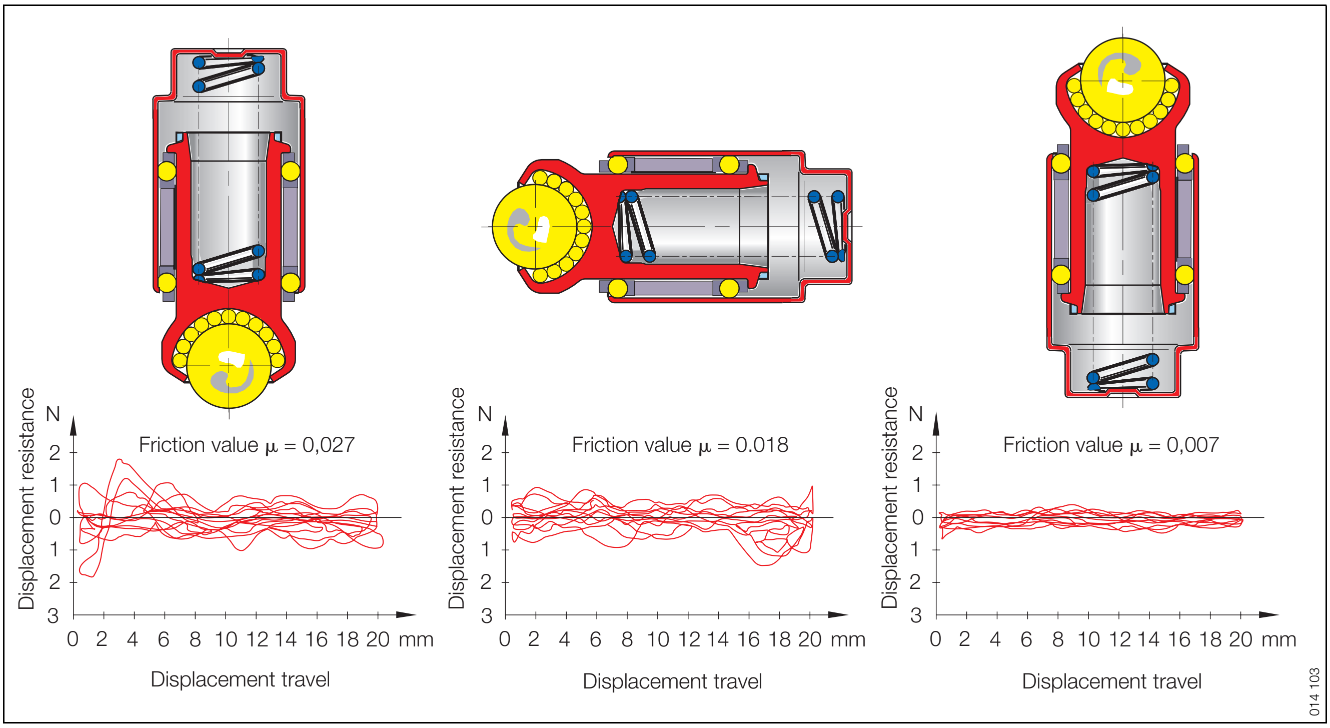


Figure 6 · Displacement resistance – dependent on the mounting position of the detent pin

Travel characteristics – Figure 7

Measurement conditions

On a test rig – see section *Test methods*, detent pins are compared with each other that have

- different bearing arrangements for the detent ball and plunger.

The selector rod is supported in rolling bearings. The ramp profile in the selector rod was matched to the diameter – 8,731 mm – of the detent ball. The total travel during gearshift into the selected gear and back to the original position is measured.

Detent pin with components supported by sliding contact

The hysteresis of the gearshift force curve has a very wide spread. This means that it is significantly more difficult for the plunger to snap automatically into the base of the groove in the selector shaft. This is due to the high friction value, determined by the design, of the movable parts.

The gearshift force resistance of 55 N to 60 N is partially induced by the friction forces, but the required difference in level to return the gearshift lever to the neutral position is thereby reduced again.

Consequences of the force curve

There is no sensation that gearshift has been achieved precisely and the gearshift operation has been securely completed. Due to the vague gearshift curve, the driver does not experience the "feel of quality".

Detent ball and plunger supported by rolling contact

The hysteresis shows a narrow-shaped gearshift force curve with a return point free from response lag. The force required to achieve the positive snap-in effect of the plunger – the large area is shown with grid lines in the diagram – was increased from 25 N for the design with sliding contact support to between 40 N and 50 N. Clear improvements were demonstrated with an increase in the diameter ratio between the detent ball and support balls.

Consequences of the force curve

In conjunction with the higher effective spring preload force precisely matched to the gearshift force curve, the detent pin with components supported by rolling contact and with reduced friction leads to the required "feel of quality". See also the section *Spring preload force*.

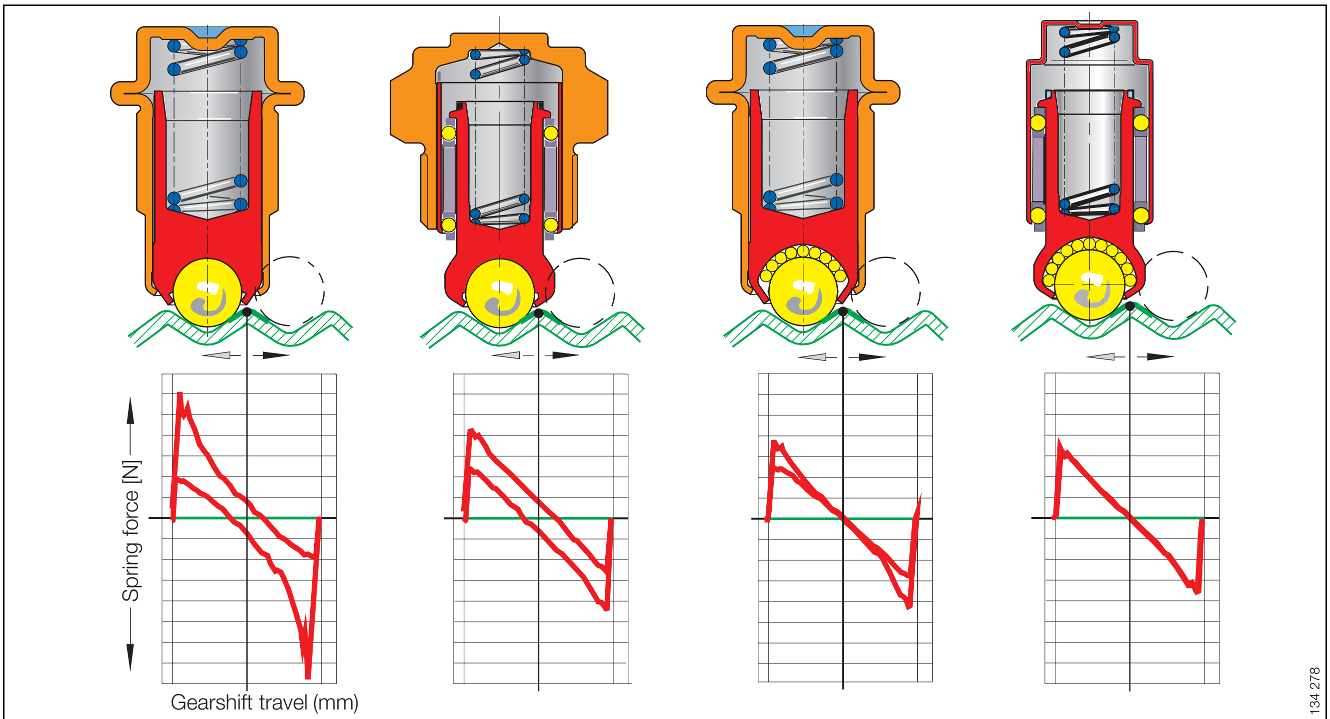


Figure 7 · Functional parts supported by sliding contact and by rolling contact – comparison

Spring preload force

The comfort and quality of the gearshift operation, the "feel of quality", is determined to a significant degree by the precise preload of the pressure springs in the detent pin.

In order to achieve an optimum gearshift force curve, it is necessary to achieve precise matching of the spring preload force in a detent pin supported completely by rolling contact, i.e. both the detent ball and plunger.

Detent pin with adjustable spring preload force – Figure 8

The ideal spring preload force for the application can be determined using a specially produced detent pin. An axially adjustable closing plug allows variation of the spring preload force.

The detent pin can be fitted in the gearbox housing without any additional work.

The variable spring preload force gives the following benefits for the customer:

- the technical aspect
  - the spring preload force – matched to the overall gearbox concept – is precisely adjusted with preparation of just one gearbox
- the technical-subjective aspect
  - the preload force required in order to communicate a "positive" gearshift feel for the specific gearbox can be quickly determined
- the cost aspect
  - the assembly, adjustment and time requirements are minimal.

This reduces

- the total development time and
- the total development costs.

