

# Introduction to Shifting Solution - Synchronizer

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## ABSTRACT

The Synchronizer is a part of synchromesh manual transmission that allows the smooth engagement of the gears. Synchronizer is a kind of clutch that allows the component turning at different speeds to synchronize their speeds using cone friction. The main function of the Synchronizer is synchronizing the speeds of the components and preventing the engagement of the gears until synchronization is achieved.

**KEYWORDS:** Synchronization, Synchomesh manual transmission, cone friction

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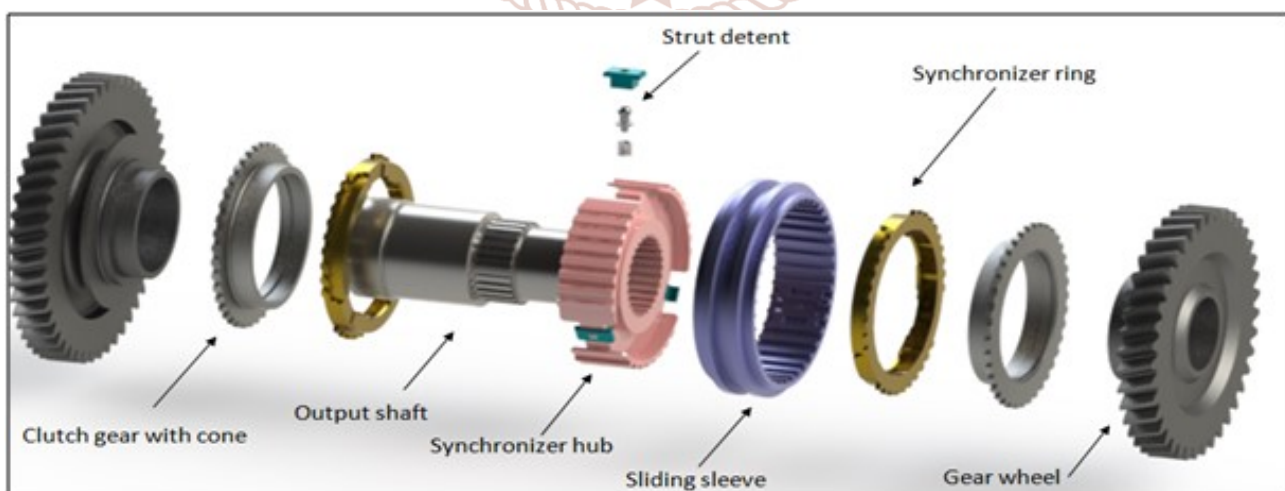


## Synchronizer:

Synchronizer is the central component of the transmission featuring the interface to the output, the clutch and by of the gear shift, to the driver. Synchronizers are the key elements in the manual transmissions (MT) and Automated Manual Transmissions (AMT).

Synchronizer can be structured by the number of cones used like single cone, dual cone and triple cone. The Synchronization always follows the same sequences of

operations. The Sleeve is moved by the shift fork towards the gears to be engaged. As long as there is speed difference between the sleeve – hub system and the gear wheel, the sleeve is blocked by the Blocker ring (Sincro Ring) and thus the synchronizer creates the friction torque. When the speeds are Synchronized, the sleeve can be moved further and engages into the Spline if the engagement ring at the gear wheel.

