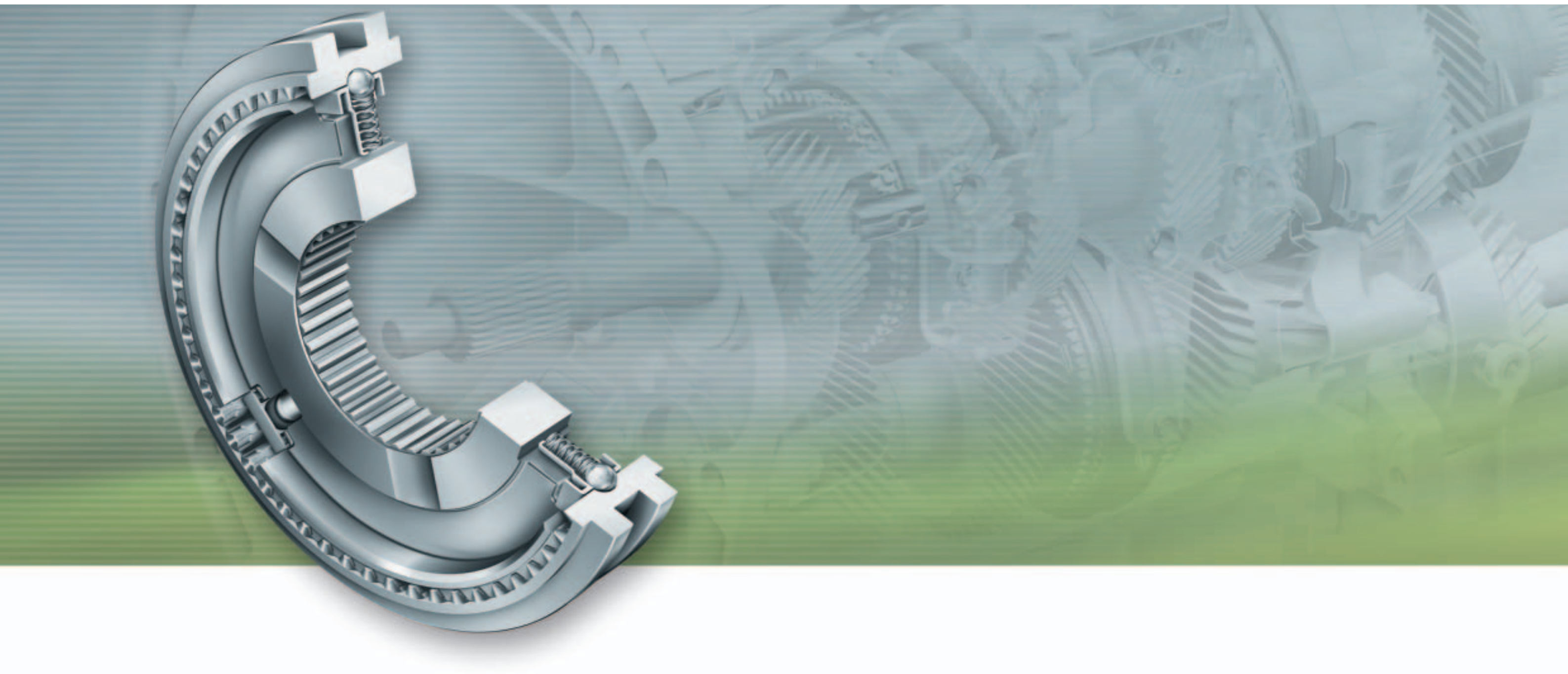


INA selector hub assembly

Technical Product Information

SCHAEFFLER GROUP
AUTOMOTIVE

Contents

Synchronisation systems

Definition
Requirements
Systems in general

Definition

Synchronisation is derived from the Greek **syn** (together) and **chronos** (time) and is defined as “ensuring the occurrence in unison of two events or processes”.

Requirements

The continual increase in the performance capacity of engines and clutches is leading to significant increases in transmission torques and mass moments of inertia. This places ever-increasing demands on automotive transmissions and their components. Optimisation purely at the component level is therefore no longer sufficient. Solutions are now required that are comprehensively oriented to the overall concept of the vehicle.

For synchronisation of the manual transmission, for example, there is a need for products that are compact, have optimised mass and run smoothly while ensuring the highest functional reliability. These components are also expected to minimise the gearshift force and improve gearshift comfort.

Systems in general – *Figure 1*

Synchronisation systems match the different speeds of the gear to be engaged and the shaft to each other.

The systems currently available are:

- the dog clutch
  - as a direct gearshift clutch without synchronisation
- the multiple disc synchronizer (1)
  - synchronisation by means of discs with friction surfaces, suitable for high power transmission
- the cone friction clutch (2), (3), (4)
  - the state of the art in mechanical manual transmissions, designed as a blocking synchronizer.

Blocking synchronizers are used as:

- single cone synchronizers (2) or
- multiple cone synchronizers (4).

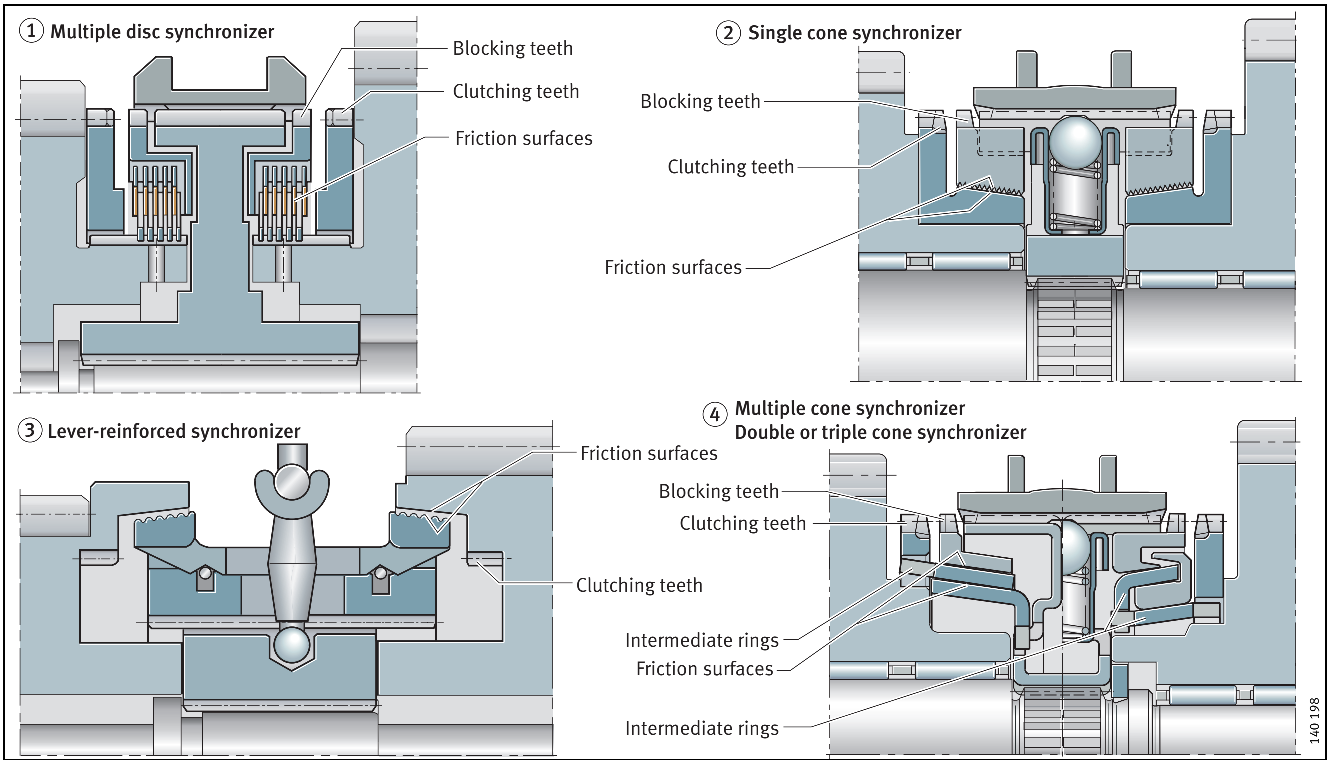


Figure 1 · Synchronisation systems – selection

Single cone synchronizer

Design

In order to ensure correct functioning of the gearshift, synchronisation is carried out first (the different speeds of the freewheel and shaft are matched to each other) following by clutching (the freewheel is linked to the shaft by geometrical locking). In order to ensure that synchronisation occurs before clutching, a finely tuned blocking function is necessary.

Design – *Figure 2*

This single cone synchronizer is a conventional blocking synchromesh as found in the Borg-Warner or ZF-B system. Springs (6) preload the struts (5) for presynchronisation. Synchronisation is carried out by a cone friction clutch with a single cone on the gear cone body (2)/synchro ring (3).
This cone friction clutch supports the total frictional energy.

The torque is transmitted via the teeth on the selector sleeve (7) which, when engaged, links the freewheel (1)/gear cone body (2) with the selector hub (4)/shaft.

The blocking function is achieved by the interaction between the dog teeth of the synchro ring (3) and the selector sleeve (7).

Coefficient of friction and gearshift behaviour

For correct functioning of the synchro mechanism, the cone friction clutch must have a sufficiently high coefficient of sliding friction during the entire slip phase. If the coefficient of friction is too low, the synchro mechanism will release prematurely; engagement will occur before synchronous running is achieved. Since the teeth of the selector sleeve and the gear cone body will then come into contact, undesirable noise will occur or the components will be damaged.

In order to achieve a high level of gearshift comfort, the cone friction clutch should have a low coefficient of adhesive friction; this will give “smooth gearshift behaviour”. The requirement is therefore for high synchronisation performance with precisely matched coefficients of friction.

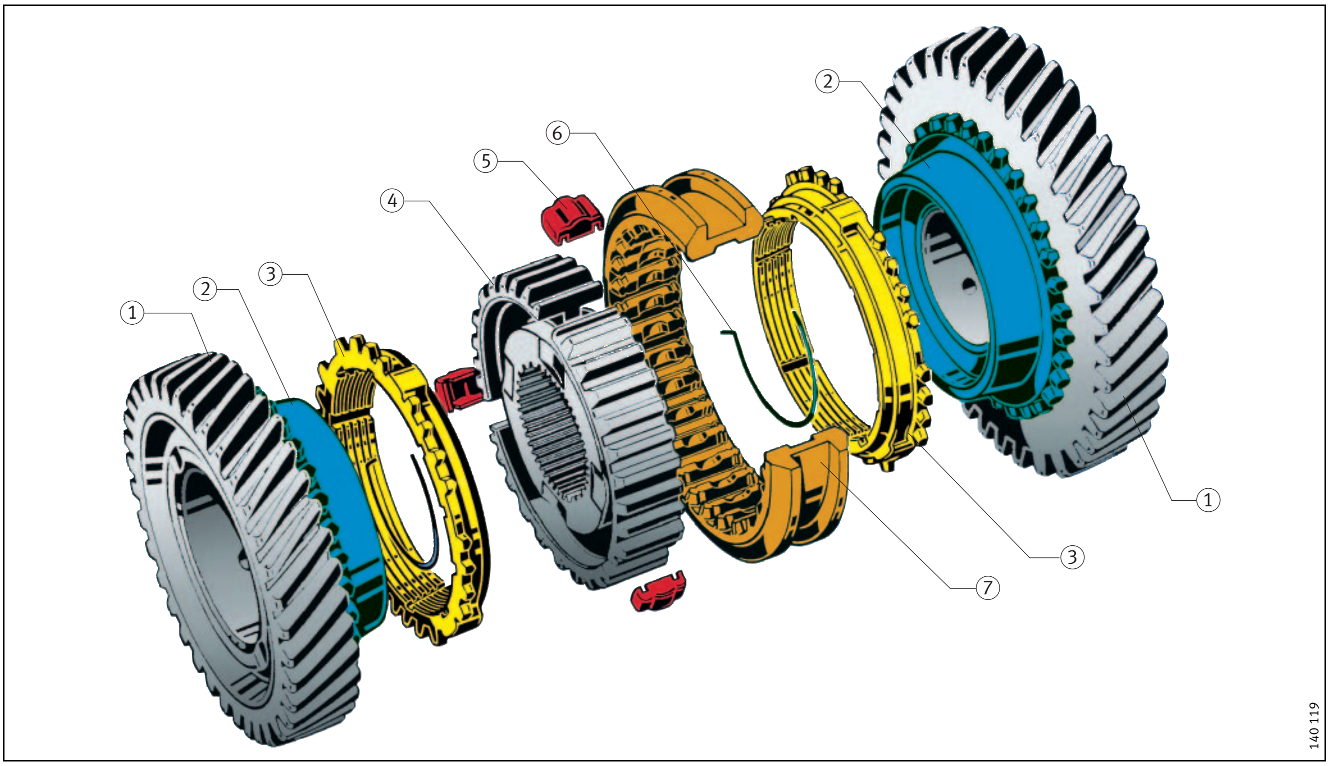


Figure 2 · Single cone synchronisation – ZF-B blocking synchronizer

Components – *Figure 3*

Selector hub

The selector hub ⑱ is linked by geometrical locking to the transmission shaft ①. It supports the components for presynchronisation ⑰ in a recess on the outside diameter ⑲ and guides the selector sleeve ⑬ in a tooth spline set ⑯. Slots ⑳ distributed around the circumference secure the synchro ring ⑧ guided on its end face against rotation.

Selector sleeve

The inside diameter of the selector sleeve ⑬ has spline teeth ⑯ with roof angles ⑫ on the end faces. The sliding surfaces of the gearshift fork mesh in a circumferential slot ⑮ on the outside diameter. The selector sleeve can therefore be axially displaced. Recesses ⑭ on the inner teeth centre the detents ⑰.

Struts

Presynchronisation is carried out using struts ⑰ – in this case detent pins (description of struts: see page 14).

Synchro ring

Conventional synchro rings ⑧ are normally made from brass alloys or sintered steel. For better lubricant displacement, threads or grooves ⑪ can be machined in. INA synchro rings are made from cold formed steel. The required friction values are achieved by means of coatings, for example a specially developed spray coating. On the outside diameter are the blocking teeth ⑨ with the roof angles ⑩ aligned to the selector sleeve.