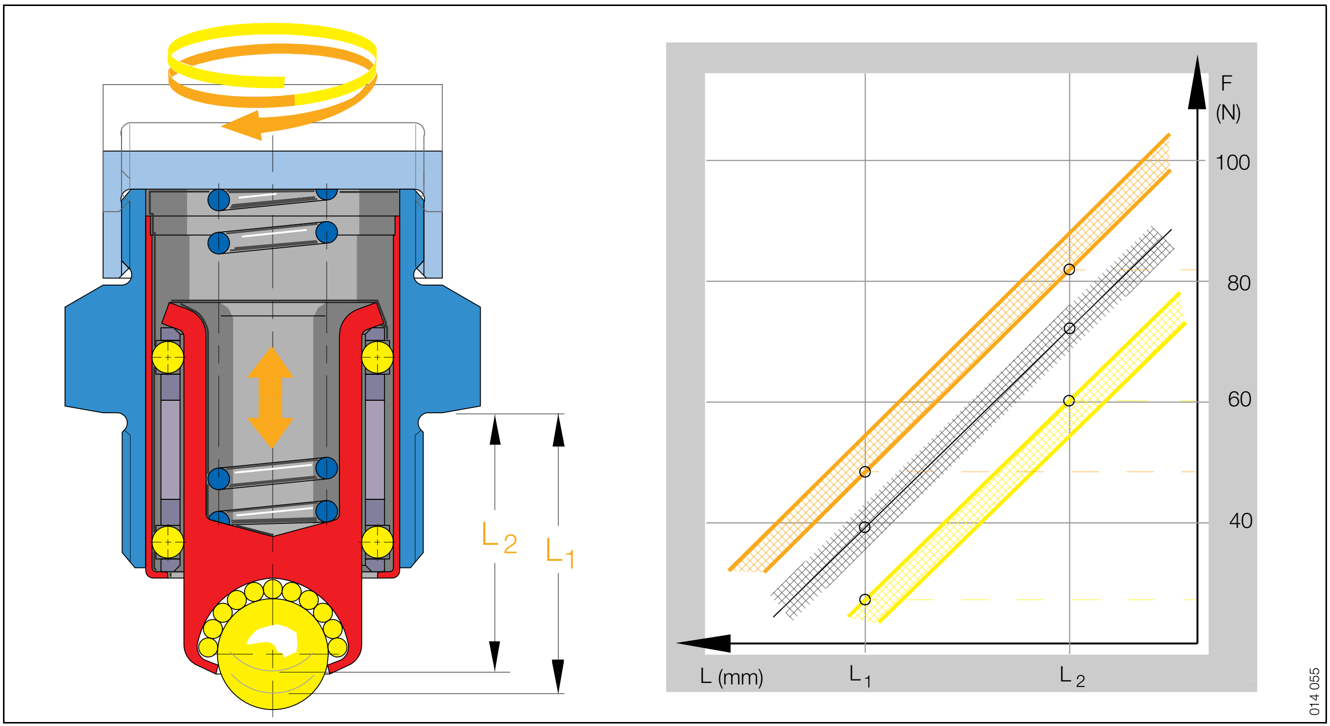


Figure 8 · Spring preload force

Sealing

If detent pins are to be fitted in the gearbox housing from outside, the must fulfil the following requirements:

- they must create an airtight seal in relation to the gearbox housing
  – after assembly, gearboxes are checked for leaks by means of compressed air;
- they must be securely seated
  – detent pins with a screw fitting thread must be fitted with a defined tightening torque;
- they must operate as corrosion-free as possible throughout their operating life
  – where detent pins are located on the outside of the gearbox, the external parts of the detent pin are exposed to corrosive media.

Sealing compounds

Detent pins with a threaded body are generally provided with a sealing compound on the thread.

For reasons of production technology, the coating covers two to three turns of the thread – determined by the jet width of the spray nozzles in the application device (1 mm – 2 mm) and the frequency of rotation (1 to 1,5 times).

Threaded steel body – Figure 9

A micro-encapsulated, yellow adhesive (OT precote 30) or a red adhesive (Loctite) is used on threaded steel bodies.

The micro-capsules are breached by the compressive and/or shear loads occurring when the detent pin is screwed in. The fluid released hardens once it comes into contact with the binder system. This gives good sealing action even though only a small quantity of sealing agent is required.

The adhesive also prevents corrosion in the thread connection. The screw connection can thus be loosened again without damaging the thread and by the use of normal tools.

Aluminium threaded body – Figure 10

In the case of aluminium threaded bodies, the coating OT precote 30 tends to cause fretting in the flank area. The white sealing agent OT precote 5 is therefore used.

However, this film-forming dispersion containing non-reactive material requires thicker application over a larger area.
The coating should therefore cover at least two to three turns of the thread.

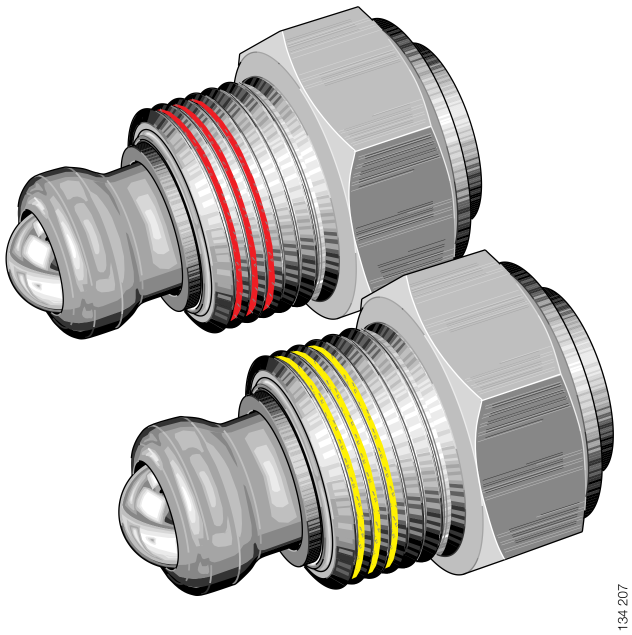


Figure 9 · Sealing compound for steel threaded bodies

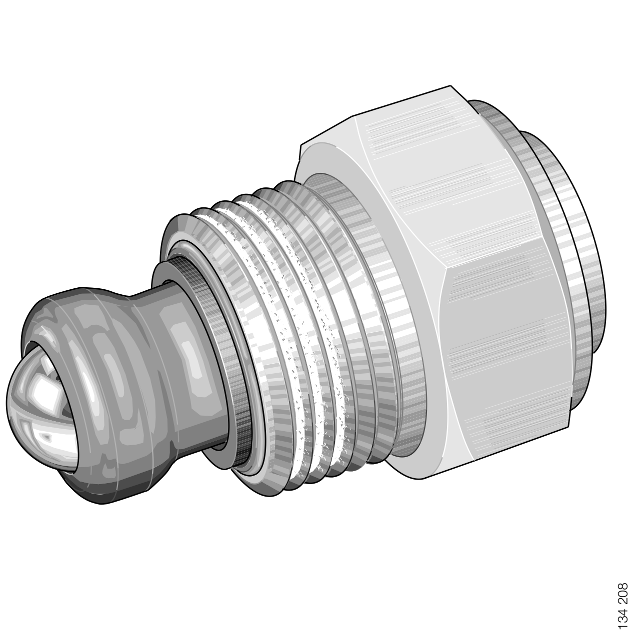


Figure 10 · Sealing compound for aluminium threaded bodies

Support washers – Figure 11

As an alternative to sealing compounds, special support washers of various thicknesses depending on the material – steel, aluminium, pressboard – can be used.

However, this type of seal has a disadvantageous effect on the additional axial tolerance. This has a negative effect on the specific spring characteristics of detent pins and leads to a further scatter in characteristic curve values.

Special sealing edges – Figure 11

Special sealing edges on the locating faces of threaded bodies are a technically straightforward and economical sealing method. These detent pins can be loosened and refitted once.

The full effectiveness of the sealing action depends, however, on the tightening torque and surface quality of the locating face. If they are used several times over with repeated loosening and fitting, this sealing method no longer fulfils the INA quality standard.

INA has a patent for the method *Special sealing edge*.

Press fit – Figure 11

Certain types of detent pin are not screw mounted but are simply pressed into the gearbox housing. In addition to the secure sealing action achieved by a press fit, these products can be fitted easily and cheaply.

Fitting should be carried out by machine using a press-in tool. A force-dependent shut-off point should be set at approx. 8 000 N.

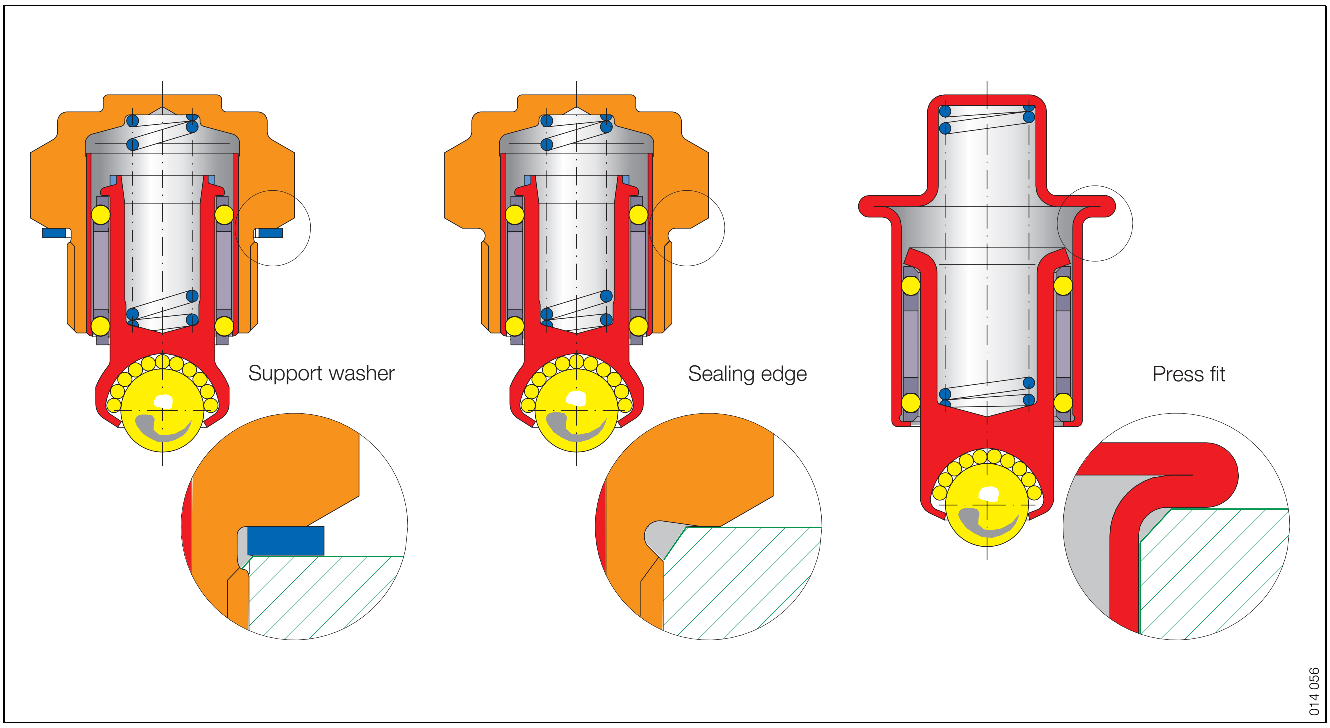


Figure 11 · Sealing – support washer, sealing edge, press fit

Design of adjacent components
Fitting and dismantling of detent pins

Design of adjacent components

Design of ramp for locking function – Figure 12

The following data are mean values for standard applications:

ramp radius R_1	>1 mm
ramp angle α	30° to 45°
hardness of raceway according to HRC or HV	>60 or 680
case hardness depth of raceway Eht	0,15 mm +0,1 mm
surface quality of raceway R_Z	1,6 μm

The ramp raceway for the detent ball is subjected to a spring preload force F_F of between 30 N and 130 N.