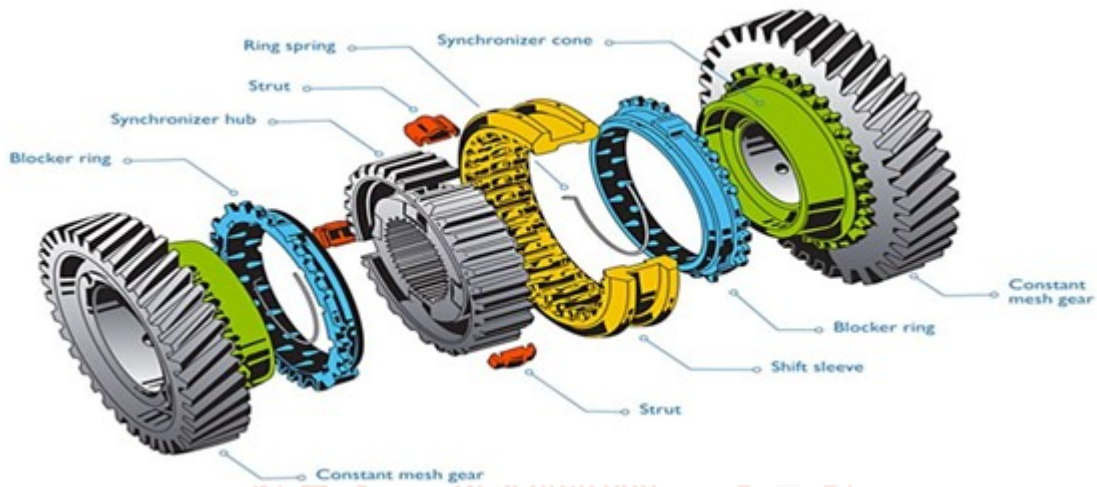


Exploded view of Single Cone Synchronizer



**Cross-Sectional view of Single Cone Synchronizer**

**Introduction to Synchronizer Parts:**



1. **Synchronizer Hub:** Synchronizer Hub is rigidly connected by Spline to the either rotating input shaft or the rotating output shaft. Synchronizer Hub usually has both Internal and External Spline.
2. **Synchronizer Ring or Blocker Ring:** Blocker Ring has a conical surface that is guided on the conical surface of the Clutch Body Ring (CBR). The purpose to have this conical surface is to produce the friction torque that is needed to synchronize the input and output shafts rpm. The external teeth interlocks with internal teeth of the Sliding Sleeve. The Blocker ring are provided with the thread or groove patters to maintain the lubrication on surface, to avoid the hydrodynamic oil film and to minimize the forces. Following are types of Blocker rings.
  - A. Brass Synchro Ring
  - B. Bronze Synchro Ring
  - C. Sintered Bronze Synchro Ring
  - D. Molybdenum – Low Synchro Ring
  - E. Molybdenum – High Synchro Ring
  - F. Thread Bronze Synchro Ring
  - G. Carbon Synchro Ring
  - H. Woven Carbon Fiber Synchro Ring



(A)



(D)



(F)



(H)



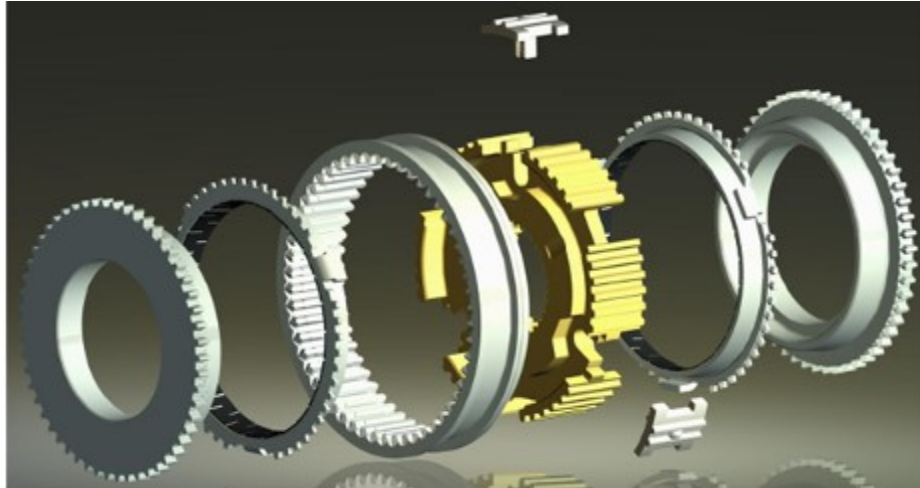
(G)

3. **Clutch Body Ring:** CBR is external teeth and conical surface on which the Blocker Ring guides. The CBR matches the speed of the gear with the speed of the Synchro Hub during synchronization. The CBR is either spline fitted or press fitted or welded with the gear wheel. The external teeth with the chamfer on both the sides of the teeth interlocks with the chamfer on the internal teeth of shift sleeve

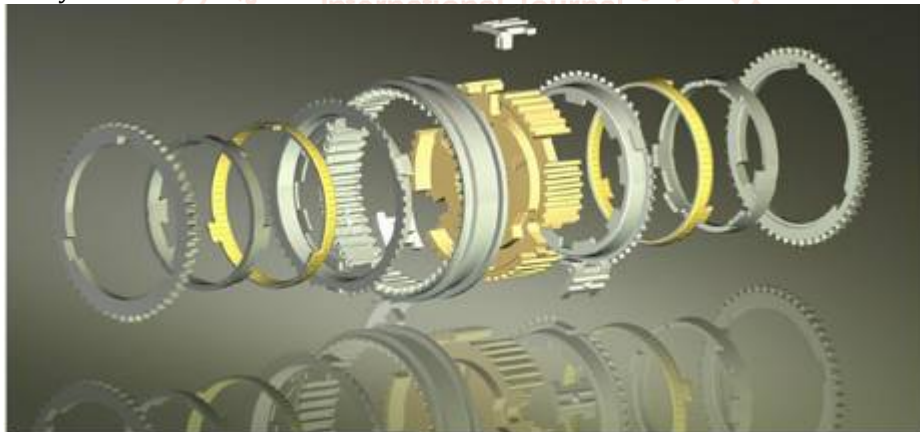
- 4. **Sliding Sleeve:** Sliding Sleeve has a groove on the outer periphery for the gear shift fork. The Internal Spline of the Sliding Sleeve is in constant mesh with the External Spline of the Synchro Hub. Thus, Sliding Sleeve can only axially move from neutral position to an engaged position.
- 5. **Strut Detent / Centering Mechanism / Struct Key:** The Strut Key is a spring loaded ball or roller fixed in a cage. This mechanism is arranged on the circumference of the synchronizer body, positioned between the groove in synchro hub and the inner groove in shift sleeve. This component is used for the pre-synchronization; that generates the load on the synchro ring to perform the synchronization process. In addition, maintains the sliding sleeve in the central position on the hub between both gear wheel and below a limit axial force. The Synchronizers are composed by three element of Strut Key arranged at 120°. In case of larger synchronizer, four elements of strut key could be arranged at 90°.