Clutch body

The gear cone body ⑤ is made from steel and is rigidly linked to the constant mesh gear ④, for example by welding. It has an outer cone ⑪ and clutching teeth ⑥ with roof angles ⑦ aligned to the synchro ring.

Constant mesh gear

The constant mesh gear ④ is supported on the shaft ② and designed with involute teeth ③ for transmission of torques.

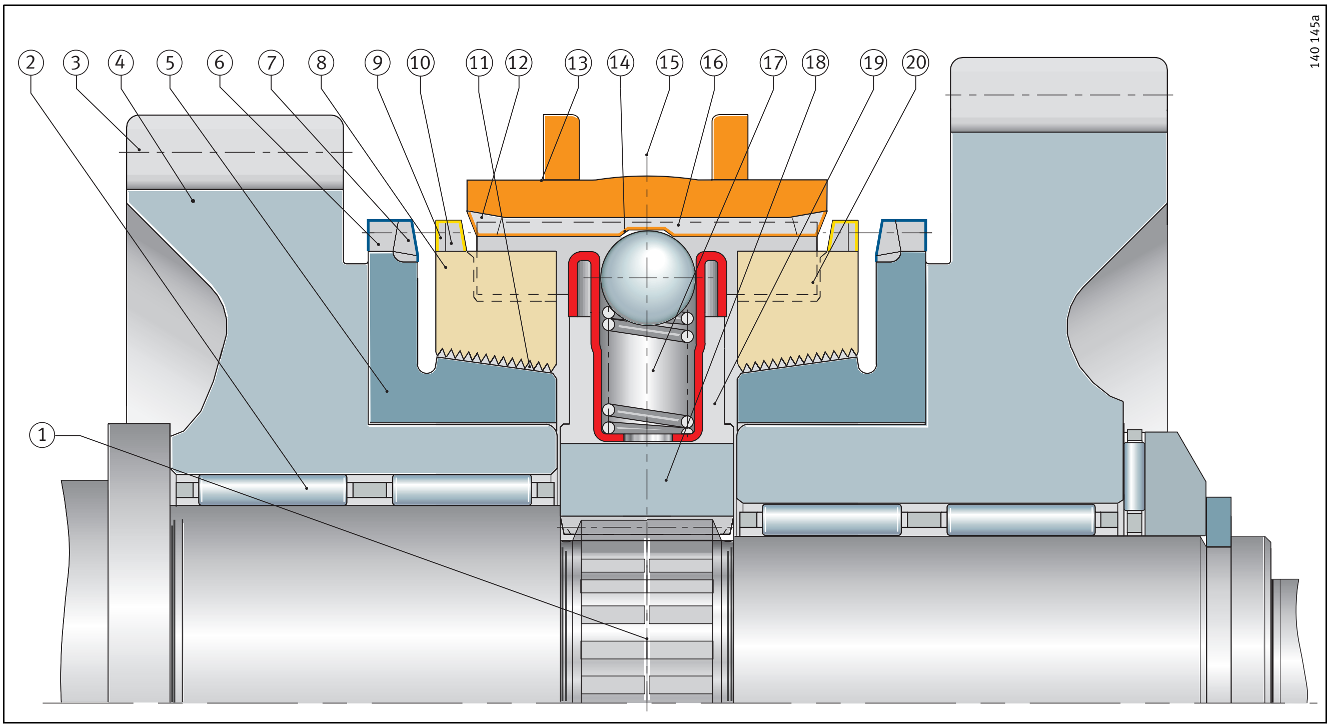


Figure 3 · Single cone blocking synchronizer – components

Function – *Figure 4*

Component drawing (see *Figure 3*, page 6). The selector sleeve ⑬ is in the neutral or idling position.

Synchronisation – A

The selector sleeve ⑬ is moved out of the idling position axially toward the constant mesh gear ④.

Due to blocking in the ramp profile on the teeth of the selector sleeve ⑫, the struts ⑰ are also moved axially. They press the synchro ring ⑧ against the friction cone ⑪ on the gear cone body ⑤ of the constant mesh gear ④.

If the constant mesh gear and shaft are rotating at different speeds, a frictional torque is built up and the gear is presynchronised. Due to the frictional torque, the synchro ring ⑥ rotates immediately by the available clearance of the anti-rotation lugs in the synchronizer body ⑳. As a result, the dog teeth ⑫ on the selector sleeve come into contact with the blocking teeth ⑩ on the synchro ring – premature axial throughshift of the selector hub is prevented.

The axial force increases. The frictional torque is now fully effective and matches the different speeds of the gear wheel and the synchro ring to each other, thus synchronising the gear.

Disengaging – B

Once speed uniformity is achieved, the frictional torque is eliminated.

Since the gearshift force is still acting on the blocking teeth ⑩, the gearshift sleeve rotates the components under frictional locking, the synchro ring ⑧ and the gear body ⑤, ④.
As a result, the teeth of the selector sleeve ⑯ slip into the gaps in the blocking teeth ⑨.

Free flight – C

The torque loss ㉑ – splash losses, bearing and seal friction – reduces the speed of the freewheel ④.

During moment-free displacement of the selector sleeve, this leads to a slight difference in speed between the selector sleeve/synchro ring and the gear cone body.

Meshing – D

The teeth of the selector sleeve ⑯ come into contact with the dog teeth ⑦ of the constant mesh gear ⑤. They rotate the gear body ⑤ and ④ until the selector sleeve can be shifted. The shift sleeve reaches its final position, it is coupled and the gear is engaged.

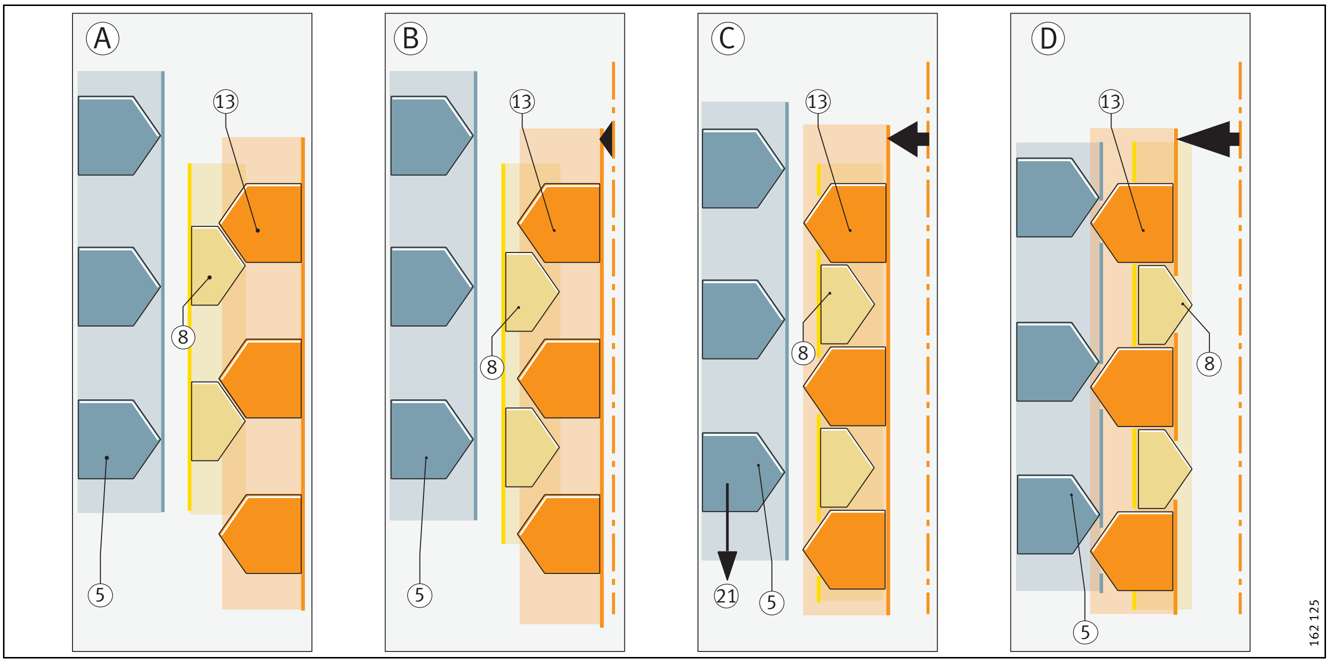


Figure 4 · Gearshift phases, shown in terms of the blocking teeth and clutching teeth

Multiple cone synchronisation

Design and function
Synchro rings

Design and function – *Figure 5*

A multiple cone synchronizer has essentially the same design as a single cone synchronizer. The two systems differ in particular in the number of friction surfaces.

An increase in the friction surface of the single cone synchronizer reduces the generation of heat during the synchronisation process. The frictional force and frictional torque remain unchanged.

In multiple cone synchronisation systems, the friction surface is expanded by intermediate rings. Due to the radial arrangement of the friction surfaces, the gearshift force acts on several surfaces. As a result, a higher frictional torque can be achieved.

Multiple cone synchronisation systems are used in preference for the lower gears – 1st/2nd gear. Due to the high speed differences, very high synchronisation performance is required in these cases and the gearshift forces are correspondingly higher.

However, high synchronisation performance can have disadvantageous effects in an inappropriate gearshift operation such as 3rd to 1st gear – at 80 km/h, the speed difference is synchronised in only approx. 0,2 sec. This can lead to clutch damage. On the other hand, this synchronisation performance ensures that only a small gearshift force is required from 2nd gear to 1st gear even at low temperatures (–25 °C).

Prospects for development

The performance capacity of multiple cone systems can be increased by specially developed coatings.

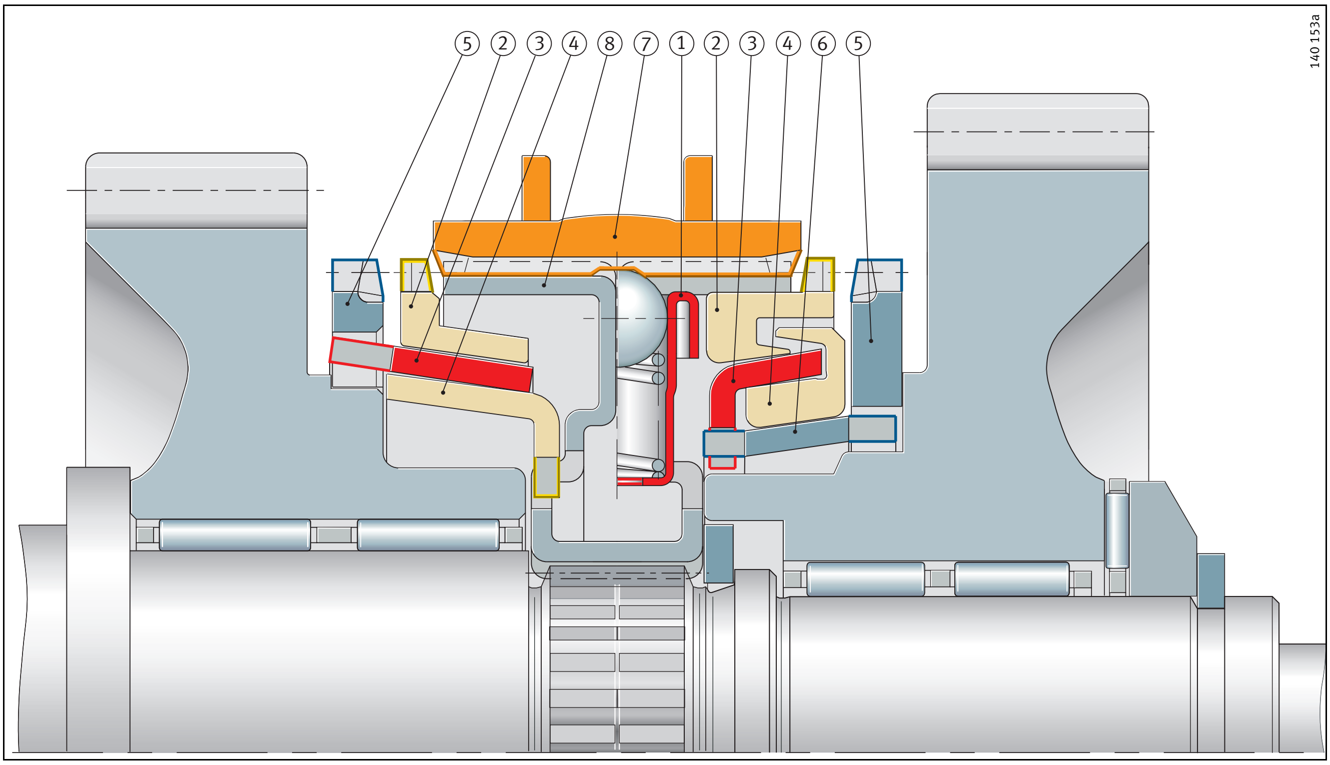


Figure 5 · Multiple cone synchronizer

Synchro rings – *Figure 6*

Conventional synchro outer and inner rings are normally made from a special brass alloy or sintered materials. INA synchro rings are made from cold formed steel and the required friction values are achieved by a coating (e.g. molybdenum, specially developed spray coating or carbon).

The cone surfaces have – depending on the material or coating – oil drainage slots. These give more rapid distribution or displacement of the lubricant. The more quickly the oil leaves the friction surface, the earlier the frictional torque increases and the slippage phase is shortened. At the same time, the oil dissipates heat from the friction assembly.

Synchro intermediate rings are normally made from steel and are also coated if necessary.

The INA synchro ring package ⑦ is secured against loss of components and comprises the synchro outer ring, synchro intermediate ring and synchro inner ring. This complete unit is designed for extremely simple mounting.

