

# The Mechanical Central Release System for the SAC - an Alternative ?

Dr.-Ing. Ad Kooy

## Introduction

In the past there has been an increase in the application of hydraulic release systems, especially in mid-size vehicles. The reasons are evident:

- a simplified automatic wear adjustment feature
- ease of installation
- good efficiency at high release loads

Figure 1: Advantages of the hydraulic release system over the mechanical release system

This trend has motivated several manufacturers to develop a concentric ring cylinder, positioned around the transmission input shaft, which acts as a slave cylinder (Figure 2). Compared to the semi-hydraulic release system with external slave cylinder (Figure 3), the new system has the advantage of eliminating the release fork. Several automotive manufacturers have introduced these CSC-systems (Concentric Slave Cylinder Systems) into production.

But why not develop a mechanical central release system as an alternative to hydraulic systems? The advantages of the centralized configuration could be used and the elimination of the release fork could give a definite cost reduction in comparison to the conventional hydraulic system. Development of the SAC puts such a possibility in a new light.

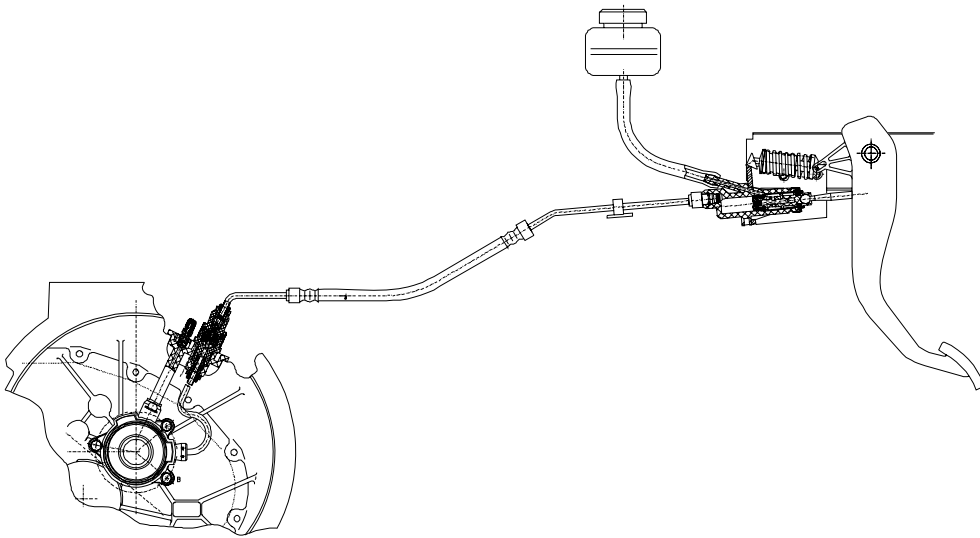


Figure 2: Operating system for a hydraulic release system, INA design

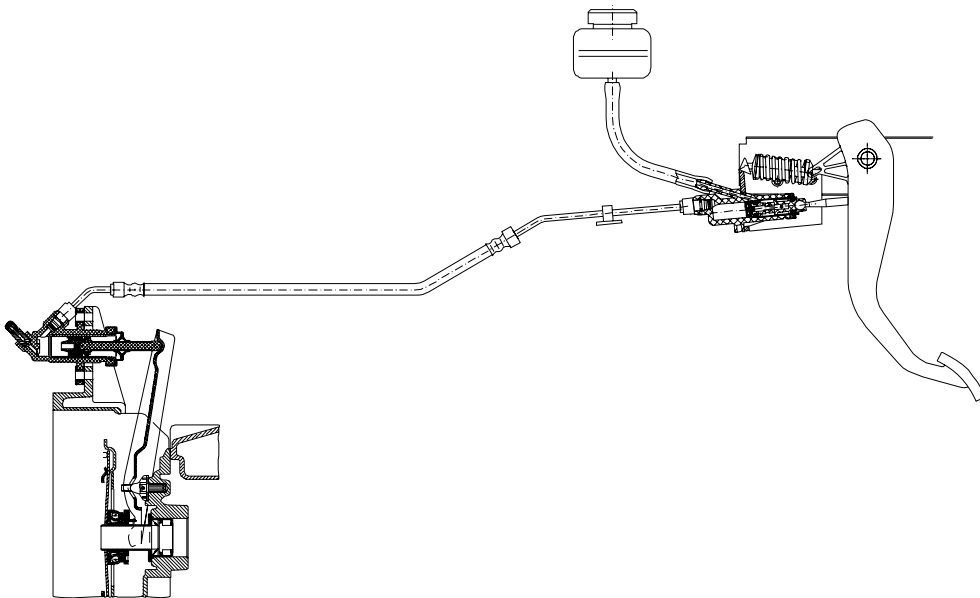


Figure 3: Semi-hydraulic release system, INA design

## Release system requirements for a SAC application

The SAC design entails an obvious change in the requirement list for a release system (Figure 4). As demonstrated in the previous presentation, the SAC lowers the release loads. A release system must have the ability to work effectively and to reset itself reliably under such low loads. This requirement favors the advantages of mechanical systems because they develop less friction than hydraulic systems with their seals. Lower requirements can be placed on the stiffness of the release system without sacrificing efficiency.