**Kinds of Synchronizers:**

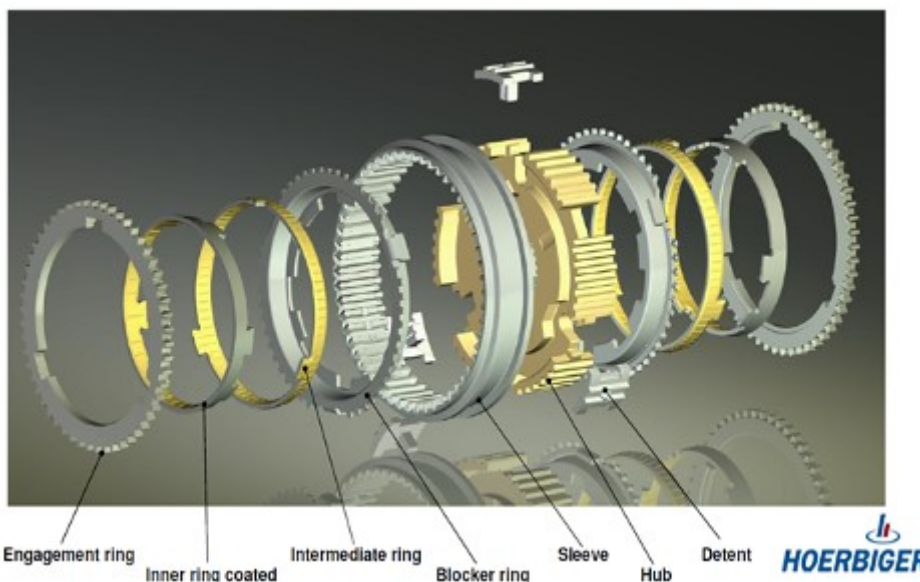
- 1. Single Cone Synchronizer



- 2. Dual / Double Cone Synchronizer

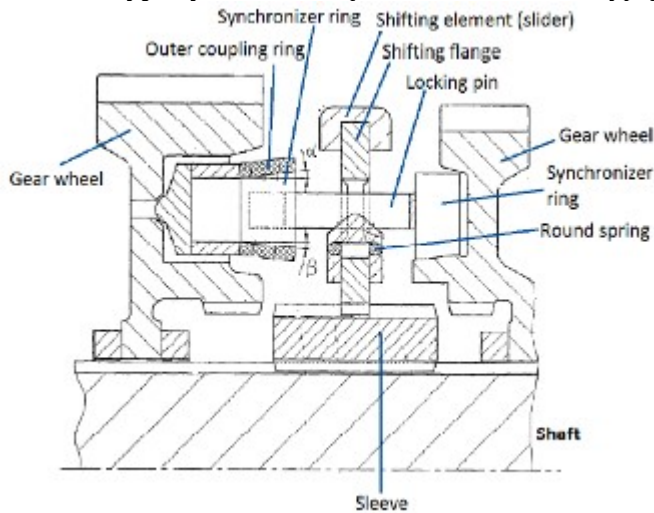


- 3. Triple Cone Synchronizer

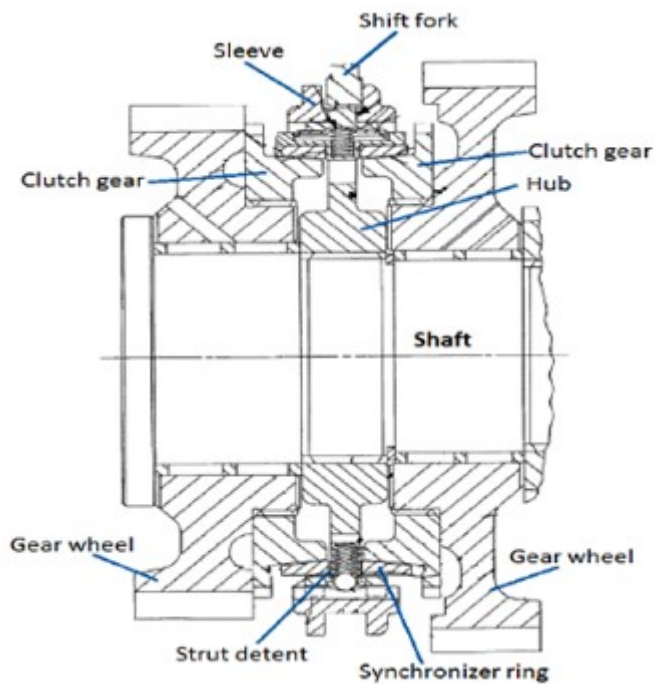


**Types of Synchronizers:**

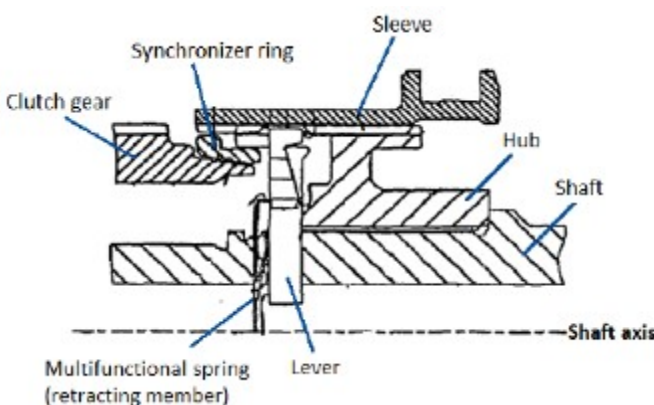
**1. Pin - Type Synchronizer (Also Known as Clark Type).**



**2. Baulkring -Type:** This type of Synchronizer is used in manual transmission are either of the strut or the strutless types.