Legend for *Figure 6*

① INA synchro intermediate or inner ring, pot type
② INA synchro intermediate or inner ring, crown type
③ INA synchro outer ring
④ Synchro intermediate ring with carbon coating
⑤ Synchro intermediate ring with specially developed spray coating
⑥ Synchro intermediate ring with molybdenum coating
⑦ Synchro ring package secured against loss of components

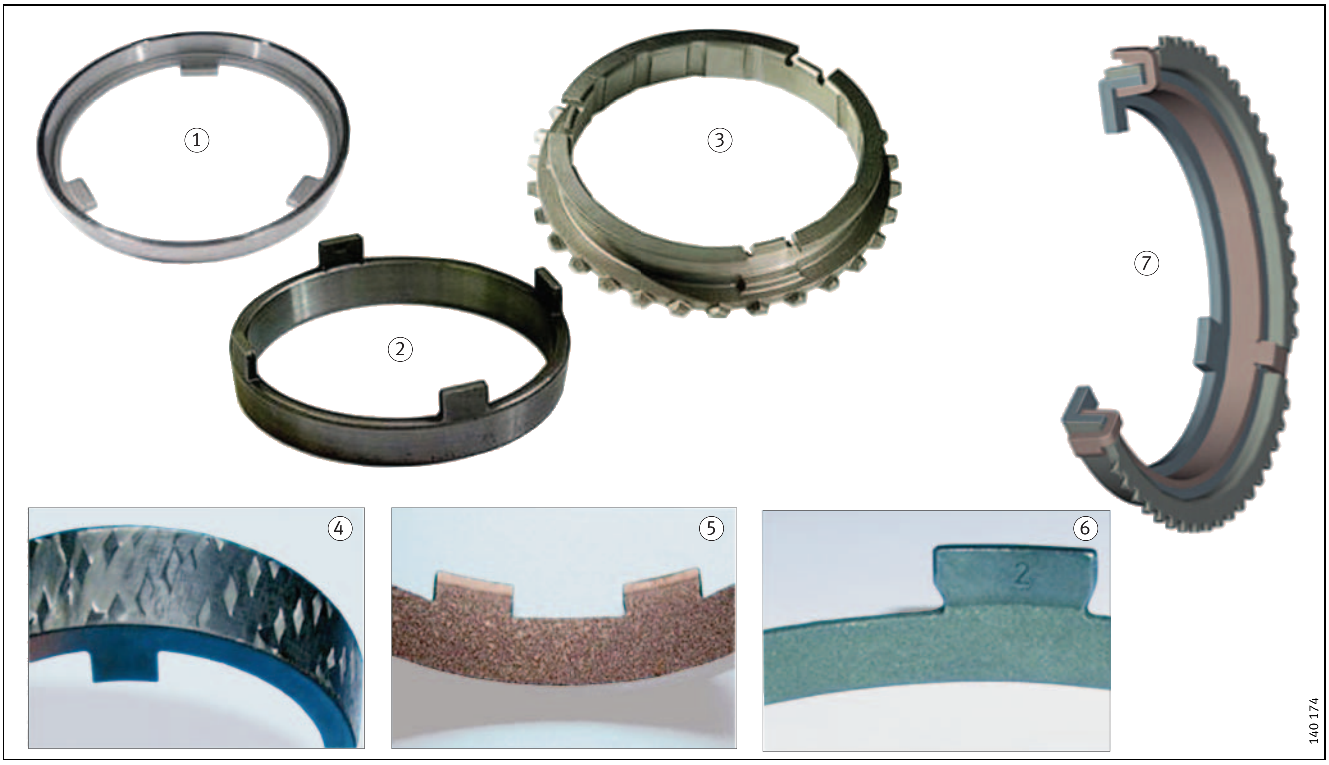


Figure 6 · Synchro rings

Comparison of single cone and multiple cone synchronisation

Gearshift force curve
Frictional torque of single cone synchronisation
Frictional torque in multiple cone requirements

Gearshift force curve – *Figure 7*

The gearshift force curves for a triple cone synchronizer and single cone synchronizer are shown.

The values were measured on the gearshift shaft.

Interpretation of measurement values

The gearshift force required is significantly lower in the case of the triple cone synchronizer.

When intermediate rings are used, the gearshift force is reduced – in comparison with the single cone synchronizer – by approx. 40%. In addition, gearshift is noticeably easier.

Influencing factors

Synchronisation must function smoothly throughout the operating life. Smooth, uniform gearshift behaviour is achieved by:

- low voscosity of the transmission oil
  – higher oil temperature –
- short synchronisation times
- sufficient gearshift forces at the gearshift lever
- low sliding speeds between the friction surfaces
- low mass moments of inertia
- optimised geometry of components
- smooth surface structure of teeth.

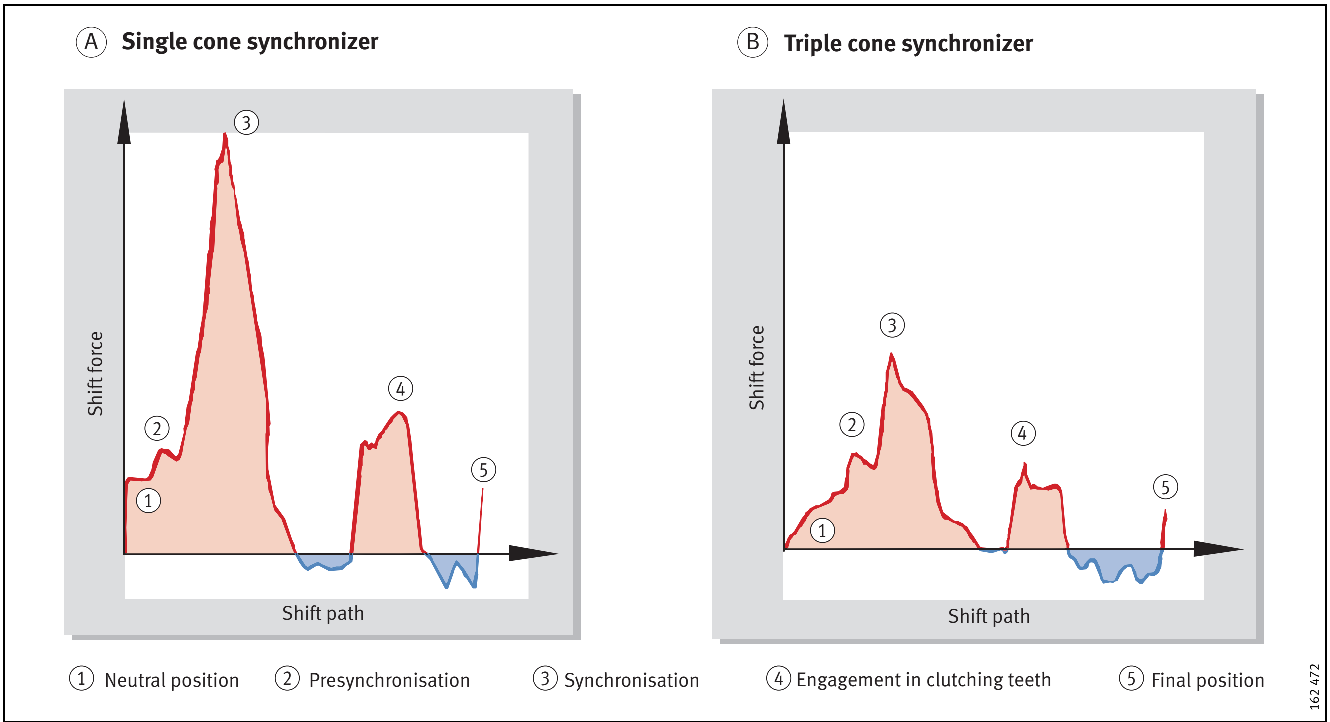


Figure 7 · Gearshift force curve for single and triple cone synchronisation – comparison

Frictional torque of single cone synchronizer – *Figure 8*

The effective frictional torque M_K at the cone partners is built up by the axial gearshift force F_a and determined according to the formulae below.

$$F_N = F_a \cdot \frac{1}{\sin\alpha_K}$$

$$F_R = F_N \cdot \mu_K$$

$$M_K = F_R \cdot \frac{d_K}{2}$$

$$M_K = F_a \cdot \mu_K \cdot \frac{d_K}{2} \cdot \frac{1}{\sin\alpha_K}$$

F_N N
Normal force

F_a N
Axially acting gearshift force

F_R N
Frictional force

M_K Nmm
Frictional torque at cone

μ_K –
Dynamic friction value between cone partners

d_K mm
Mean effective cone diameter

α_K °
Cone angle.

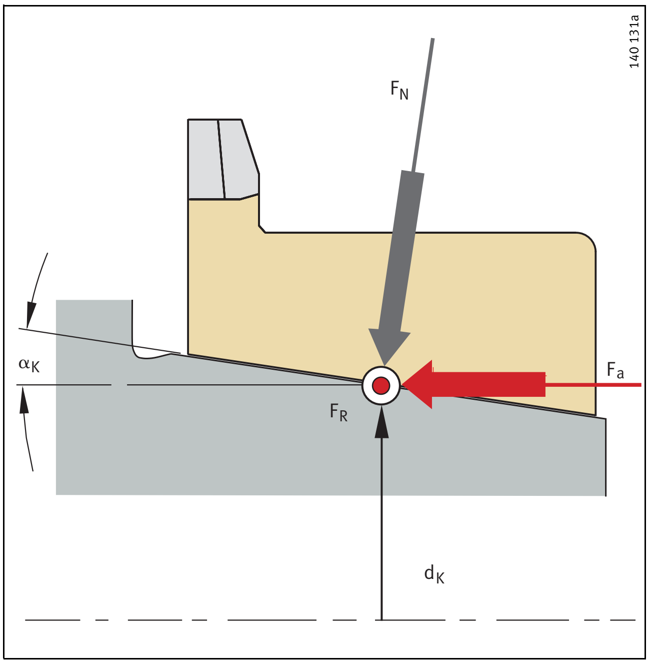


Figure 8 · Frictional torque of single cone synchronizer

Frictional torque for multiple cone requirements

If rings acting in the same direction in multiple cone synchronizers – e.g. triple cone synchronizers – are linked to each other, the cone moments acting on the blocking teeth are added together as $M_{K\,tot}$ – see formula.

$$M_{K\,tot} = F_a \cdot \frac{1}{2}\left(\frac{d_{K1} \cdot \mu_{K1}}{\sin\alpha_{K1}} + \frac{d_{K2} \cdot \mu_{K2}}{\sin\alpha_{K2}} + \frac{d_{K3} \cdot \mu_{K3}}{\sin\alpha_{K3}}\right)$$

The above formula is valid for an efficiency of 100%. In practice, however, this is not achieved, so the specific axial gearshift force must be taken into consideration in the formula – see formula:

$$M_{K\,tot} = \frac{1}{2}\left(\frac{F_{a1} \cdot d_{K1} \cdot \mu_{K1}}{\sin\alpha_{K1}} + \frac{F_{a2} \cdot d_{K2} \cdot \mu_{K2}}{\sin\alpha_{K2}} + \frac{F_{a3} \cdot d_{K3} \cdot \mu_{K3}}{\sin\alpha_{K3}}\right)$$

INA selector hub assembly

Design
Requirements
Components

Selector hub assemblies or selector hubs are used in single and multiple cone synchronizers. They facilitate gearshift in manual transmissions and transmit the total engine torque from the transmision shaft to the engaged gear.

Design

A selector hub assembly comprises the selector hub (*Figure 9* ①), struts (*Figure 9* ②) and the selector sleeve (*Figure 9* ③).

Requirements

In modern manual transmissions for passenger cars, selector hub assemblies must transmit a torque, depending on the ratio, of up to 2200 Nm (*Figure 9* ④). This results in increasing demands on conponent strength.

In addition, the requirements for gearshift comfort are also increasing – with reduced gearshift force and shorter gearshift times. However, the design envelope in the transmission remains constant (*Figure 9* ⑤), or is even reduced due to the ongoing increase in the number of gears.

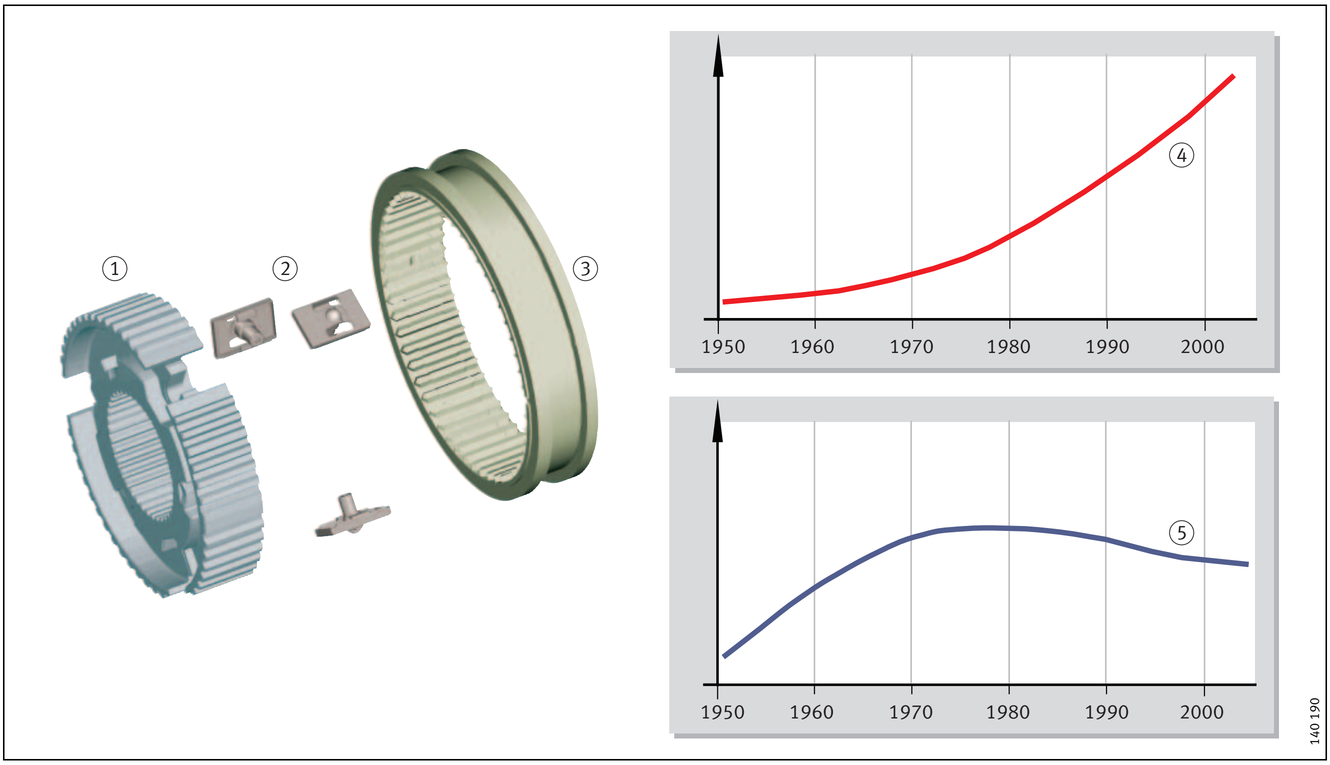


Figure 9 · Design and development of engine torque ④ and design envelope ⑤

Components

Selector hub

The selector hub (*Figure 10* ②) is rigidly linked to the transmission shaft (*Figure 10* ①) and transmits the torque and speed from the transmission shaft to the selector sleeve (*Figure 10* ③). By means of geometrical locking, the selector hub indexes the struts or ARRES (*Figure 10* ④) as well as the synchro outer rings. Depending on the design, the synchro inner rings may also be indexed. The external teeth (*Figure 10* ⑤) in the selector hub allow axial displacement of the selector sleeve and the selector hub in relation to each other.