Oil spray lubrication is adequate as a lubrication method.

Proposal for a housing design – Figure 13

Example of a detent pin screwed into the gearbox housing from outside, without sealing agent on the thread.

Uncoated detent pins of this type are only suitable outside the area of the lubricating oil level and the immediate boundary areas.

Tolerances for the housing bore

In order that detent pins remain securely located in the housing bores, the fits used must be matched to the housing material (Table 1).

Note

Dimensions X, M, E, L correspond to the component dimensions in the drawings.

Table 1 · Bore tolerances – recommendation

Housing material	Bore tolerance
Al	R6
Mg	S6
Steel	N6

Fitting of detent pins

The function of detent pins is influenced to a considerable extent by the care taken in the fitting of these products.

Pressing in of detent pins – Figure 14

- Lightly oil or grease the housing bore and seating surface of the detent pin.
- Detent pins should wherever possible only be pressed in using a press-in tool
  - – Locate the tool such that it is in concentric contact with the detent pin
  - – Ensure that the detent pin is pressed in to the length specified in the assembly drawing. If no dimension is specified, please consult INA.

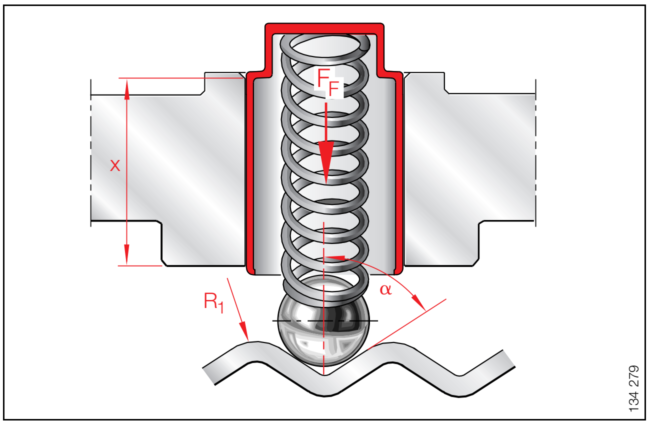


Figure 12 · Design of adjacent components

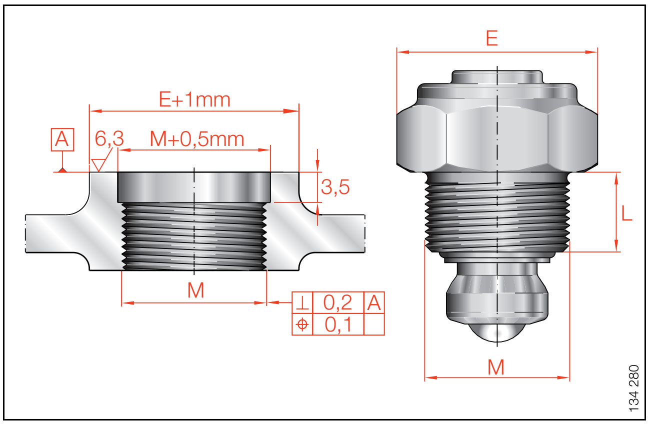


Figure 13 · For detent pins that must be arranged in a particular position

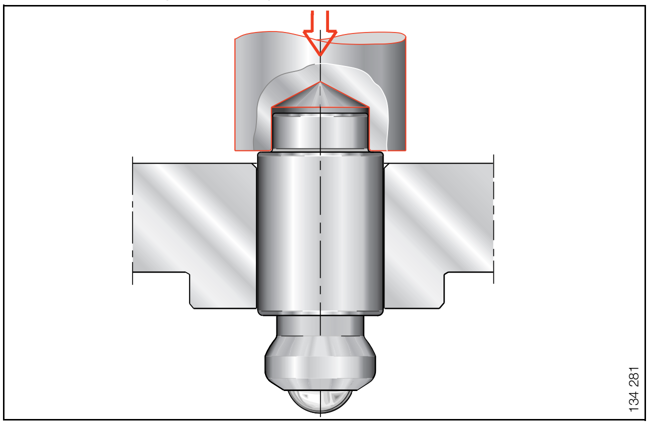


Figure 14 · Pressing in of the detent pin

Dismantling of detent pins – Figure 15

Detent pins are high precision components. Their level of quality is demonstrated, for example, by the fact that there is no spare parts requirement for these products – the operating life generally exceeds, for example, the life of the gearbox. In normal circumstances, therefore, they do not need to be dismantled.

However, it may be necessary to dismantle detent pins

- on automatic gearbox assembly lines using robots,
- for the separation and reintegration of materials used in the economic process – recycling.

Depending on their external form and the design of the adjacent construction, the detent pins are either

① pressed through

or removed using an extraction tool by means of

② an appropriately shaped base profile of the formed housing,

③ a circumferential collar on the housing,

④ a formed recess on the housing seat.

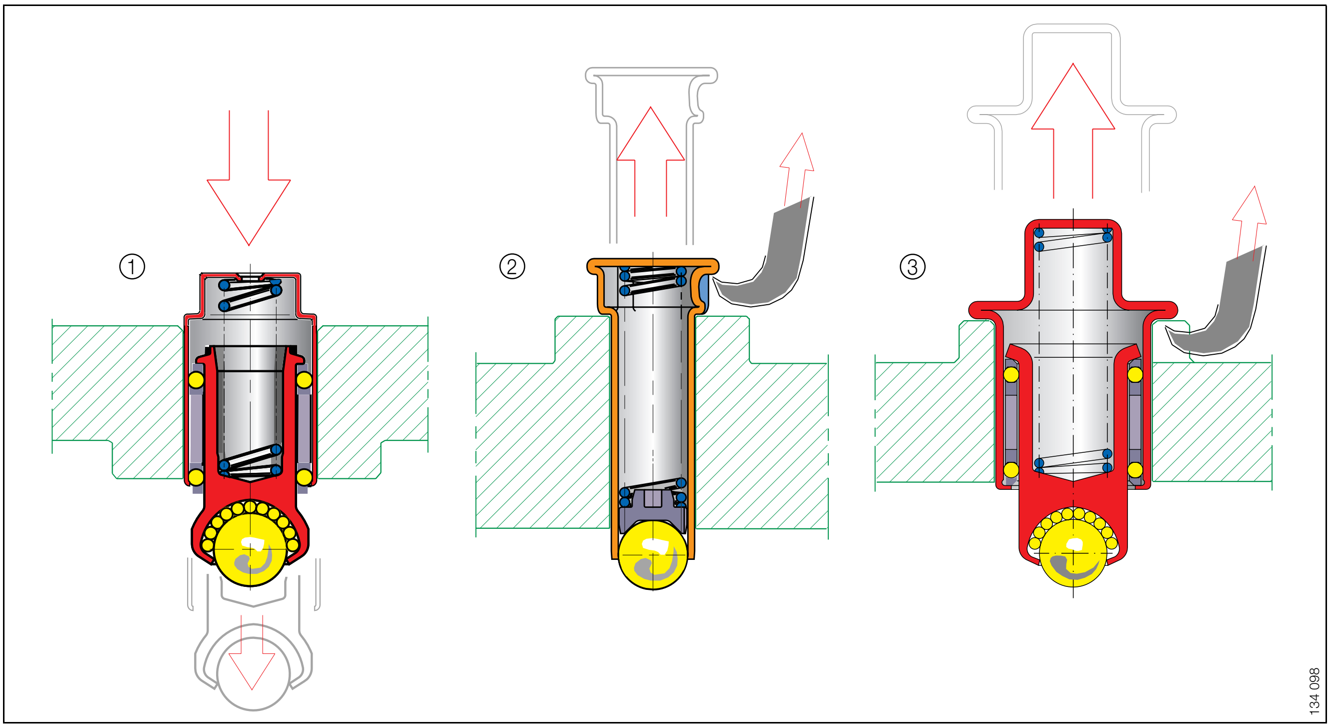


Figure 15 · Dismantling of detent pins

Tightening torque

Tightening torque for threaded bodies

Detent pins with a threaded body should be located in the gearbox housing with a defined tightening torque – for measurement values for tear-off torques see Figure 16.

Plastic threaded bodies – in some cases reinforced with a steel corset – are not currently used in volume production.

Measurement conditions

The values were determined:

- on thin-walled threaded bodies of identical geometry and dimensions – made from different materials
- with "technically dry" threaded flanks.

Changes in the friction value

If the parts are oiled (e.g. with gearbox oil), or plated (e.g. with sealing agent oil), friction is reduced. The measurement values are then up to 50% lower than in the "technically dry" version.

Coated threaded bodies – e.g. with Corrotect® – show slightly higher tear-off torques.