**3. Lever - Type:** The lever type Synchronizer is provided with the inner circumference of the Sleeve and arranged between the hub and synchronizing ring. As the sleeve is sliding towards the engaging position the lever presses the synchronizer ring towards the gear by the principle of leverage.



**Synchronizer Dimension and Significant Parameter:**

Figure shows the main dimension of the Synchronizer. The wear on the friction surfaces is usually due to the factor that determines the service life of the synchronizer. The shift movement "s" at the gearshift sleeve is approx. 10-13mm. The permissible wear  $\Delta S_{perm}$  is generally between 1- 1.5mm. The wear reserve of the synchronizer unit is calculated by subtracting the operating clearance from the permissible wear. The maximum  $\Delta V_{max}$  is of the order 0.15mm for taper synchronizers.

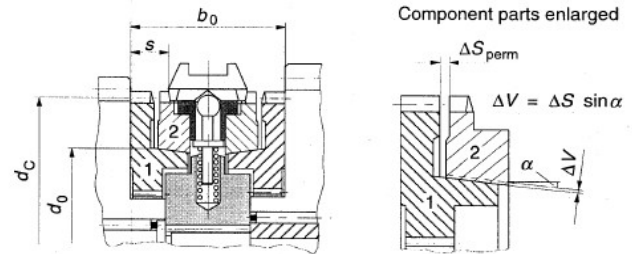
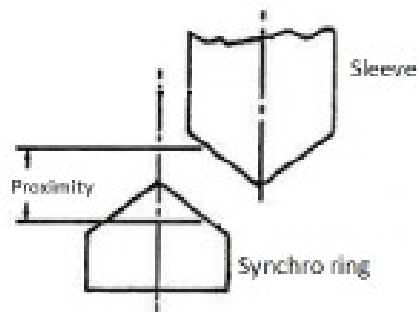


Figure 9.11. Dimensions.  $b_0$  Overall pack length;  $d_0$  Nominal diameter;  $d_c$  Clutch diameter;  $\Delta S$  Wear path;  $\Delta S_{perm}$  Permissible wear path incl. clearance;  $s$  Shift stroke at the gearshift sleeve;  $\Delta V$  Wear at the synchroniser ring;  $\alpha$  Taper angle

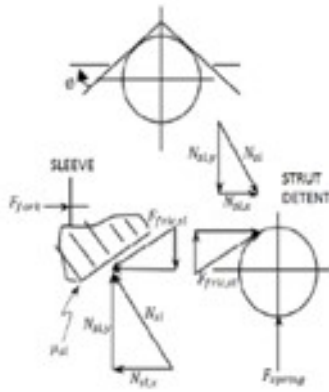
**1. Shift Effort:** Shift effort is also called as Operating Force. This is the load the driver has to apply at the shift lever and is the result of a summation of the static shift effort, due to the ramp profile, and the dynamic shift effort, due to the synchronization action.

**2. Proximity:** Axial distance from the sleeve tooth pointing to the synchronization ring tooth pointing contact.

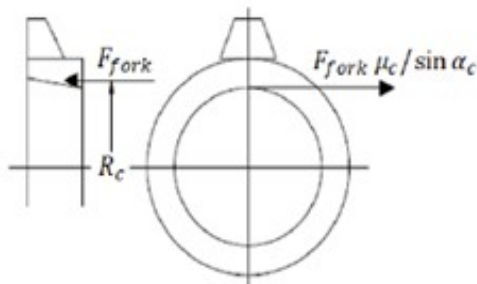


**3. Break through Load (BTL):** BTL is also known as Push through Load which is produced by the force applied by the ball of the strut - detent mechanism to the sleeve in order to traverse the proximity distance. It should start to build as soon as the sleeve moves from the neutral position due to the contact with the ball and should stay until there is maximum contact area between the teeth chamfers of the sleeve and blocking ring. A reduction of BTL prior to the contact will unload the blocking ring and interrupt the oil wiping action resulting in a lower friction co-efficient and consequently in a Gear Clash. On the contrary, BTL continuing beyond the contact point will cause the ring locking and thereby require a higher effort to gear shifting.

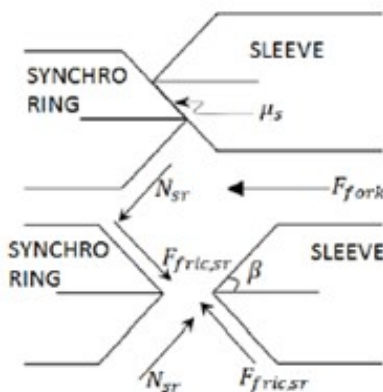
The BTL depends on the detent spring rate, strut bump or ball height, co-efficient of friction between detent ball and sleeve and ramp angle of the annulus groove in the sleeve. The mathematical expression of this parameter can be calculated from figure shown below.