Selector hubs are normally produced by sintering or by costly machining of forged blanks. In INA selector hub assemblies, this component is designed on the basis of customer requirements. For highly loaded selector hubs, manufacture by means of INA advanced technology is particularly suitable.

Selector hub

The selector sleeve (*Figure 10* ③) transmits the torque and speed from the selector hub via the constant mesh gear to the engaged gear, the axial gearshift force to the struts and influences the blocking function. This highly loaded component was previously produced by costly machining. The special characteristic of the INA selector sleeve is its manufacture by forming technology, without the generation of swarf.

As a result, INA selector sleeves have the following advantages:

- 100% quality and functional monitoring online
- wide range of designs and variants
- optimised material utilisation
- small dimensional fluctuations
- optimised manufacturing costs.
- high component quality (surface quality and tolerances)
- reduced wear during running-in

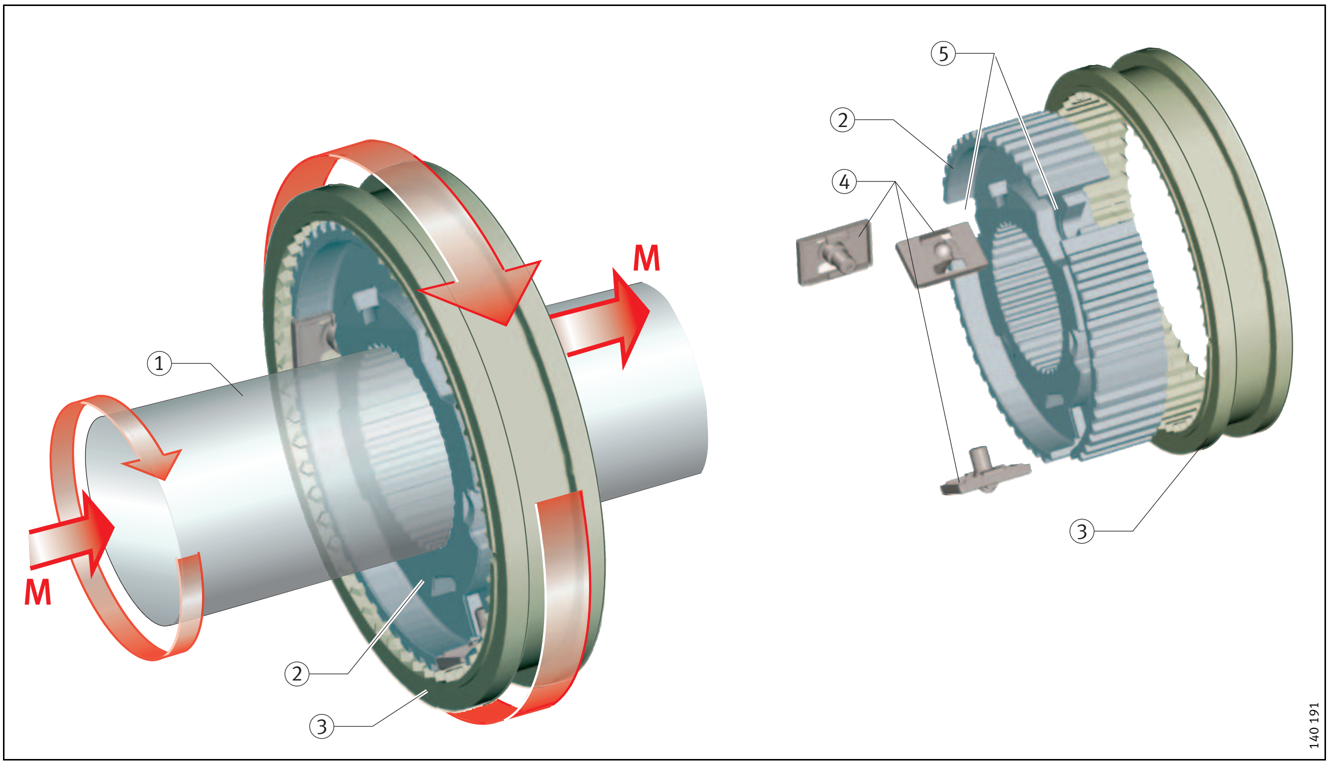


Figure 10 · Selector hub and selector sleeve

Struts – *Figure 11*

For presynchronisation (see page 7), axially movable struts are used. The struts are arranged on the circumference of the selector hub and are preloaded against a slot in the selector sleeve teeth by springs.

Conventional struts for presynchronisation comprise at least two individual parts – a spring and a contact head.

Handling for assembly presents problems since the individual parts must be fitted under spring loading.

In addition, there are considerable logistical requirements since different individual parts from different suppliers must be conveyed together to the assembly station for selector hub assemblies.

Some designs require – in addition to the slots – deep holes in the selector hub for location of the springs. This reduces the strength of the selector hub and increases the production work involved and the manufacturing costs.

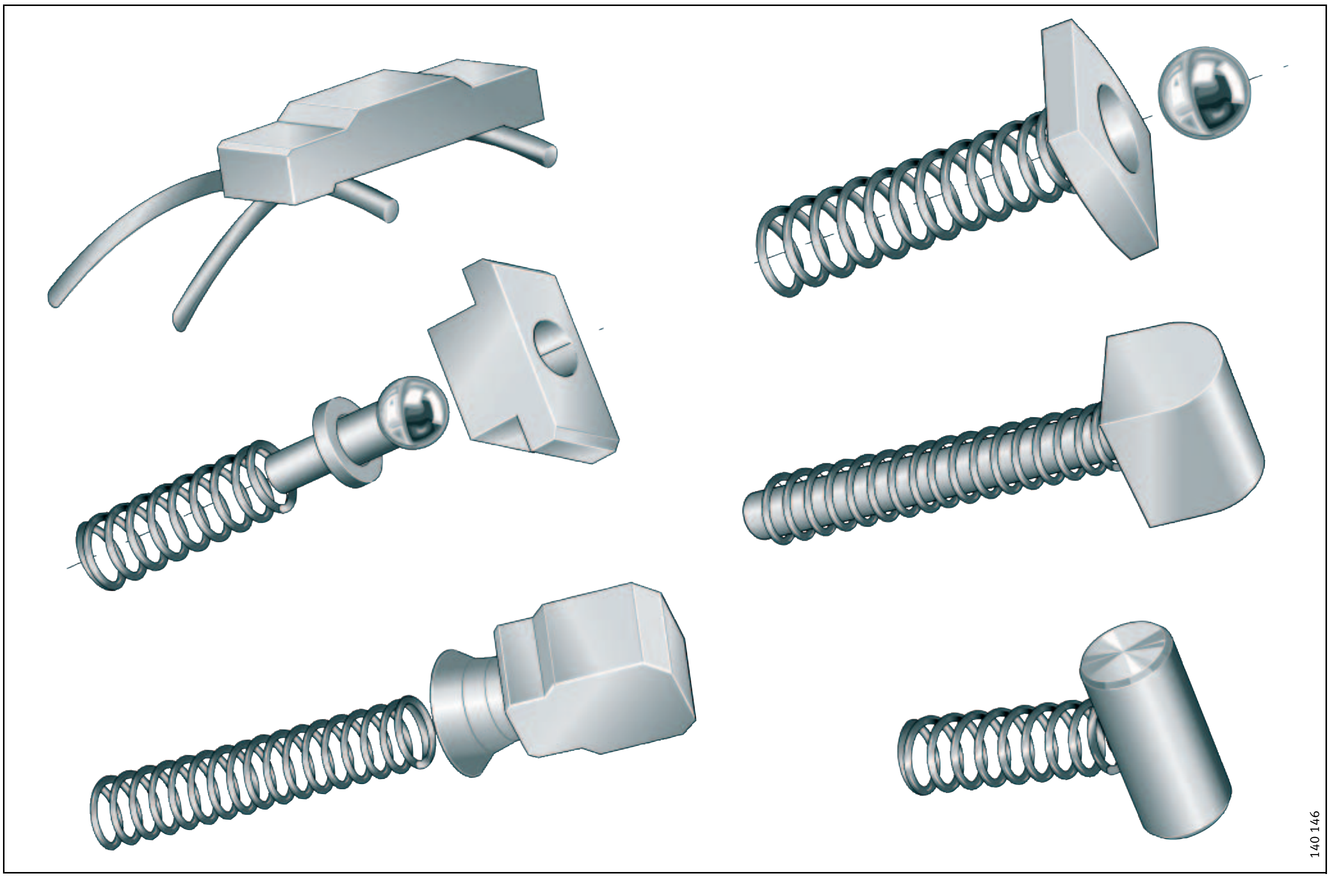


Figure 11 · Conventional struts

INA detents ARRES – *Figure 12*

For presynchronisation in INA selector hub assemblies, the disadvantages of conventional struts can be avoided by the use of the detents ARRES developed by INA. These offer decisive advantages in terms of function and assembly. The INA detents have improved axial guidance due to the large guidance surfaces 1 and offer reduced risk of tilting.

Due to their single piece design, INA detents can be fitted more easily.

Detents ARRES are specially developed for the specific application. Parameters such as spring force and sliding surface have a decisive influence on gearshift and comfort and are therefore matched to each transmission.

The advantages of ARRES at a glance:

- easier assembly due to single piece design
- a single supplier for the complete component
- assured quality due to 100% process monitoring
- good guidance in the selector hub due to large guidance surfaces
- no holes required in the selector hub
- low wear of the guidance surfaces due to optimised surfaces and materials.

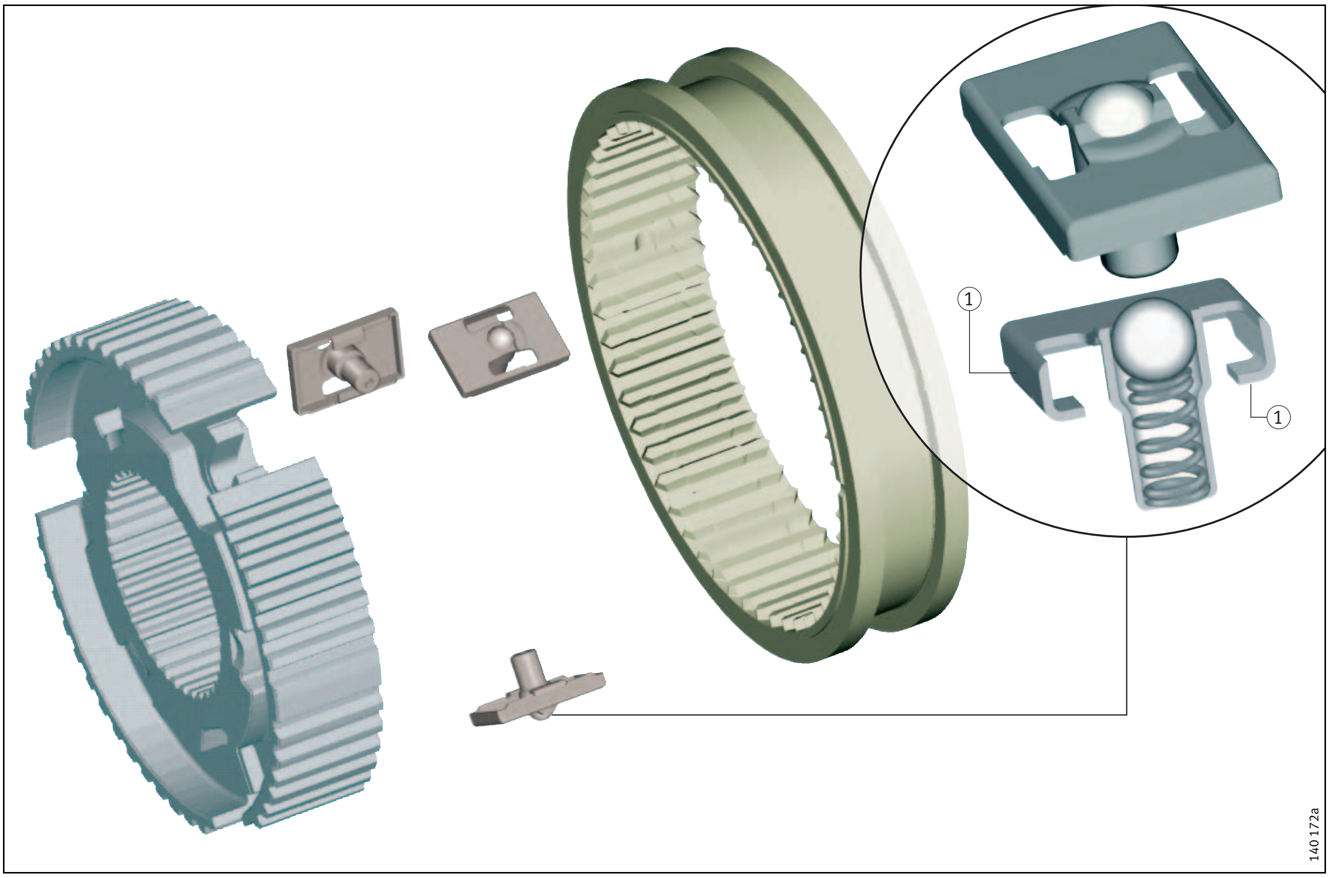


Figure 12 · INA detents – ARRES

Design of the selector sleeve – *Figure 13*

Roof and lead angle

The roof angle ① is matched to the teeth of the synchro outer ring. The lead angle ② describes the inclination of the roof apex, ensures easier meshing of the clutching teeth and thus assists in achieving gearshift comfort.