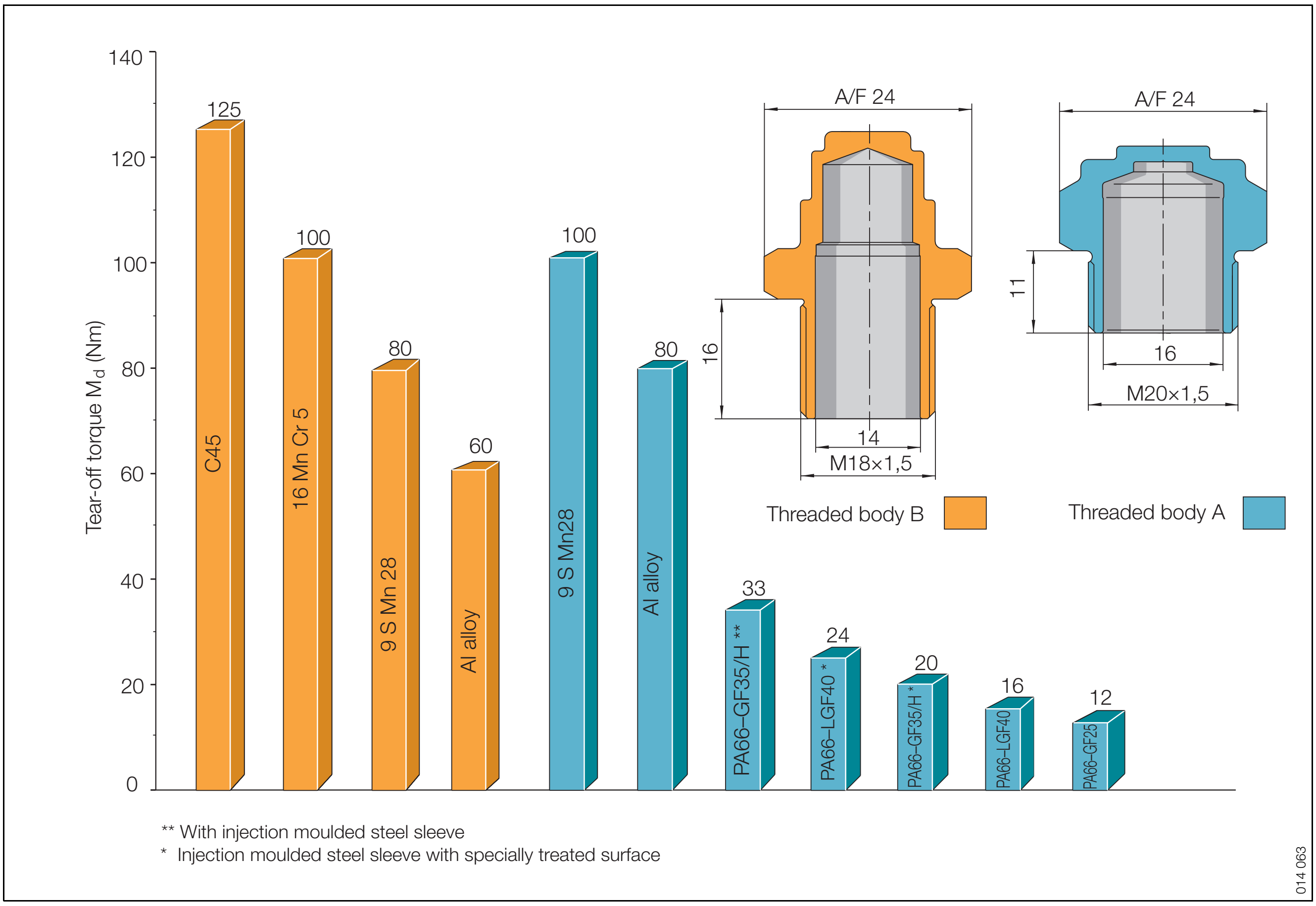


Figure 16 · Tear-off torques of threaded bodies

Anti-corrosion protection

Depending on the design principle of the gearbox, component parts of the detent pins may protrude from the gearbox housing. These parts are exposed to corrosion as a result of environmental influences and must be appropriately protected.

The results of various anti-corrosion protection measures are shown in Figure 17. The treated parts were subjected to a salt spray mist test in accordance with DIN 50 021.

Corrotect® plating

The INA special plating Corrotect® is an extremely thin – preferably 2 μm – protective layer applied to all surfaces by electroplating methods. It gives long-term protection of detent pins – for example against the action of salt water, contaminated water and gritting salt. Due to the very thin layer, the process is also highly suitable for rolling element raceways.

Under load, the layer is compacted into the surface roughness profile. Smaller bright areas remain protected against rust due to the cathodic protection effect.

The coloured chromate passivation (blue, yellow or black) can be used for colour coded identification of detent pins. Yellow and black chromate passivation contains Cr(VI). Alternatively, iridescent forms of chromate passivation free from Cr(VI) are under development.

Phosphating

Phosphating offers only very limited protection. It is sufficient for mounting positions with little risk of corrosion.

Zinc plating and chromating

Since the layers are up to 20 μm thick in these cases, these process are not suitable for:

- rolling element raceways
- parts to be joined inside each other, since the layer thickness has too pronounced an effect on the bearing operating clearance.

Corrosion-resistant material

For certain requirements, aluminium alloys are used for the screw mounting bodies of detent pins.

These:

- offer optimum protection against corrosion
- prevent stress corrosion in gearbox housings made from aluminium alloys
- are resistant to seawater for overseas transport.

Plastic is another corrosion-resistant material.

INA detent pins preferably have iron/zinc platings with chromate passivation. Components with raceways are plated with Corrotect®. If parts with Fe/Zn chromate passivation are used in magnesium gearbox housings, for example, the plating must be additionally sealed using silicate. If temperatures in excess of +90 °C are possible, please consult INA.

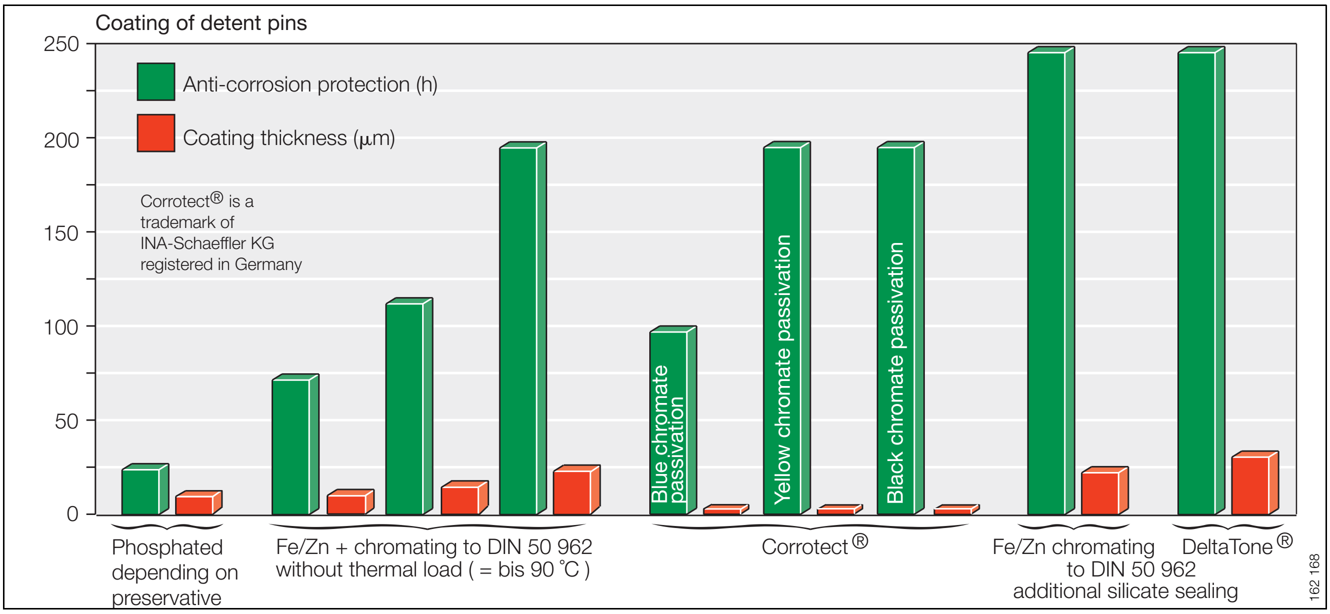


Figure 17 · Anti-corrosion protection for detent pins

Ramp profile

Products involved in selecting and engaging gears must have the technically correct "optimum gearshift curve" and communicate this clearly and reliably to the driver.

This is achieved by means including

- support of the gearshift elements by means of rolling bearings,
- a generally smooth and low-friction curve for the operations of selecting, engaging and securing gears
- the precisely defined preload force of the spring elements in the detent pins.

However, the design of the adjacent parts can also have a detrimental effect on the selection and engagement process. Whether the driver assesses the gearshift operation as positive or negative will depend, for example, on

- the design of the contact zone between the selector rod or selector shaft and the detent ball – the ramp profile.

Contour of the ramp profile

If the ramp contour is not geometrically matched to the detent ball, the gearshift forces and torques will have a noticeably unfavourable effect on the gearshift feel and the driver.

Ramp contour, version 1 – Figure 18

If the contour of the ramp profile is not matched to the detent ball, the torque curve will be of this form. Even with slight motion of the selector rod, the torque curve increases further; i.e. the force required only decreases when the detent ball reaches the cusp point in the ramp contour. No "positive gearshift feel" can therefore be expected.

Ramp contour, version 2 – Figure 18

The torque curve is significantly more precise and uniform. This optimised curve is achieved by changing the position of the contact point between the detent bal and locking groove. This is now at the transition from the groove tangent to the radius shoulder. For optimum results, however, this point must not deviate from the theoretically ideal value by more than $\pm 10°$.

The modified contour gives the following improvements:

- significantly smaller running marks in the contact zones,
- uniform efficiency,
- longer operating life,
- a gearshift curve that gives the optimum gearshift feel.