4. **Synchronizer Torque (Ts):** Synchronizer torque is also known as Cone Torque and is due to the friction force generated in the direction of the cone angle between the cone and the friction surfaces when the sleeve moves axially to contact with the blocker ring, which pushes axially the CBR and drains the lubrication out. This force can be assisted (upshift) or resisted (downshift) by the total system drag. The Cone torque should be always higher than the index torque at every point during the synchronization process to prevent the clash or noise and to complete the synchronization process successfully.



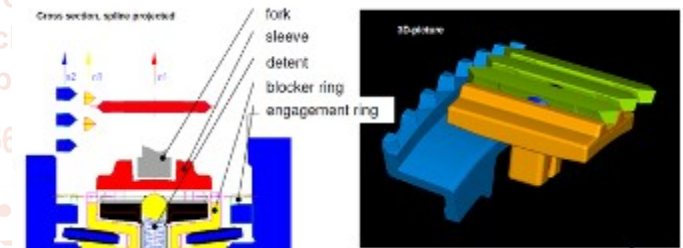
5. **Index Torque / Blocking Torque:** Index torque is generated due to the friction force in the direction of pointing angle between the two chamfers of synchronizer ring teeth and sliding sleeve teeth. During the synchronization, this torque acts in opposite direction to the synchronization torque. It is a function of the axial force applied to the sleeve, teeth pointing angle, pitch diameter of the blocking ring, surface coefficient of friction between the teeth pointing surfaces of sleeve and blocker ring. The Index torque must be higher than the total drag of transmission in order to satisfy the smooth gear shiftability even in cold conditions.



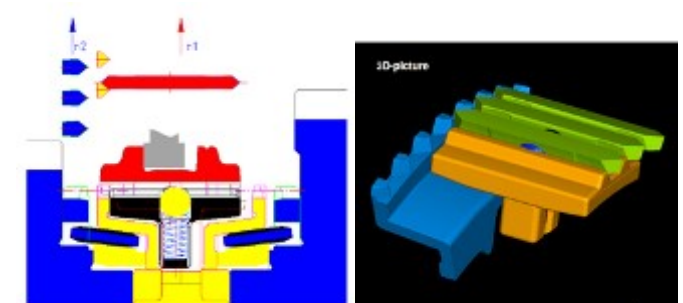
- 6. **Drag Torque:** Drag torques are the power losses due to the clutch drag, transmission oil churning and friction of the rotating components. Always acts to slow down the speed of the rotating components.
- 7. **Shift Impulse:** It is the product of the gear shift effort applied to the gear shift knob in Newtons (N) and the synchronization time in seconds (s). It is usually used to determine the gear shift performance.
- 8. **Boost Force:** This is an additional force generated due to ramp surfaces defined in the hub outer circumference and provides an increase of the shift force without any increase in load of the shift lever.
- 9. **Coefficient of Friction:** COF on cone shaped surface varies with the thickness of the lubricant between the CBR and the Ring. The COF on the cone surface increases suddenly while the sleeve forces the blocker ring to move forwards the CBR for draining the lubricant out. It decreases after synchronization as the blocker ring slides away from the CBR. Thus the COF is the function of material, temperature and lubrication. High COF produces higher adhesive wear and thus leads to lesser durability of the synchronizer.
- 10. **Spring Rate:** The Spring stiffness affects the reaction force of the spring and thus affects the load transmitted to the synchro ring.

**Synchronization Process:**

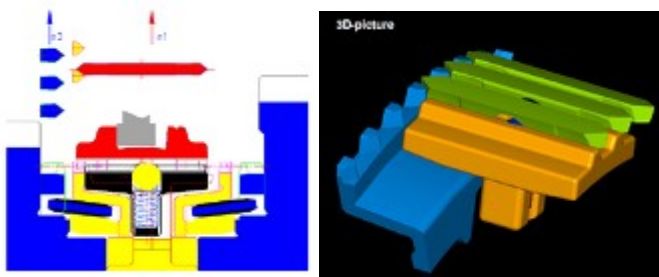
**1. Neutral Position**



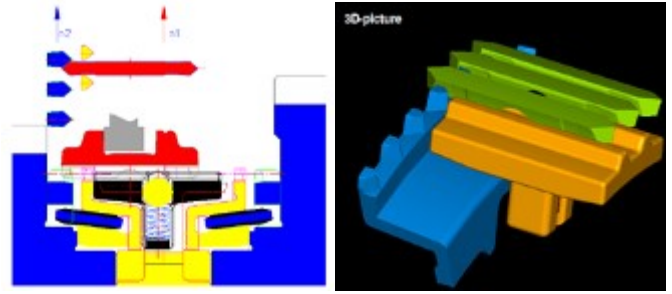
2. **Presynchronization or Asynchronization:** Before the shifting starts, the Sliding Sleeve is held in the middle position by detent mechanism, *refer neutral position*. The Shift Force  $F_s$  Triggers the axial movement of the Sliding Sleeve which causes the thrust pieces to act on the detent ball pins to presses the Blocker ring with its counter-taper against the friction taper of the CBR. The speed difference between the Sliding Sleeve and the Blocker Ring relative to the idler gear causes the Blocker ring to turn until the dog teeth engages in the groove wall. This is the of the Synchronization. The detent generates a force up to 50-100N which creates a friction torque.