Recess

The recess ③ prevents, for example, the clutching teeth on the selector sleeve separating from the constant mesh gear in the engaged condition.

Locking slot (securing ramp)

The detents engage in the locking slot of the securing ramp ④ of the selector sleeve. The ramp profiles on both sides ensure that, when the selector sleeve is displaced, the struts are moved, pressed axially against the synchro outer ring and thus activate presynchronisation.

The profile of the locking slot also influences gearshift comfort.

Gearshift fork slot and thrust washers

The gearshift fork locates in the gearshift fork slot ⑤. It presses against the thrust washers ⑥ and displaces the selector sleeve in an axial direction during gearshift.

End stop

The end stop ⑦ restricts the axial displacement distance of the selector sleeve since the clutching teeth of the gear cone body is precisely defined in position.

Clinch

The clinch ⑧ is a special feature of the INA selector sleeve and can be attributed to the manufacturing process. The resulting gap in the teeth can be used as an assembly aid when building the transmission.

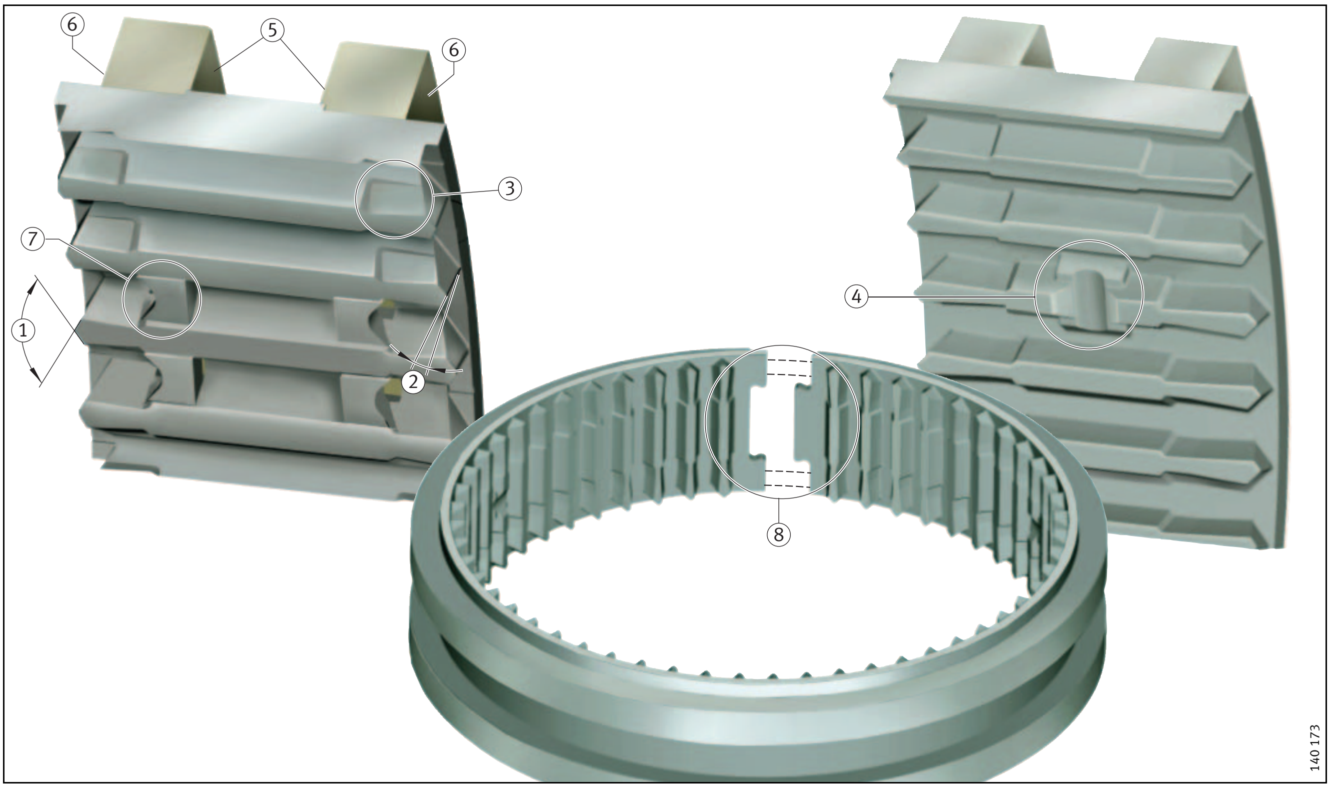


Figure 13 · Design of the selector sleeve

Software

The development of an INA selector hub assembly is carried out using the most up-to-date design and calculation software.

Design software – *Figure 14*

INA selector hub assemblies are modelled in three dimensions. The data can therefore be compared at any time with the adjacent construction. In addition to design envelope analysis, this tool can also be used to carry out tolerance studies.

Design using BEARINX® – *Figure 15*

BEARINX® is the tool for designing all synchronizers within the transmission.

Calculation is carried out on the basis of:

- transmission structure and power flow
- geometry of the shaft systems
- gearshift force curve
- slippage time
- torque losses.

From these data, BEARINX® calculates:

- the mass moments of inertia
- the speed differences
- the ring geometries
- the friction linings
- the blocking teeth
- the clutching teeth.

The program can achieve automated calculation of variants and carries out optimisation calculations.

Calculation

FEM calculation software – *Figure 16*

For calculation of the stresses occurring in all the components of a selector hub assembly or a gear stage, a special three-dimensional calculation software is used. This makes it possible, as early as the development stage, to ensure that INA selector hub assemblies fulfil the customer requirements for component strength and torque transmission.

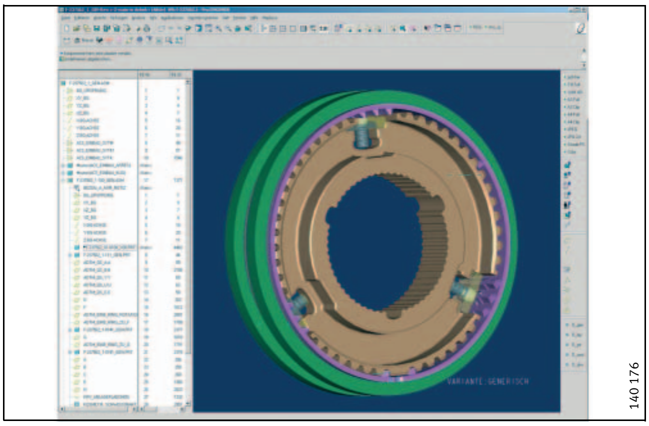


Figure 14 · 3D model

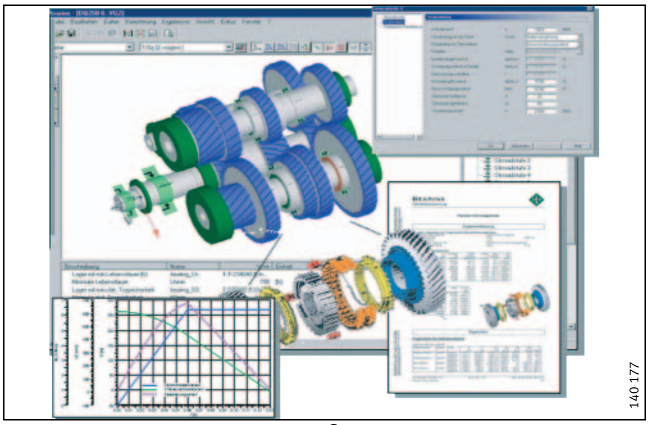


Figure 15 · Design using BEARINX®

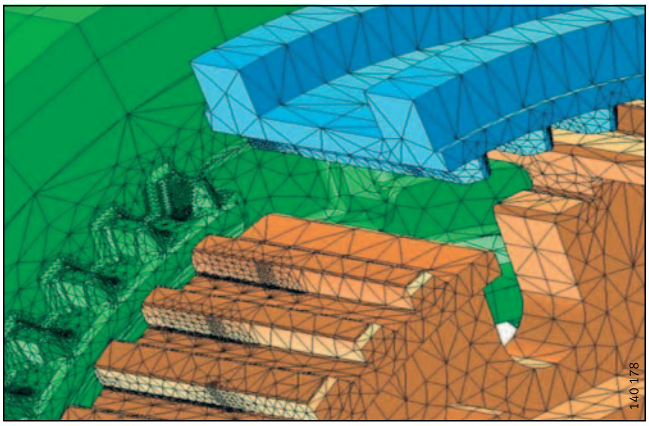


Figure 16 · FEM analysis: excerpt

Blocking torque on the blocking teeth – *Figure 17*

For reliable speed matching, the blocking torque M_s must be sufficiently high – approximate calculation of the blocking torque according to the formula.

$$M_s = F_a \cdot d_s \cdot \frac{1}{2} \frac{\left(\cos\frac{\beta}{2} - \mu_s \cdot \sin\frac{\beta}{2}\right)}{\left(\sin\frac{\beta}{2} + \mu_s \cdot \cos\frac{\beta}{2}\right)}$$

$$F_a = F_a' + F_a''$$

M_s Nmm
Blocking torque

d_s mm
Mean effective diameter of the blocking teeth

β °
Angle of dog tooth incline on blocking teeth

μ_s –
Static friction value at dog tooth incline

F_a N
Axially acting gearshift force.

Synchronisation – matching of speeds

In order that the different speeds of the gear to be engaged and the gearshift element located on the shaft can be matched to each other, the frictional torque M_k must:

- be sufficiently high on the cone partners (formula)
- always act against the blocking torque M_s during synchronisation (formula).

$$\frac{M_k}{M_s} \geqq 1$$

If $M_s > M_k$, the selector sleeve can be throughshifted without matching the speeds of the gear and the synchronisation device to each other.

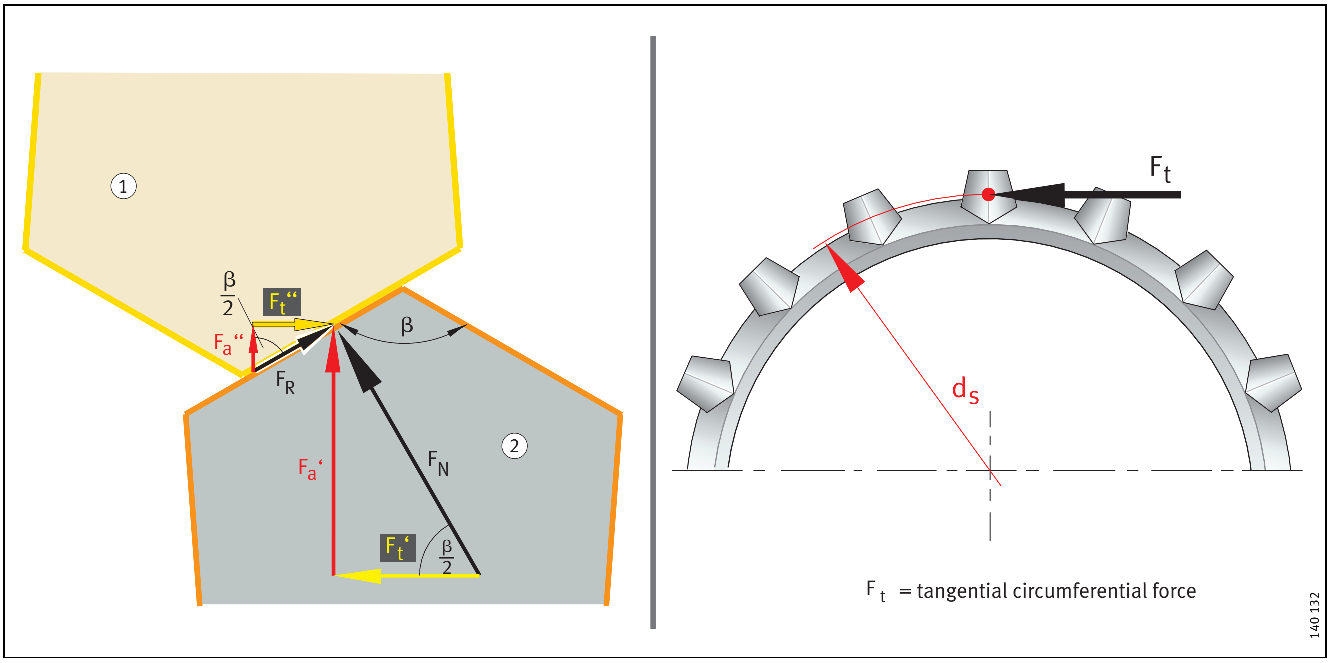


Figure 17 · Blocking forces on the blocking teeth

Simulation – *Figure 18*

The tilting clearance describes the clearance between the selector sleeve and the selector hub as a function of displacement of the selector sleeve and influences the gearshift comfort of the transmission.

A precisely matched tilting clearance is a precondition for smooth and uniform displacement of the selector sleeve.

In the development phase, tilting clearances can simulated for INA selector hub assemblies in order to examine the appropriate customer requirements. After analysis of geometries and forces, optimum tooth sizes can be simulated at an early development stage using a tool for kinematic simulation.

The software used applies the possibility of controlling movements of parts within a subassembly by changing defined parameters.

For visualisation, the simulation parameter KIPPSPIEL as a function of the simulation parameter TRANS (= axial position of the selector sleeve) is applied to a diagram. It is thus possible, for example, to check changes to the tooth geometry of the gearshift sleeve and their effects on the tilting clearance by means of variant comparison.