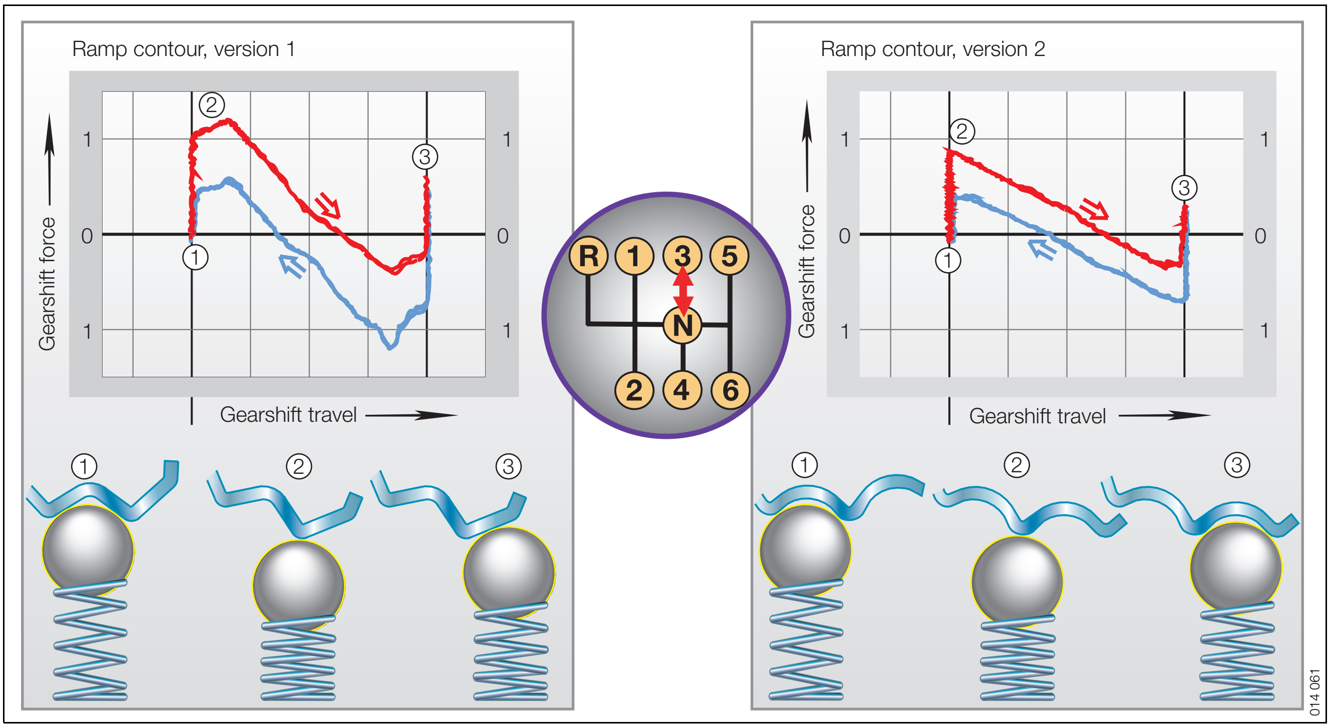


Figure 18 · Torque curve of various ramp contours

Load conditions

In order to determine the correct size of detent pin, the loads occurring must be taken into consideration.

Force conditions – effective and resultant forces

Detent pins are used under predominantly static load. The significant factors for determining the bearing load are therefore the distance a from the loading point and the supporting/base width b of the bearing arrangement (Figure 19). Since the force is applied outside the support base b (typical for detent pins), the force is not supported favourably.

When the selector rod is activated, the external forces act on the detent pin (Figure 20). Due to the rolling motion of the detent ball, the distance a from the loading point continues to decrease. At the same time, the active force increases in accordance with the spring rate of the detent pin. The following must therefore be taken into consideration in the design of the detent pin:

- the minimum gearshift force F_S, the coefficient of friction μ and the bearing load F_A (formulae 1 to 3).

$$F_S = F_F \cdot \tan(\beta + \delta) \qquad (1)$$

$$\mu = \tan\delta = \tan\left[\arctan\left(\frac{F_S}{F_F}\right) - \beta\right] \qquad (2)$$

$$F_A = F_S \cdot \frac{a + b}{b} \qquad (3)$$

F_F N
Spring preload force

F_S N
Minimum gearshift force

F_A N
Bearing load at support point A

F_B N
Bearing load at support point B

a mm
Distance between detent ball and row of support balls A

b mm
Distance between support ball row A nd B

F_R N
Friction force ($F_R = F_N \cdot \mu$)

F_N N
Normal force component

δ °
Friction angle

α, β °
Ramp angle relative to initial basis ($\beta = 90° - \alpha$)

μ –
Coefficient of friction.

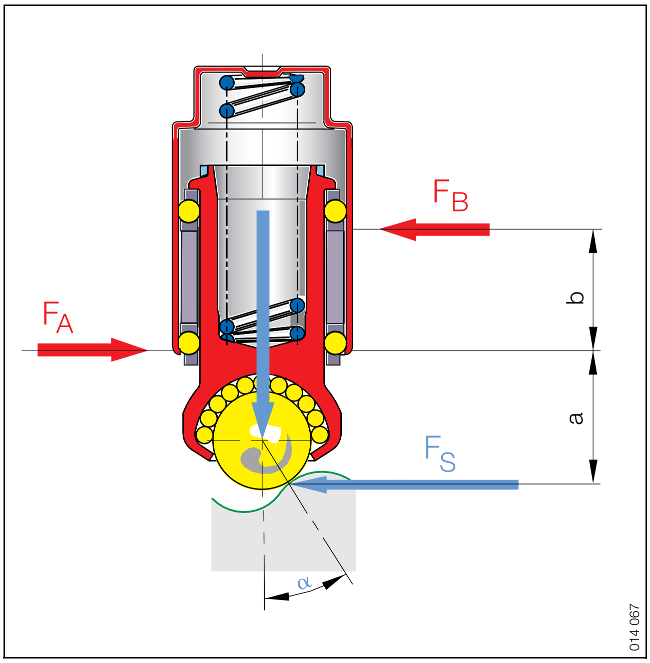


Figure 19 · Forces acting on detent pin

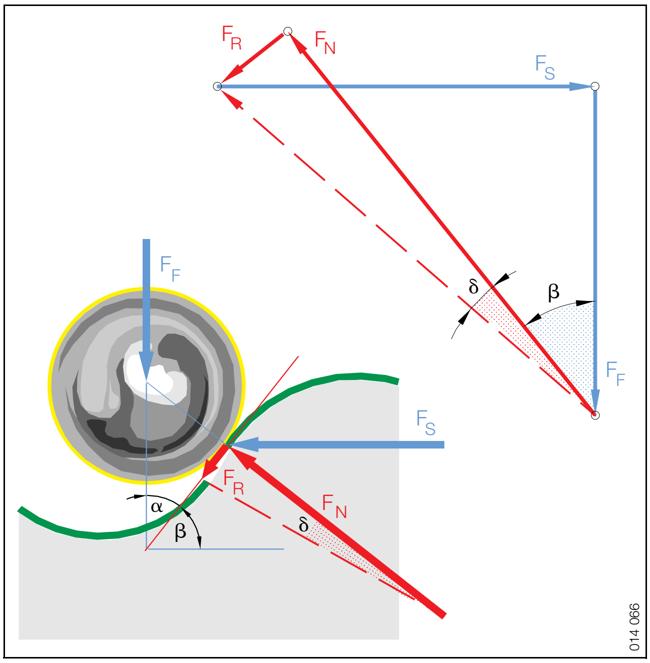


Figure 20 · Forces acting on detent ball and resulting pattern of forces

Test methods

Practical test methods are used

- to confirm or reject theoretical assumptions,
- as a means of preventive quality assurance in order to ensure that the required product characteristics are achieved.

Idealised, theoretical load conditions are replaced in these tests by characteristic loads that are representative of actual driving conditions.

Test conditions and focus of tests

If there are no customer specifications, comparable INA test conditions are used. The detent pin generally then acts under the required spring preload force against the original ramp contour.

Displacement resistance – Figure 21

The selection resistance – the rolling resistance of the detent ball, see also Figure 4 – is measured against a flat rail. The rail is held in a fixture that can be swivelled into the different possible mounting positions of the detent pin.

The clamping force – see spring preload F_1 – applied to the detent ball is set in accordance with the functional position.

Test conditions

Spring preload	F_1 = 30 N to 130 N
Displacement travel	s = $\pm$20 mm
Displacement speed	v = 5 mm/s to 50 mm/s (adjustable)
Lubricant	Esso gearbox oil ST SAE 85–W90
Drip feed lubrication	approx. 1 drop/min.