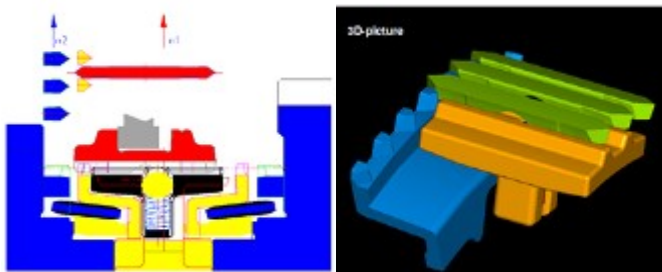
**3. Blocking Position:** The Sliding Sleeve is move further which brings the constant mesh internal gear of Sliding Sleeve and the constant mesh external gear of the Blocker ring come in contact. The main synchronization action starts here. The Shift Force  $F_s$  is applied to the synchronizer ring via the detent mechanism and the dogs. Here the speed difference is reduced until  $n_1 = n_2$ .



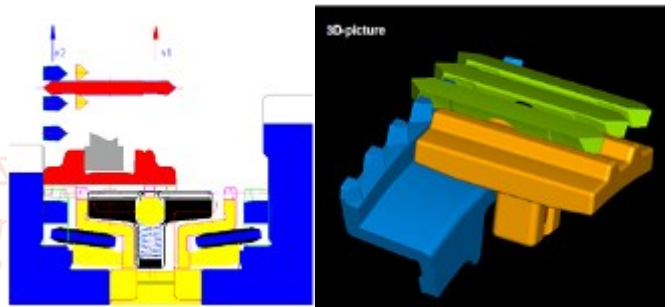
**6. Engagement:** The Sliding Sleeve enters into the engagement ring. The Speed difference in  $n_1$  and  $n_2$  causes bumps at the entering into the engagement ring.



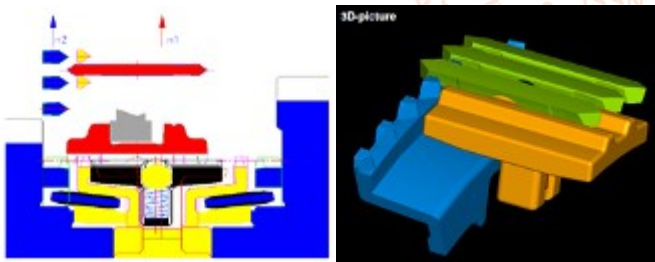
**4. Blocking Release:** At this stage where  $n_1 = n_2$ , the blocking condition is no longer valid. The Sleeve can turn back the blocker ring and move forward through the spline of the blocker ring.



**7. Gear Shift:** When the Sliding Sleeve has completely moved into the engagement ring, the gear is shifted. The back tapered teeth on the Sliding Sleeve and the Blocker ring avoid the decoupling under load.



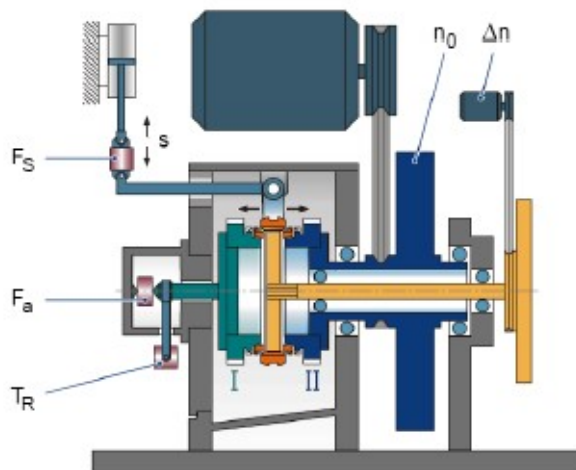
**5. Free Flight:** The Sliding Sleeve Slides further through the spline of blocker ring. In this phase, new speed difference between  $n_1$  and  $n_2$  can occur.