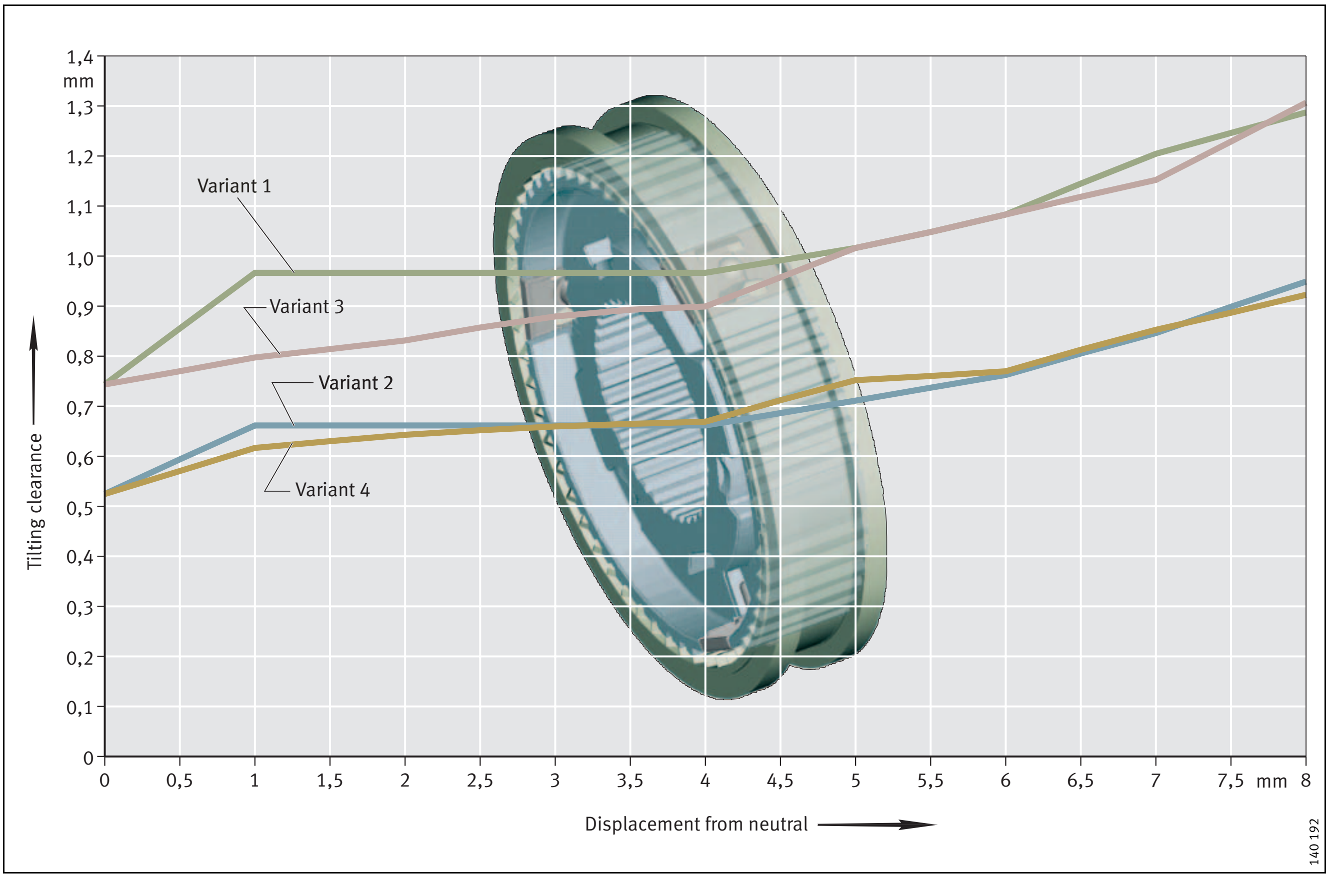


Figure 18 · Tilting clearance simulation

3D tolerance analysis – *Figure 19*

The analytical tool makes it possible to investigate how different tolerances on the individual components of a synchronisation unit affect the functional capability of the system.
The components can therefore be designed optimally in relation to the tolerances and functional capability of the system. Considerable savings can thus be achieved in development and prototype costs.

In the different synchronisation stages (neutral, presynchronisation, main synchronisation, engaged), meaurements relevant to the specific function are made. The program determines the tolerance chain and analyses the influence of tolerance on a defined closing dimension (measurement).

The results given by the analysis are the arithmetic extreme values (worst case), the standard deviation of the tolerance chain, the sensitivity of the dimensions examined and the influence of the dimensions examined on the total deviation. On the basis of the results, the arithmetic and statistical deviations are determined and compiled in a results list.

With modern process data recording, measurement values can be fed directly into tolerance analysis, allowing the effects on the complete system to be investigated.

In the example, a complete synchronisation unit was investigated in relation to the effects of individual part tolerances on the complete system.

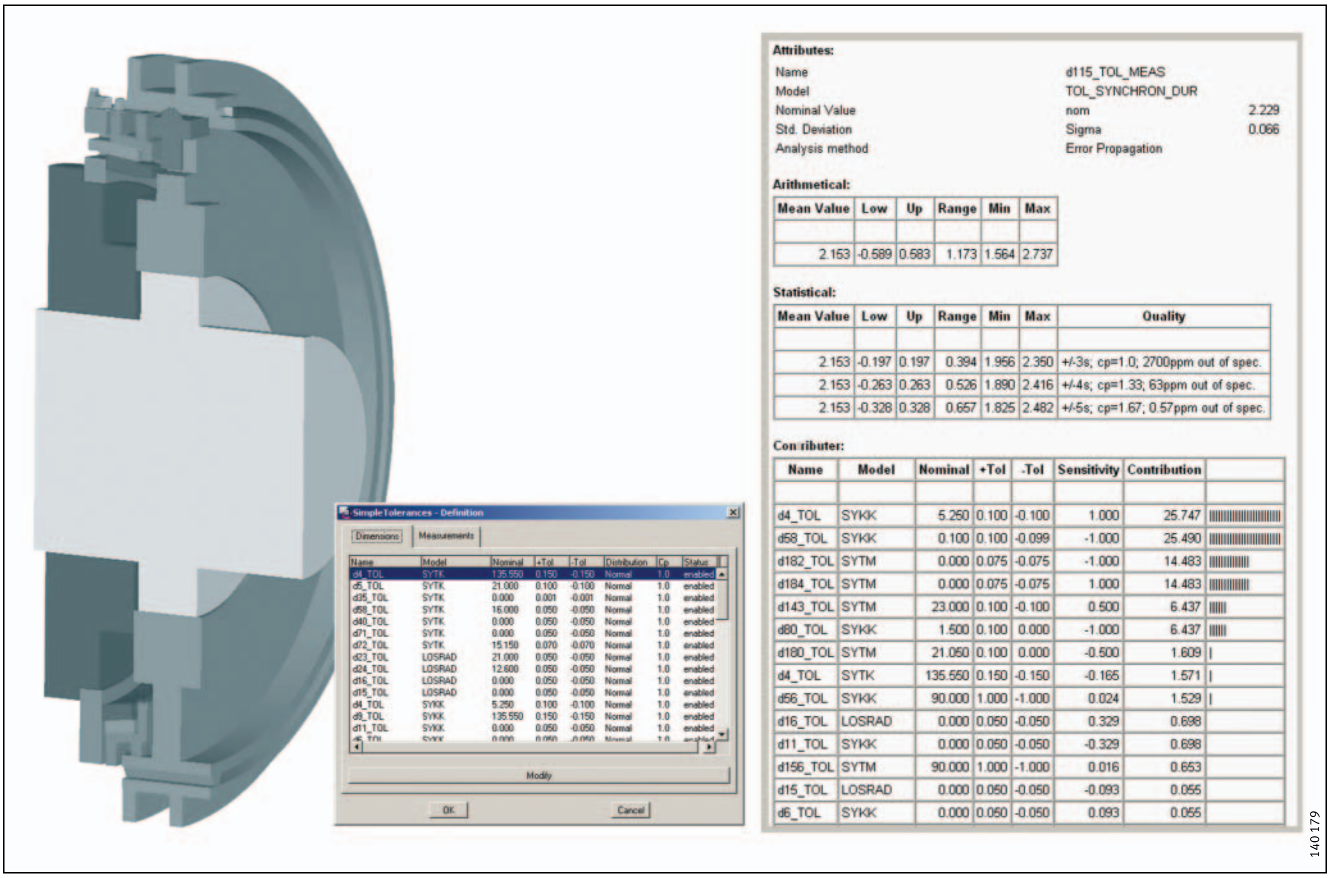


Figure 19 · Tolerance analysis

Test methods

Versatile test devices are available for the development of INA selector hub assemblies.

In addition to facts such as fatigue strength and operating life that can be discretely tested, characteristics such as gearshift comfort can also be investigated.

One impressive example is gearshift force simulation: as early as the development and design process, components and geometries can be optimised in relation to low gearshift force and high gearshift comfort.

Test rigs (selection)

Operating life and function cycle – *Figure 20*

In testing of operating life and function, the transmissions or components are tested under operating conditions. The drive and load are simulated by two motors. Speeds, torque, oil flow, oil temperature or any vibrations occurring are measured.

Transmission test with vehicle simulation – *Figure 21*

In these transmission tests, various vehicle can be simulated. In this way, testing can be carried out on front or rear wheel drive, different transmission systems (by means of a gearshift robot) and various loads and speeds.

Fatigue strength test rig – *Figure 22*

On the fatigue strength test rig, component strength is tested by means of defined force applications.

Figure 20 · Operating life and function test

Figure 21 · Transmission test with vehicle simulation

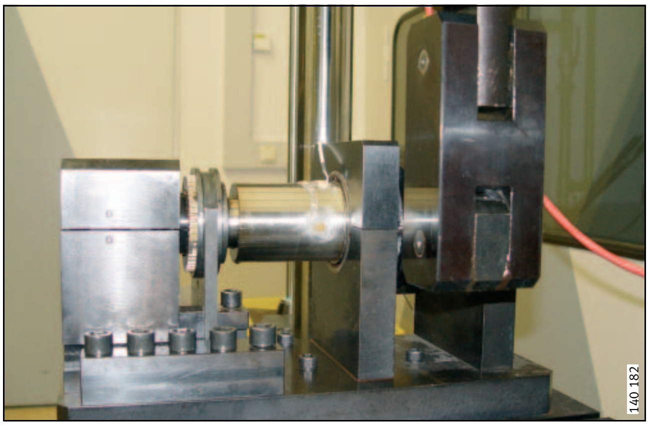


Figure 22 · Fatigue strength test rig

INA selector hub assembly

Test rigs
Quality and functional monitoring

Gearshift robot and data collection – *Figure 23*

Once INA components have successfully completed the rig tests, they are investigated in vehicle tests, for example in relation to gearshift force or gearshift characteristics. Fleet tests can be carried out without specially trained personnel by means of a gearshift robot. Long term monitoring is ensured by means of fully automated data collection.

Gearshift force simulation – *Figure 24*

The basis of gearshift force simulation is a tool that, directly in the 3D development software, simulates the effect of geometrical changes on the gearshift force. This eliminates the need for several development loops and, following adjustment of the components, allows direct checking of the effect on the gearshift force.

Gearshift force measurement – *Figure 25*

Despite the versatile simulation tools available, the INA components produced are tested in relation to gearshift force and gearshift comfort. On the test rig, the forces (rotary and longitudinal forces) required to select the relevant gears are measured. Comparisons can thus be made between simulated and measured gearshift forces.

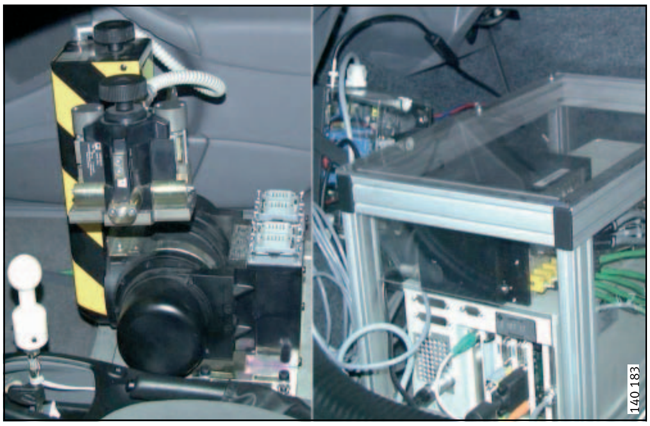


Figure 23 · Gearshift robot and data collection in vehicle test

Figure 24 · Gearshift force simulation

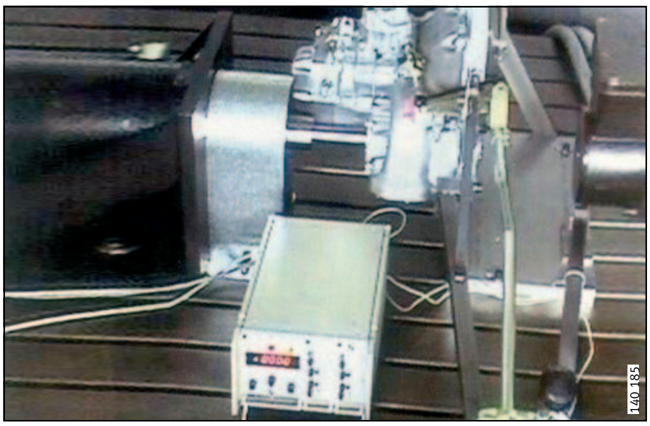


Figure 25 · Gearshift force measurement

Quality and functional monitoring – *Figure 26*

Online monitoring

The manufacturing equipment developed in-house for the production of INA selector sleeves has monitoring devices for all significant manufacturing and functional parameters.
As a result, irregularities ranging from the condition of the raw material to the finished part products are detected immediately and control can be exterted on the influencing factors in the subsequent manufacturing process until clarification is achieved. Production of reject parts is this reduced to a munimum.

Before selector sleeves and selector hubs are fed to the automatic assembly machine, their dimensional and gauge compliance is checked 100% in an integrated inspection process.