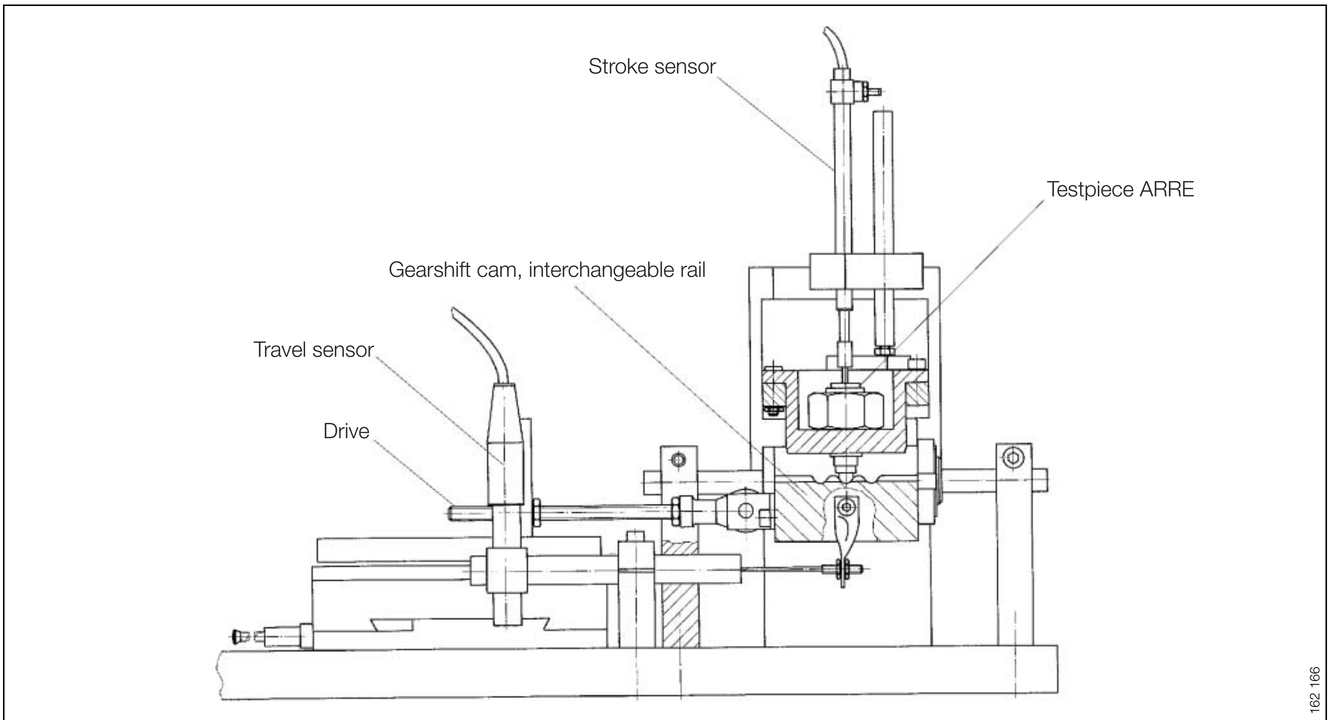


Figure 21 · Test rig for measuring displacement resistance (selection resistance and engagement resistance)

Engagement resistance – Figure 22

The engagement resistance – see also Figure 5 – is recorded as the engagement hysteresis – as stroke characteristics. This displacement force occurs when the plunger supported by a bearing moves against the pressure spring.

The force is introduced via the detent ball and occurs

- under vertical load free from transverse forces or
- under 45° load – this corresponds to a tilted plunger.

The engagement resistance can be measured – Figure 22

① concentric to the direction of motion, directly on the plunger. A hole is required in the base of the housing for the measurement sensor.

② If the test ram is cut at an angle of 45°, there is a distortion of the spring travel since the relative motion between the ram and ball is included in the travel signal.

In practice, the stroke characteristics are relevant for a loading direction of 45°. When traversing the gearshift ramp, a continuously variable transverse force is active – it occurs only at the apex point/cusp point of the ramp contour.

The hysteresis curve is measured several times in order to record the stroke characteristics. The force on the detent ball is applied from various directions – the measurement points are rotated four times by 90°.

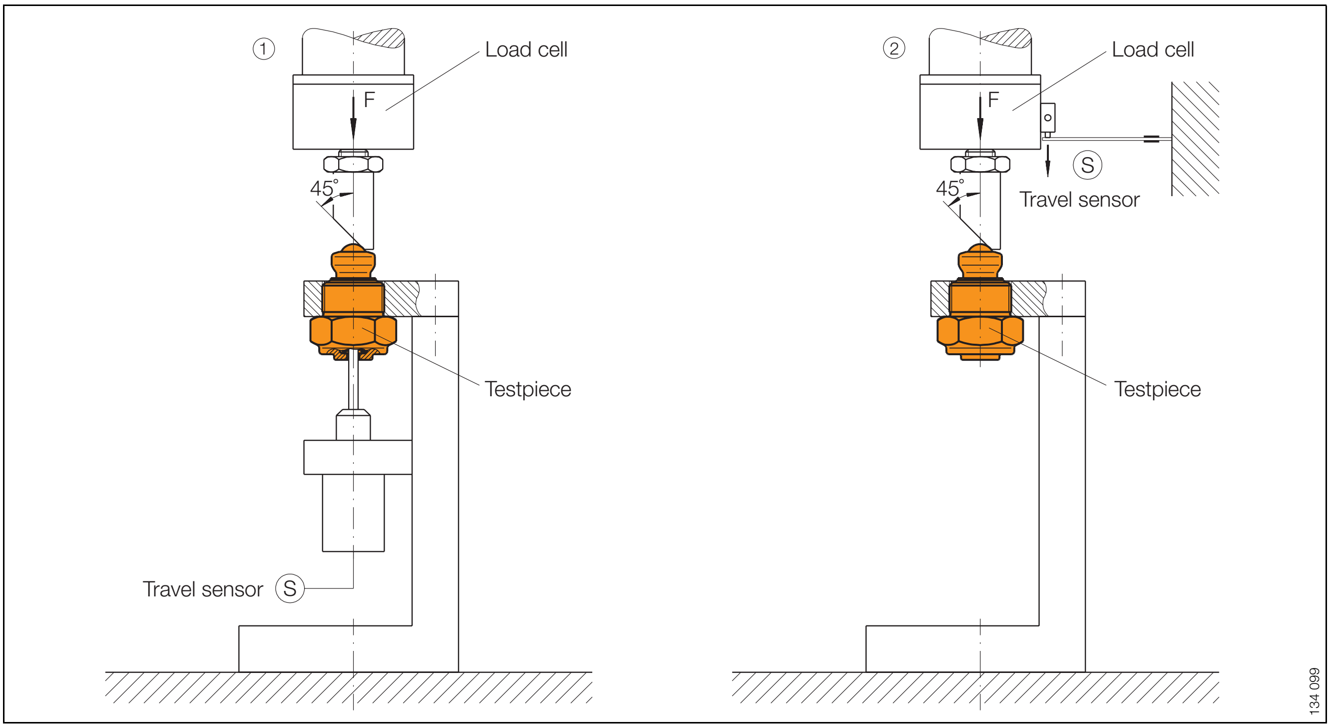


Figure 22 · Test apparatus for measuring engagement resistance

Total resistance

The total resistance is measured as rolling characteristics – see also Figure 7 – of the detent ball/plunger over a ramp contour – Figure 23, lower half. The ramp profile is part of a profiled rail and corresponds to the original profile.

Displacement force

The displacement force is measured in the same test apparatus. However, the profiled rail with the ramp contour is replaced by a flat, ground rail.

Test conditions

Spring preload	F_1 = 30 N to 130 N
Swivel angle	α =15° to 30° (depending on function and ramp geometry)
Lubricant	Esso gearbox oil ST SAE 85–W90
Drip feed lubrication	approx. 1 drop/min.

Explanation of force curve – Figure 23 –

P_1
Neutral position

P_1 P_2
Start of gearshift

P_2
Adhesive friction overcome

P_2 P_3
Moving up ramp A_1

P_3
Traverse of ramp crest

P_3 P_4
Moving down to ramp A_2

P_4
Reversal of gearshift direction

P_4 P_5
Start of new gearshift operation

P_5
Adhesive friction overcome

P_5 P_6
Moving up ramp A_2

P_6
Traverse of ramp crest

P_6 P_1
Moving down to ramp A_1

etc.

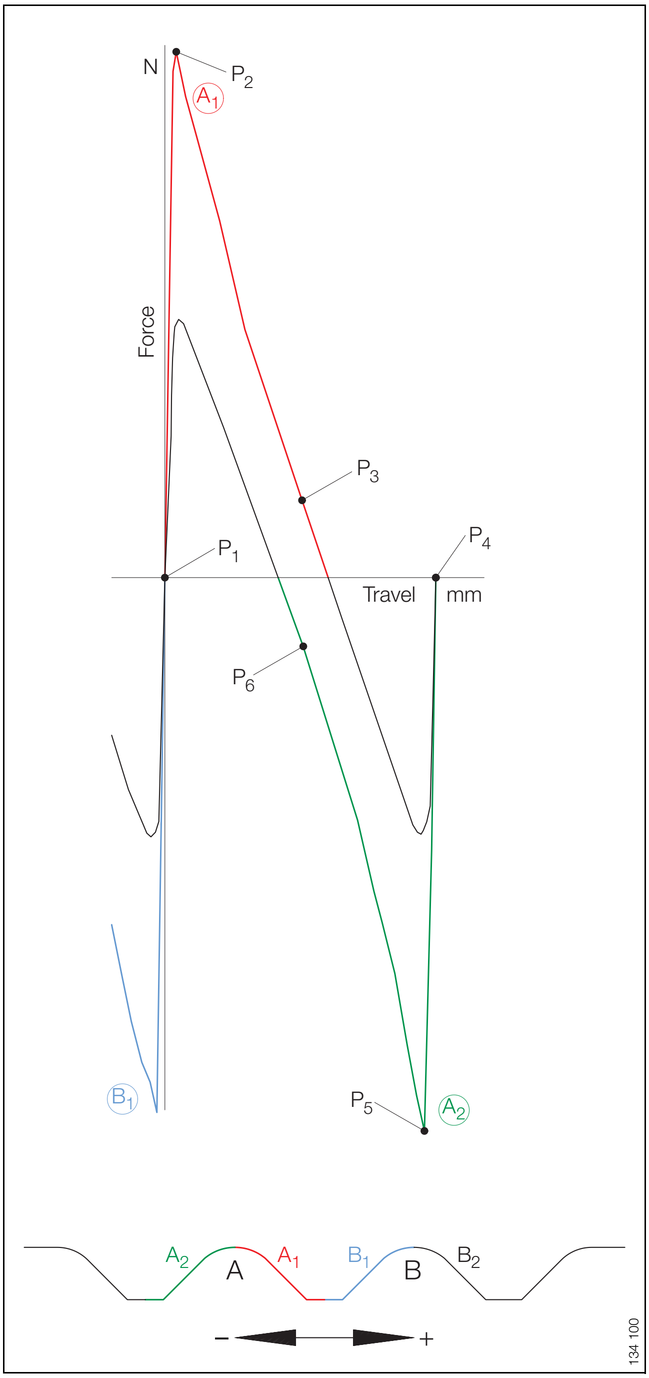


Figure 23 · Gearshift resistance – force curve

Operating life of gearshift cycle – Figure 24

The detent pin is positioned against an original gearshift cam. The cam is in the neutral position. The shaft supporting the gearshift cam is supported by bearings of series RLF. A crank drive is used to induce oscillating motion of the selector shaft.