P.T.O

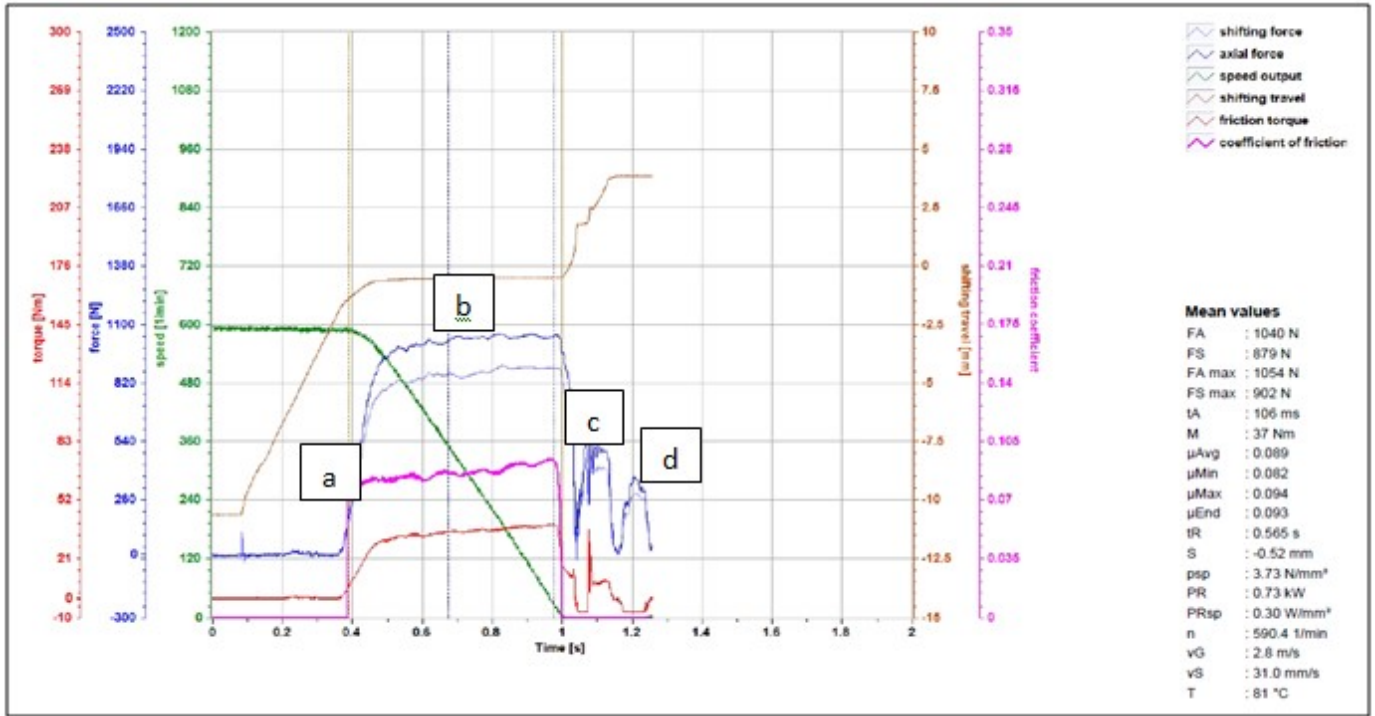
**Synchronizer Functionality and Endurance Test**

The Synchronizer is subjected to the functional and endurance test before it is released for Industrial production. The Synchronizer is most widely tested on the Horizontal test rig which is capable to provide the data like friction, wear, friction torque, Shift travel, Shift force etc. Shown here below is the test-rig ZF/FZG SSP 180, developed at the Gear – Research Center (FZG) of Munich University.



The Following graph is the data generated by the Test Rig of the Synchronizer under the Test.

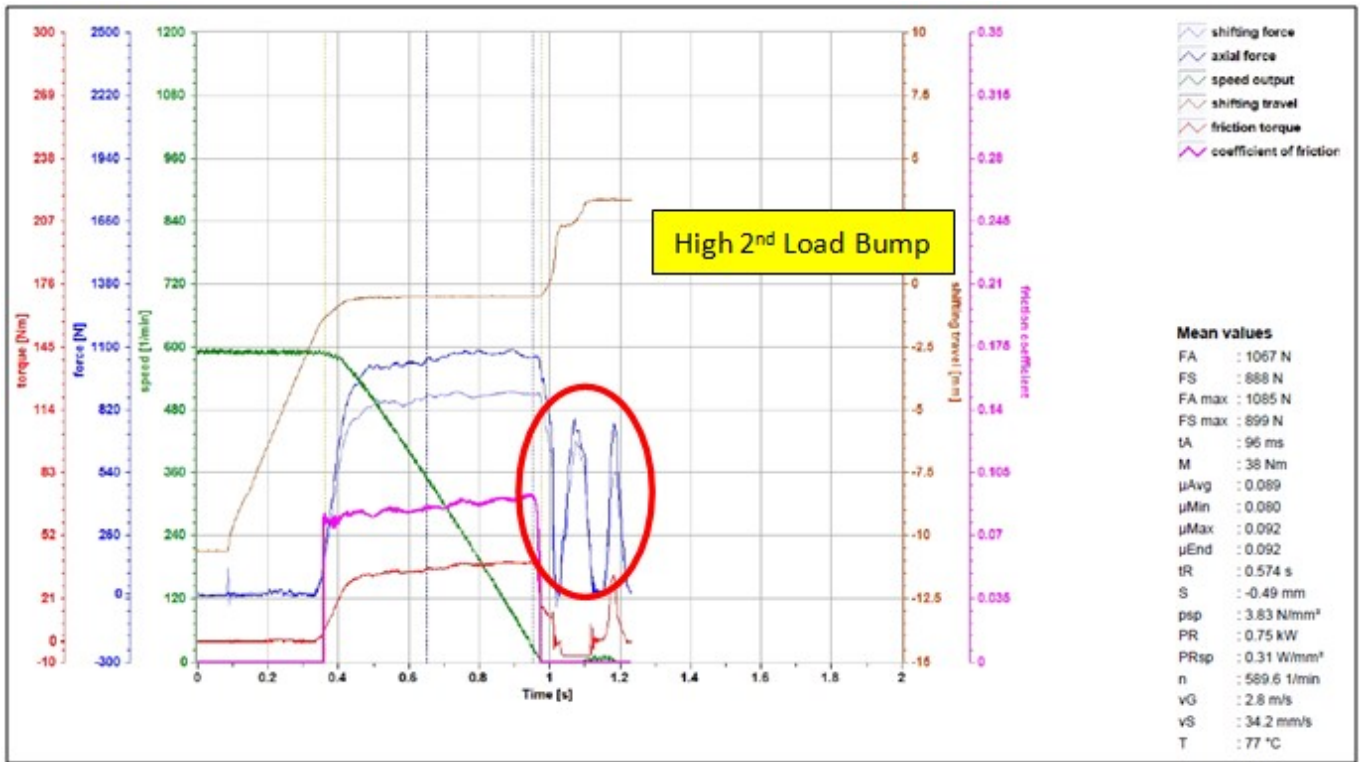
1. Normal Shift.