Force and travel monitoring is carried out alongside the joining and assembly processes. In the automatic assembly process, important functionalities such as displacement force are subjected to 100% inspection. Checking of the tilting clearance and torsional flank clearance can also be carried out.
Product characteristics of the selector hub assemblies that cannot be measured on the individual components can thus be ensured in the assembled product.

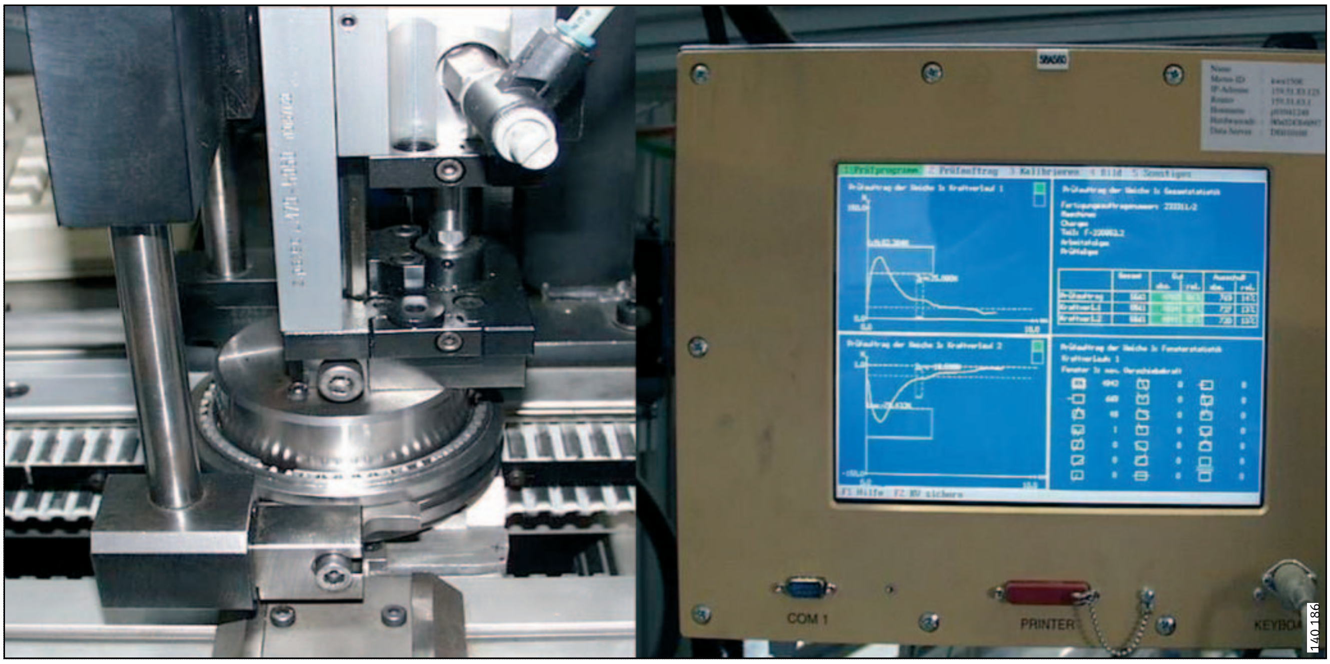


Figure 26 · Displacement force measurement of the selector sleeve on the selector hub

Range of variants – *Figure 27*

On the basis of INA design and manufacturing technology, it is possible to fulfil all normal requirements in passenger vehicle manual transmissions and automated manual transmissions in relation to design, dimensions and torque transmission levels.

It is also possible, for example to produce certain special tooth forms such as asymmetrical roof angles without additional outlay.

The range of variants is a major advantage of INA selector sleeves. In addition to the current volume design ①, the essential selector sleeve element can be used to produce a wide variety of gearshift fork guidance systems such as rolled or drawn profiled rings. Selector sleeves with outer rims ② and ③ are required for high torque levels. Selector sleeves with deep drawn gearshift fork guides ④ to ⑥ can also be produced.

In addition to the end stops that can be integrated at any position in the tooth system, stamped recesses can be realised between the teeth ④ that can act, for example, as an end stop for the gear cone body.

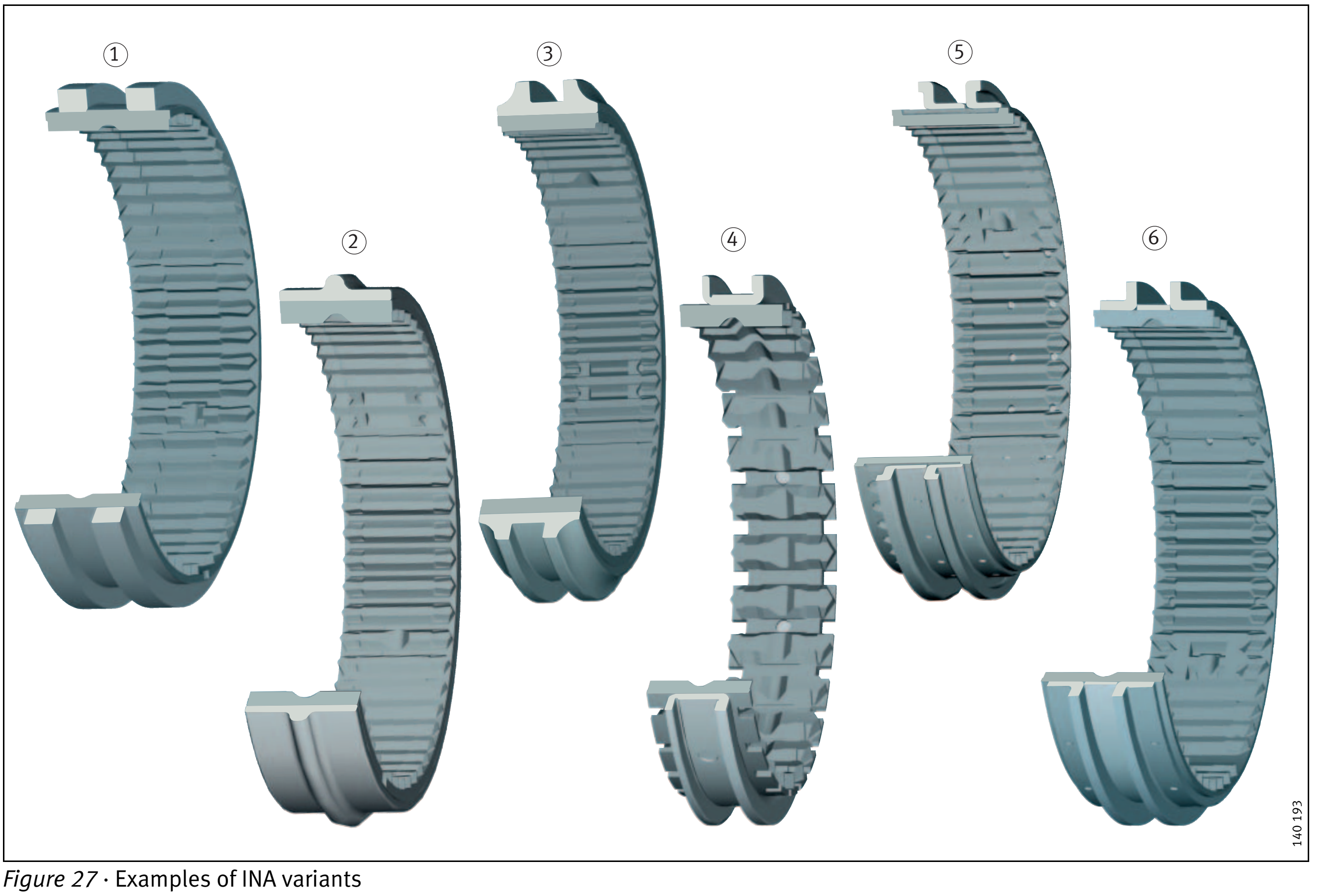


Figure 27 · Examples of INA variants

Component quality

Material utilisation

INA manufacturing technology is designed for high volume production. Attention has therefore been paid to achieving optimum material utilisation. The result is material utilisation approaching 100%.

Due to INA manufacturing methods, “leaner” designs are possible; depending on the design, component mass can be also be reduced.

Surface quality – *Figure 28*

INA technology for shaping without swarf generation allows very high component surface quality (*Figure 28*). The formation of grooves by tools, such as is found in processes involving swarf generation, does not occur in the INA technology. A smooth surface is produced that has proven beneficial especially in the frictionally hampered longitudinal movement of the selector sleeve during the gearshift process.

Heat treatment

INA selector sleeves manufactured by forming methods are made from case hardening steels with high load carrying capacity. Special heat treatment processes are required here and have been specifically developed. These processes allow, for example, highly uniform parts with low dimensional variation.

Stress distribution – *Figure 29*

In swarf-forming manufacturing processes, edges are created as an inevitable consequence of the tool geometry. Edges create a notch effect (*Figure 29* 1, red area) and thus increase the risk of fracture. With the INA manufacturing processes without swarf generation, however, optimum profiles are achieved at these points (*Figure 29* 2). In calculations – using the same dimensions – stress values up to 30% lower were determined.

The defined radii and freedom from burrs on the roof apexes of the clutching teeth in INA selector sleeves have a positive influence on the fracture risk and wear behaviour of the roof angles. Furthermore, gearshift comfort is increased through “smoother” meshing between the clutching teeth of the selector sleeve and gear cone body.

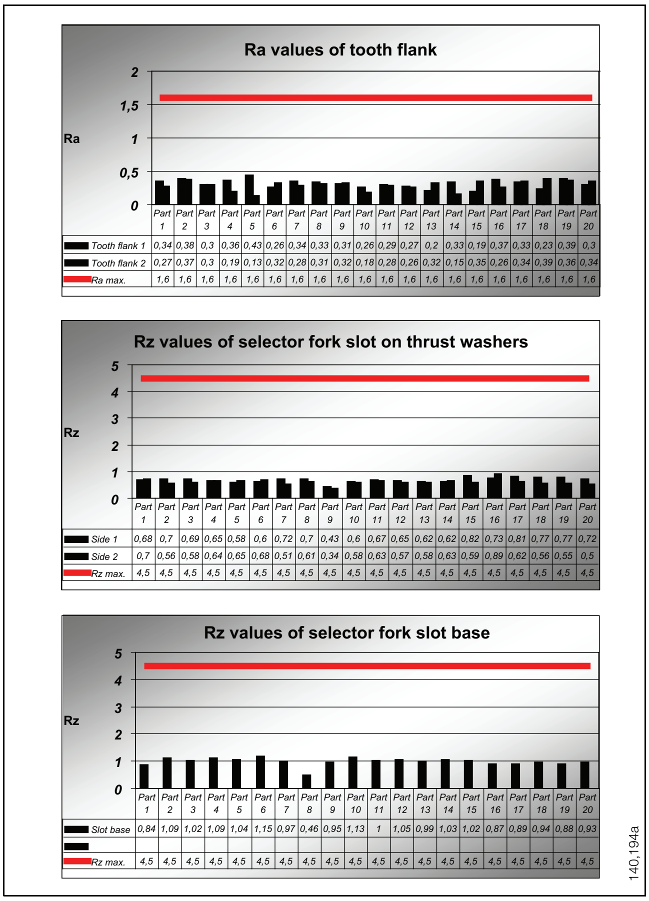


Figure 28 · Roughness measurement on gearshift sleeve manufactured by swarf-free methods (excerpt)

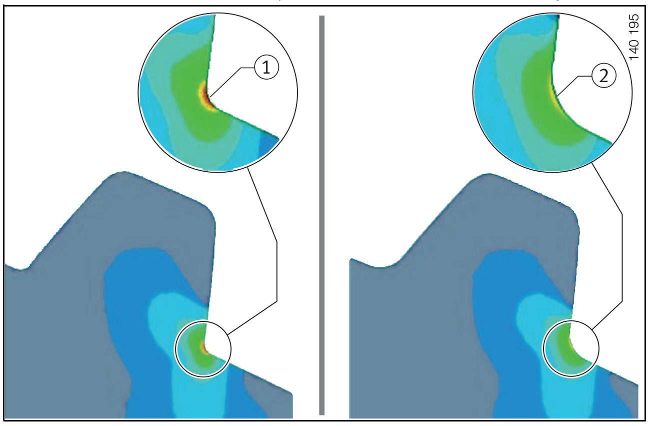


Figure 29 · Stresses due to different tooth root profiles

Tool wear – *Figure 30*

The tooth geometries of transmission elements must be produced to high accuracy. This requirement necessitates high outlay on maintenance and replacement of cutting tools when swarf-forming methods are used for manufacture.

The periodic variations in actual dimensions typical of swarf-forming processes due to tool wear are substantially eliminated in swarf-free manufacture, since quasi-static wear of the forming tools can be assumed if used appropriately. The change in component accuracies in the INA technology ① in comparison with swarf-forming production ② of selector sleeves is shown in *Figure 30*.

With the INA technology, consistent quality even with very high production quantities is ensured. Approx. 1 000 000 selector sleeves can be produced using one forming tool.