Operating life of selection cycle

In contrast to the structure described above, the force measurement element is arranged in an offset position. Furthermore, the selector shaft undergoes linear motion.

Force measurement

The gearshift resistance is measured directly on the detent pin using the force measurement element, i.e. without the influence of the shaft bearing arrangement.

Test conditions

Spring preload[1)]	F_1 = 30 N to 130 N
Gearshift frequency	f = 1 Hz
Engagement and selection	n = 10^6 double gearshift operations
Swivel angle[1)]	α =15° to 30°
Displacement travel[1)]	s $\approx$ 20 mm
Lubricant	Esso gearbox oil ST SAE 85–W90
Drip feed lubrication	approx. 1 drop/min.

1) According to specification.

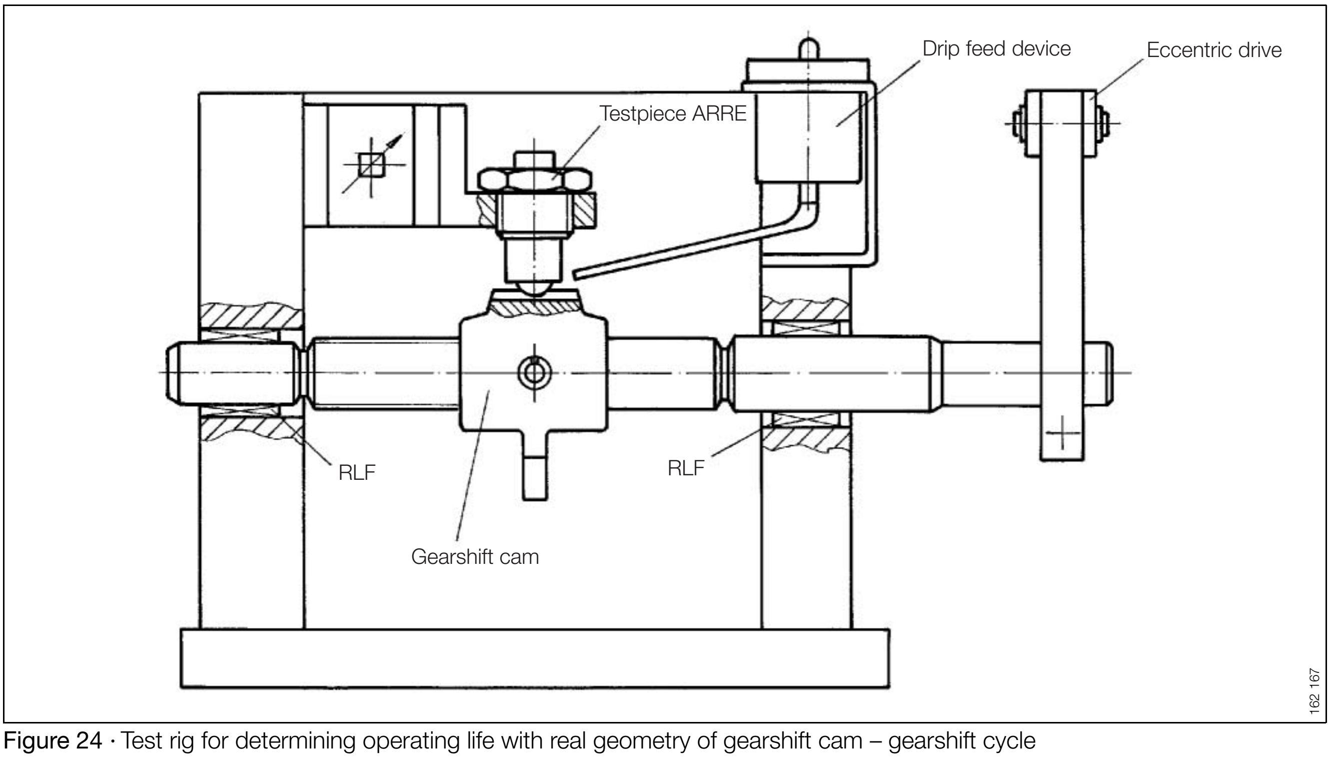


Figure 24 · Test rig for determining operating life with real geometry of gearshift cam – gearshift cycle

Running marks

Since detent pins are subject to generally increasing requirements, such as lower gearbox mass, they must be designed with the minimum possible dimensions. An important objective here is to design the detent pin within the limit range of the static load safety factor.

With "optimum limit design", however, running marks occur; e.g. after 1 000 000 gearshift cycles – Figure 25:

- on the ball cup raceway due to the loading of the support balls by the detent ball,
- on the surfaces of the support balls due to the bearing load F_A.

Test evaluations of various endurance tests show, however, that

- running marks do not influence ease of gearshift or the gearshift feel.

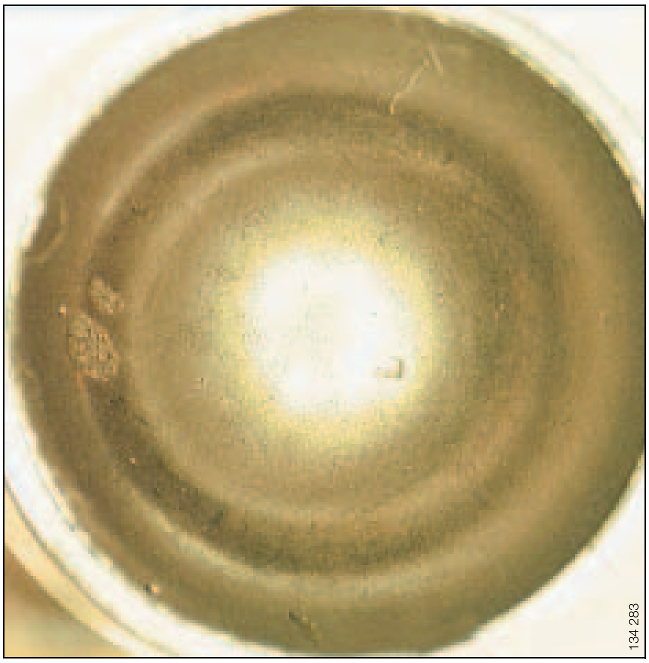


Figure 25 · Running marks on the ball cup raceway

Summary

The design of the detent pin influences

- the gearshift behaviour and the gearshift curve

and thus

- the quality of the gearshift and the gearshift feel experienced by the driver.

Design

The work required for a detent pin – the design – depends in principle on the sensitive complete gearshift system in the gearbox. A significant reduction in the friction value is achieved, for example, with a detent ball without support.

For many applications, detent pins with only one functional part – the detent ball – supported by sliding or rolling contact is sufficient, for example for locking of the

- selector rod or selector rail and the
- selector jaw or selector fork.

For positioning or running on a contour, for example in the case of a selector shaft with simultaneous selection and engagement function, a detent pin with complete support by rolling contact – detent ball and plunger for the stroke – is used. The spring preload force is then matched in optimum terms to the operating conditions

Fixing

Detent pins are simply screw mounted with the appropriate tightening torque or pressed into the gearbox housing.

Anti-corrosion protection

As an anti-corrosion measure, detent pins

- are treated with the INA special plating Corrotect®
- or components of the detent pins are chromated or
- made from corrosion-resistant materials.

Ramp profile

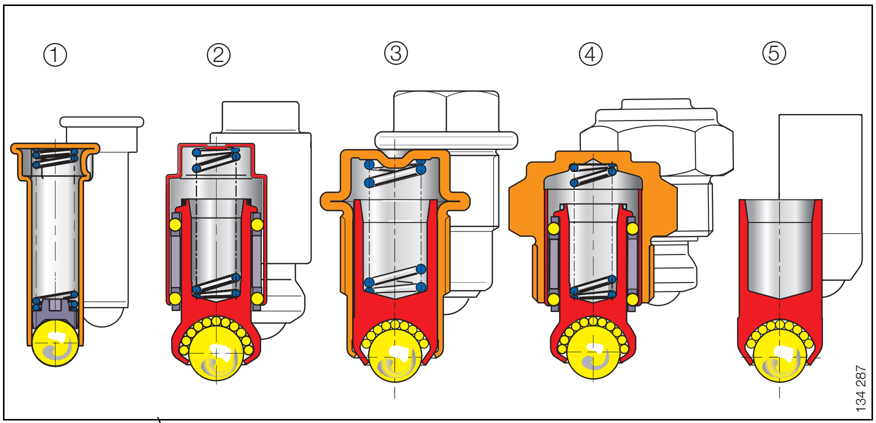
In addition to the design of the detent pin, the selection and engagement operation is also influenced by the ramp profile – the contact zone between the selector rod or selector shaft and the detent ball.

Test methods

Comprehensive mechanical test methods are used to ensure the function and quality of detent pins.

The test methods are based on customer specifications and stringent INA quality standards.