- A. Presynchronization
- B. Synchronization
- C. Engagement of Sliding Sleeve and Clutch Teeth.
- D. Final Positon.

2. **Second Load Bumps:** The 2<sup>nd</sup> Load Bumps are occurred when the sleeve enters the engagement ring. If the resistance is too high, it can be felt at the gear shift knob





Reason for the 2<sup>nd</sup> Load Bumps could be:

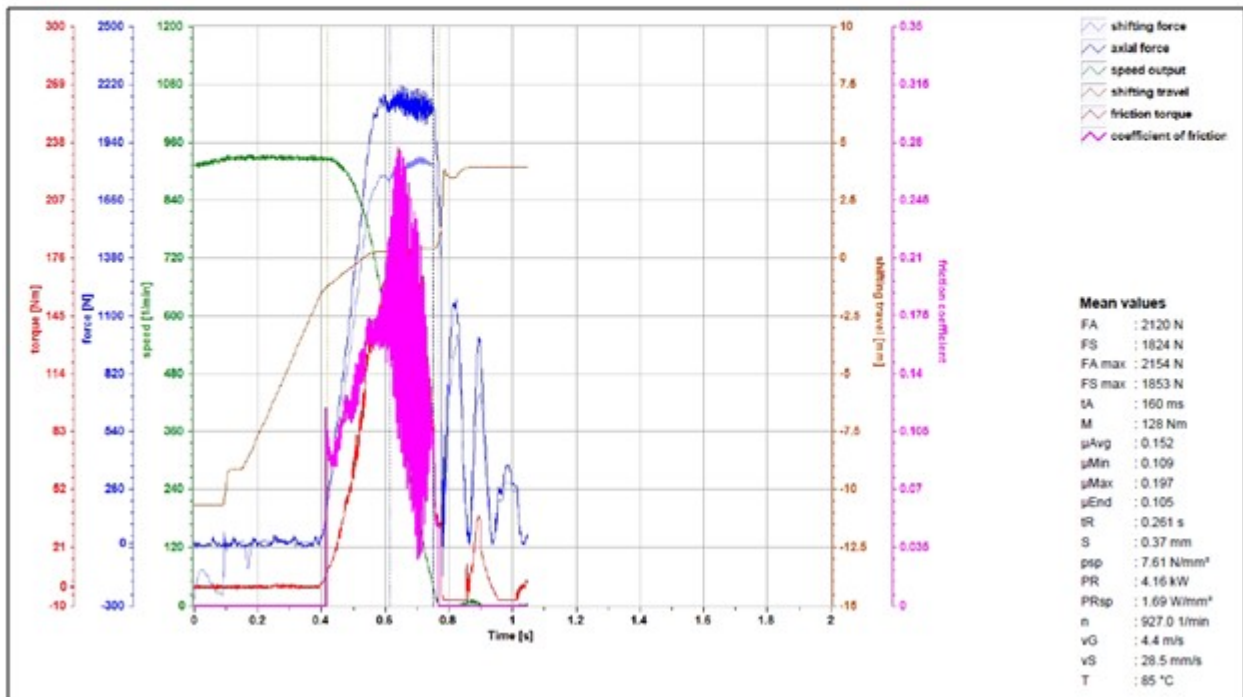
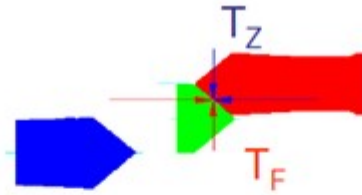
1. High drag torque, especially in the cold transmission
2. High friction torque
3. Losses in shift system
4. Clutch not open fully, 100%.

Possible measure to avoid load bumps:

1. Low Viscosity oil, low friction bearings
2. Reduced the chamfered angle so as to respect the blocking safety
3. Reduce losses in shift system.
3. **Clash:** Clash occurs when the blocking safety is not given. In this case the sleeve moves towards the engagement ring before the speed difference has been synchronized.

Blocking Safety: Friction Torque,  $T_F > T_z$ , Blocking release torque.





Reasons for Clash could be:

1. COF too low for design layout
2. COF changes over lifetime
3. Oil viscosity too high at low temperature
4. High wear
5. Shift fork position decentralized

Possible measures to avoid clashing

1. Increase the Blocking Safety ( chamfer angle, cone angle, friction lining)
2. Improve the groove geometry
3. Improve the COF increase in presynchronization (detent force)
4. Increase the wear gap.