Legend to *Figure 30*

① Dimensional range with INA technology
② Dimensional range with swarf-forming production

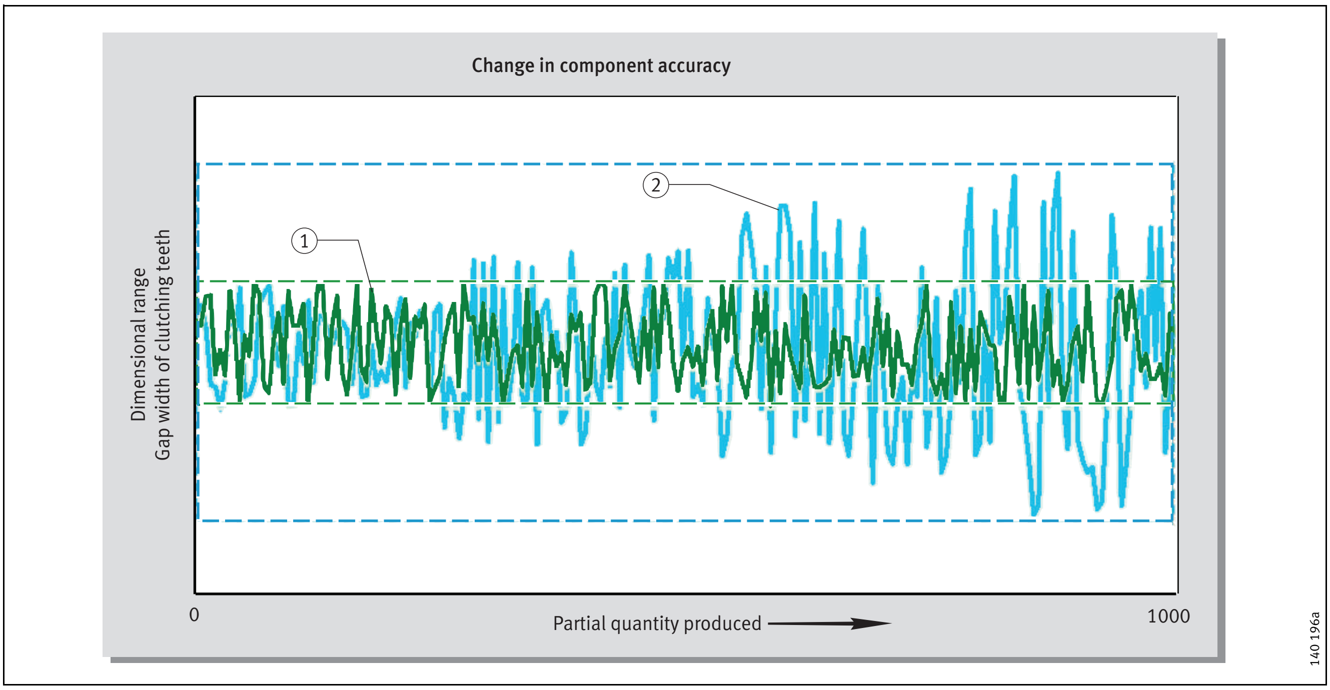


Figure 30 · Change on component accuracy

Gearshift comfort – comparison of technology

A comparison between a selector sleeve produced without swarf formation – using INA technology – and a variant produced by a swarf-forming method is shown in *Figure 31*.

For this comparison, one selector sleeve produced with swarf formation and two selector sleeves produced by swarf-free means were used that had already been shifted 50 000 times, in other words they had been “run-in”.

The selector sleeve produced by the swarf-forming method shows, even after the running-in period, pronounced running-in behaviour and lower efficiency than a swarf-free selector sleeve. This example clearly illustrates the advantages of INA selector sleeves in relation to performance capacity and gearshift comfort.

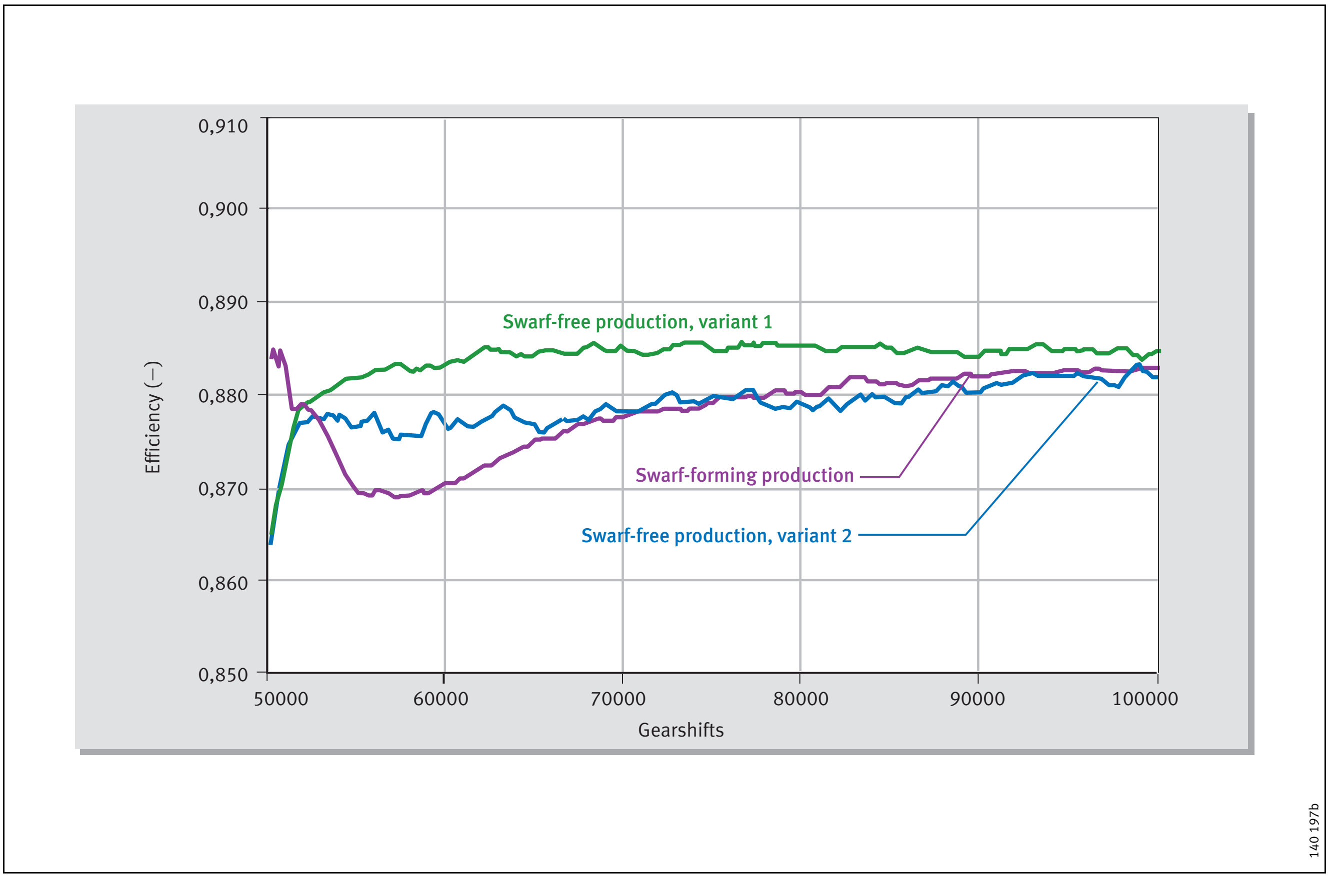


Figure 31 · Comparison of swarf-forming and swarf-free production (excerpt)

Costs – *Figure 32*

In addition to the previously stated advantages such as seamless online quality and functional monitoring, design flexibility, high material utilisation and good component quality as well as low tool wear, the use of INA selector hub assemblies also allows cost savings.

Due to the better material utilisation and longer tool life, it is possible to achieve optimised pricing levels with the INA selector hub assembly.

Furthermore, considerable cost advantages are achieved since there is no need for assembly and inspection work at the customer for the selector hub assembly.

Further cost savings can also be achieved through the reduced outlay on logistics and stockholding since INA operates as a system supplier providing the selector sleeve, presynchronisation and selector hub.

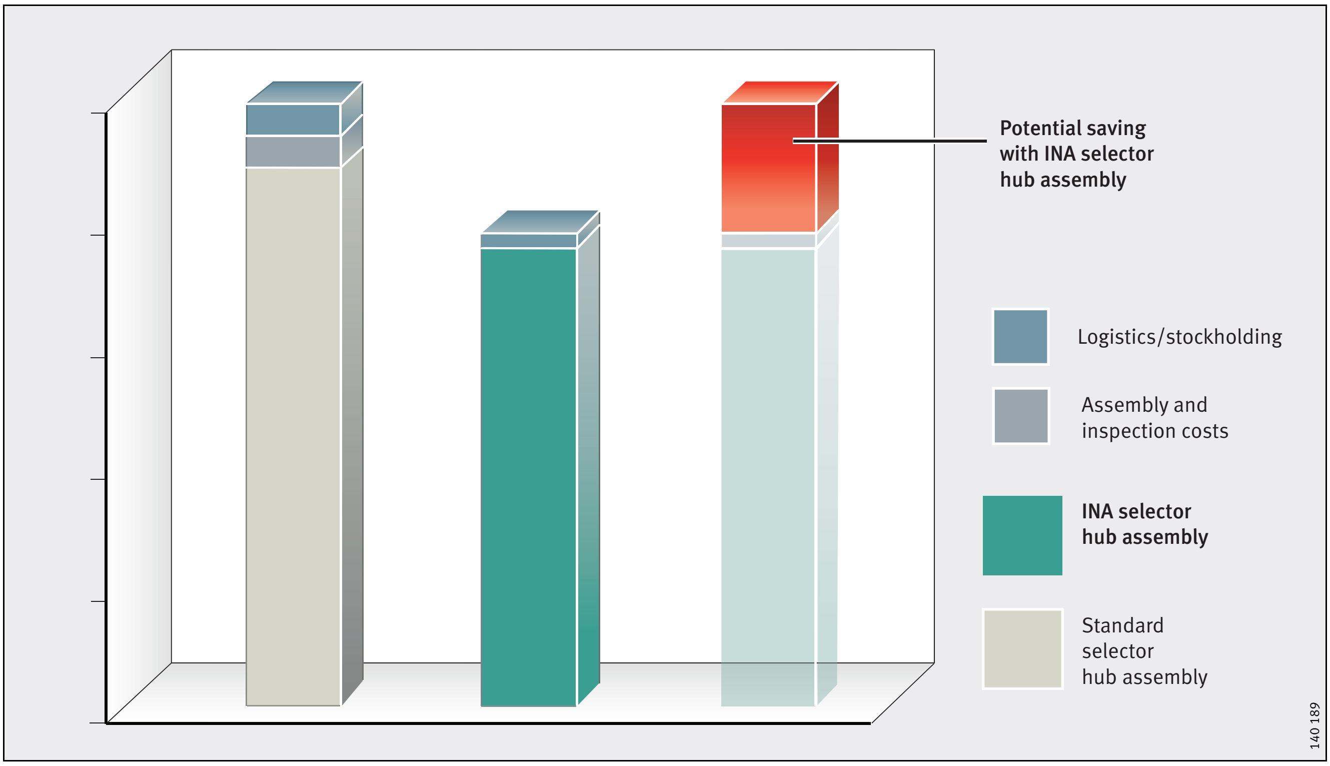


Figure 32 · Cost comparison

Packaging

Standard packaging – *Figure 33*

The standard packaging for INA selector hub assemblies is cardboard cartons holding 16 pieces each. For protection against corrosion, the selector hub assemblies are packed in VCI paper.

Durable packaging – *Figure 34*

Special durable packaging or packaging for automated handling, for example with assembly by robot, is also offered.

Further packaging according to customer requirements is also possible.

Figure 33 · Standard packaging

Figure 34 · Durable packaging

Checklist
Selector hub assembly

Basic information

Device designation: ______________________________

Transmission type: ______________________________

Gear/gear stage: ______________________________

Torque in gear stage: ______________________________

Gearshift force in gear stage: ______________________________

Gearshift time in gear stage: ______________________________

Differential speed in gear stage: ______________________________

Synchronisation type:

- ❑ Single cone synchronizer
- ❑ Double cone synchronisation system
- ❑ Triple synchronisation system
- ❑ Other system: ______________________________

Presynchronisation type

- ❑ Struts with spring
- ❑ Detents “ARRES”
- ❑ Other system: ______________________________

Environmental conditions

Transmission oil: ______________________________

Contamination conditions (standard): ______________________________

Special features: ______________________________

Adjacent construction

Drawings

- ❑ Transmission drawing
- ❑ Presynchronisation
- ❑ Synchro ring(s)
- ❑ Freewheels
- ❑ Selector sleeve
- ❑ Selector hub
- ❑ Gear cone body
- ❑ Selector fork

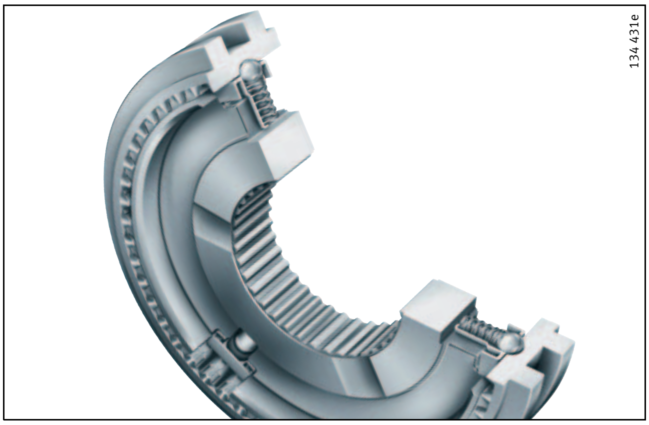
Information (if no appropriate drawing available)

Insertion depth in freewheel: ______________________________

Material of selector fork shoe: ______________________________

Connection of gear cone body to freewheel: ______________________________

Design envelope of selector hub assembly: ______________________________



Selector hub assembly

Component information (where not apparent from attached drawings)

	Selector sleeve	Selector hub
Material:	________	________
Hardness:	________	________
Surface treatment:	________	________

Selector teeth

Number of teeth:	________________	
Modulus:	________________	
Pitch circle diameter:	________________	
Mesh angle:	________________	
Profile displacement:	________	________
Tip diameter:	________	________
Root diameter:	________	________
Back angle:	________	
Roof angle:	________	
Roof pitch:	________	
Ramp angle:	________	

Selector fork slot dimensions

Diameter: ________

Width: ________

Other requirements

Planned wear distance: ________

Inspection and test conditions

Which tests are planned – specifications ________________

____

____

Assembly/packaging

Assembly at customer

❑ Manual ❑ By robot

❑ Special packaging required: ________________

____

____

MATNR 023203307-0000/TPI 125 GB-D 0806.5 · Printed in Germany

Schaeffler KG

Industriestrasse 1–3
91074 Herzogenaurach (Germany)
Internet www.ina.com
E-Mail Info@de.ina.com

In Germany:
Phone 0180 5003872
Fax 0180 5003873

From Other Countries:
Phone +49 9132 82-0
Fax +49 9132 82-4950

TPI 125 GB-D