Checklist



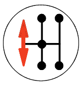
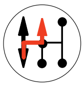
ARRE – types*)

Legend

❑ Tick appropriate box

☐ Enter relevant information

1) Attach customer drawing

	No	Yes
Basic function ⓐ  ⓑ 		
Lock engagement motion only ⓐ – engagement of gear . . .	❑	❑
Lock preselection and engagement motion ⓑ	❑	❑
Additional function		
Guide additional components – e.g. locking plate .	❑	❑
Provide stop facility . . .	❑	❑
Possible use as safety/lock . . .	❑	❑
Special sealing required. . .	❑	❑
Reverse light switch function . . .	❑	❑

Spring preload force

Current spring preload force/spring rate . ☐

Spring characteristic curve1) . . . . ☐

Adjacent construction

	No	Yes
Initiation of gearshift motion – separate rotary/linear motion or via selector shaft	❑	❑

Adjacent construction of detent pin1)
– relating specifically to switch function

Ramp contour of shaft or of locking piece1)

Maximum usable design envelope1). . . . . ☐

Note design envelope required for retention of detent ball1)

Mounting position of detent pin in gearbox1)
– select vertical or horizontal position of detent ball for jolt-free running

Material of gearbox housing
– steel, aluminium etc. . . . . ☐

Operating conditions

Force situation. . . . . ☐

Temperature range
– note heat sources. . . . . ☐

	No	Yes
Special anti-corrosion protection . . .	❑	❑
Special requirements . . .	❑	❑

☐

☐

☐

☐

☐

Assembly

	No	Yes
Robot assembly . . .	❑	❑
Manual assembly. . .	❑	❑

Screw mounted variant
– favourable tightening torque <30 Nm. . ☐

Pressed-in variant
– pressing-in force required ≧2 000 N . . . ☐

Delivered condition/delivery quantity

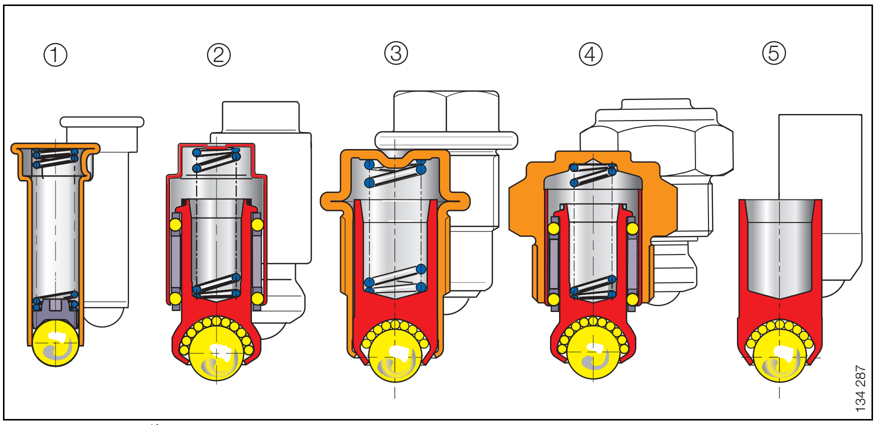
	No	Yes
Special packaging . . .	❑	❑

Number of detent pins
per gearbox/costing quantities . . . . ☐

	No	Yes
Test sample with adjustable spring force required .	❑	❑

*) Types ① and ② have the most favourable price/performance ratio. These types should be used in preference in the design of the gearshift system.

Dimension list



ARRE – types[1)]
Ⓡ – Roller detent pin

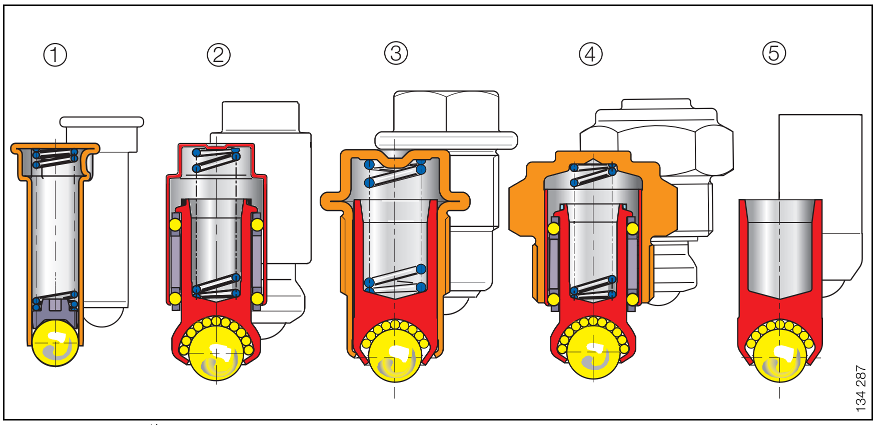
Type[1)]	Dimensions[2)] mm	Part number
③	6,000×14,000×24,000	F-228954
③	6,000×15,000×26,650	F-214970.4
③	6,000×17,000×42,000	F-223358
④	7,500×16,000×44,500	F-218416.4
④	7,500×18,000×44,500	F-218416.5
⑤	8,000×12,500×28,000	F-220578.1
②	8,000×19,000×46,200	F-236449.2-30
③	8,000×20,000×56,800	F-220303.10
③	8,000×22,000×45,600	F-223294.1
③	8,000×24,000×44,000	F-223293
⑤	8,731×11,000×23,000	F-219675.2
⑤	8,731×13,600×30,000	F-232189
②	8,731×14,500×49,400	F-227095.1
②	8,731×16,000×34,500	F-229550.1
②	8,731×16,000×37,200	F-230934
②	8,731×16,000×38,800	F-231920.13-30
②	8,731×16,000×38,900	F-223541.3
②	8,731×16,000×38,900	F-223541.4
②	8,731×16,000×38,900	F-227945.5
②	8,731×16,000×38,900	F-223541.6
②	8,731×16,000×38,900	F-230009.10-30
②	8,731×16,000×38,900	F-230840
②	8,731×16,000×38,900	F-230941
②	8,731×16,000×38,900	F-232097
②	8,731×16,000×38,900	F-235260
②	8,731×16,000×46,400	F-235582.2
②	8,731×16,000×46,400	F-237232-30
②	8,731×16,000×52,300	F-239857

Type[1)]	Dimensions[2)] mm	Part number
②	8,731×17,000×36,000	F-221102.2
②	8,731×17,000×45,200	F-235988
③	8,731×18,000×38,200	F-222707
③	8,731×18,000×38,200	F-232537
③	8,731×18,000×38,200	F-232670
③	8,731×18,000×38,200	F-228014
③	8,731×18,000×38,200	F-230065
③	8,731×18,000×38,200	F-224043.5
③	8,731×18,000×40,000	F-227107.3
④	8,731×18,000×46,700	F-217859.6
④	8,731×18,000×46,700	F-236225
④	8,731×18,000×46,700	F-236225.3
②	8,731×19,000×45,200	F-228045-930

1) Types ① and ② have the most favourable price/performance ratio. These types should be used in preference in the design of the gearshift system.

2) Dimensions in mm:
Detent ball diameter × press-in diameter/ thread diameter × total section height.

Dimension list



ARRE – types[1)]
Ⓡ – Roller detent pin

Type[1)]	Dimensions[2)] mm	Part number
④	8,731×20,000×37,500	F-223521.6
④	8,731×20,000×37,500	F-230562
④	8,731×20,000×23,500	F-223521.4
②	8,731×20,000×44,600	F-235582.4
②	8,731×20,000×44,600	F-237190
②	8,731×20,000×47,400	F-218887.5
④	8,731×20,000×37,500	F-212601.10
④	8,731×20,000×37,500	F-212601.6
④	8,731×20,000×37,500	F-224957.1
④	8,731×20,000×39,000	F-222812
②	8,731×20,000×44,600	F-230870.2
②	8,731×20,000×44,600	F-237295.1
④	8,731×22,000×38,800	F-236839
④	8,731×24,000×23,200	F-217833.8
④	8,731×24,000×44,600	F-237296
④	8,731×27,000×53,000	F-233677
①	9,000×10,850×23,300	F-223455.2
①	9,000×11,000×25,300	F-239627
①	9,000×11,000×31,300	F-229798
①	9,000×11,000×31,300	F-229623
①	9,000×11,000×31,300	F-233846
①	9,000×11,000×31,300	F-234334.2-340
①	9,000×11,000×31,600	F-230940
①	9,000×16,000×49,000	F-229549

Type[1)]	Dimensions[2)] mm	Part number
Ⓡ	10,000×10,500×38,500	F-207655
①	10,000×11,850×38,900	F-216710.1
①	10,000×12,000×33,200	F-234334.2-230
①	10,000×12,000×47,700	F-222326.1
①	10,000×12,000×47,700	F-216710.9
①	10,000×12,000×47,900	F-238312
Ⓡ	10,000×12,000×48,500	F-214995.4
⑤	11,906×17,000×31,000	F-222964.1
⑤	11,906×17,000×31,000	F-229341
⑤	11,906×20,000×45,500	F-230014.1
Ⓡ	12,000×15,000×36,400	F-231063
⑤	12,000×20,000×28,100	F-210655.1
⑤	12,000×20,000×28,100	F-211761.1
⑤	12,000×20,000×28,100	F-215187.3
⑤	12,000×20,000×28,100	F-226817-10
⑤	12,000×20,000×37,300	F-230435
⑤	12,000×20,000×37,300	F-238155
③	12,000×27,000×49,500	F-212114.1
②	12,000×42,000×25,500	F-223198.1
②	12,000×42,000×36,000	F-231621

1) Types ① and ② have the most favourable price/performance ratio. These types should be used in preference in the design of the gearshift system.

2) Dimensions in mm:
Detent ball diameter × press-in diameter/
thread diameter× total section height.

Reference list

Customer

- ADAM OPEL
- AISIN AL
- BORG WARNER
- CLARK
- CZ-STRAKONICE (SKODA)
- DAEWOO PRECISION
- DAIMLER CHRYSLER
- EATON
- FERRARI
- FIAT
- FORD
- GENERAL MOTORS
- GETRAG
- HEIDEMANN-WERKE (FORD)
- HÖRBIGER
- HYUNDAI MOTOR
- IVECO
- JOHN DEERE WERKE
- ISUZU
- KEIHIN SEIMITSA
- KIA MOTORS CORPORATION
- KOCHENDÖRFER & KIEP
- KOYO SEIKO (TOYOTA)
- NISSAN MOTOR MOTOR COMP.
- PEUGEOT
- RENAULT
- SAAB
- SEAT
- TOYOTA
- VOLKSWAGEN-KONZERN
- VOLVO
- ZAHNRADFABRIK BRANDENBURG
- ZAHNRADFABRIK FRIEDRICHSHAFEN
- ZF (USA)
- ZWN ZAHNRADWERK (AUDI/PORSCHE)

MATNR 005505526-0000 / API 14 / GB-D / 2007081 / Printed in Germany by Mandelkow GmbH

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