- Reduces the release load by 50 %
  - Favors the mechanical system thanks to lower friction
  - Lower stiffness is allowable
- During wear the diaphragm fingers travel in the same direction as the release motion
  - simple mechanical readjustment mechanism possible
  - wear travel reduced by 70 %

Figure 4: Influence of SAC on release system requirements

A further difference becomes obvious over the lifetime of the clutch. As the facings wear, the diaphragm spring finger tip travels in the same direction as the release motion. As discussed later, simple automatic adjustment mechanisms can be designed to compensate for this. In addition, by adjusting for wear in the SAC, the actual change in finger height due to the facing wear is reduced by 70 %, which saves installation space.

Requirements for the most basic possible release system must be defined primarily based on these new, SAC-induced conditions (Figure 5).

A low release load needs to be combined with low friction in order to assure reliable reset of the bearing. At such low release loads, sufficient stiffness should not present a problem. To guarantee the function of the SAC, release bearing overtravel must be avoided.

As with all hydraulic systems, this design must provide for an automatic adjustment for facing wear.

**Function**

- Low friction, sufficient stiffness
- Reset at low release loads
- Prevention of overtravel
- Automatic repositioning of the release bearing in the direction of the engine during wear
- Reduction of pedal vibrations

**Durability**

- Insensitive to contamination
- Ambient temperatures up to 200°C
- Little wear

**Installation**

- No need for more space
- Easy cable routing and installation in the vehicle

**Costs**

- Less costly than conventional release systems because fork is eliminated

Figure 5: Release system requirements

Obviously the release function must be maintained over the lifetime of the clutch, despite high ambient temperatures and contamination from facing particles.

Installation conditions are often very tight, which does not allow for additional space in the vehicle for a new release system. Furthermore, the need for fast, easy installation in the vehicle dictates that the least possible number of subassemblies are used.

With a goal of meeting the previously mentioned requirements, different basic release principles can be compared.

## **Mechanical release system principles and adjustment systems**

In the first step, it was investigated how the actuation of a cable can be used to generate an axial movement of the release bearing without using the usual release fork. Despite the sometimes bad reputation of the cable, it was chosen because the low load, typical for a SAC, clearly improves durability and reduces wear. At first LuK investigated applicable mechanical alternatives systematically.

One of those alternatives was polygonal linkages. Such linkages produce a linear or almost linear movement. Figure 6 shows an example used, among others things, for ship loading harbor-cranes. Selection of the geometrical polygon dimensions and the connection of the cable permits the lever ratio to be altered within a limited range. Space problems would be expected with this concept and also high production costs because a minimum of five joints is required.

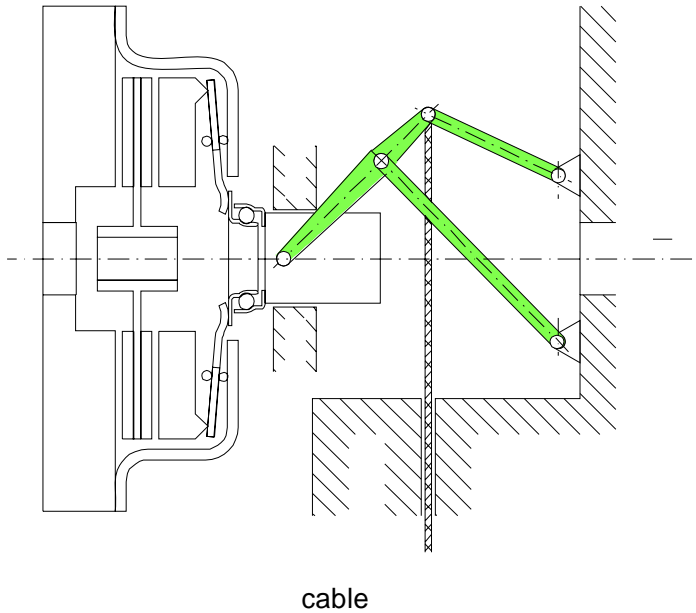


Figure 6: Polygonal linkage for release systems

Another concept is the use of two ramps (Figure 7). When the upper ramp is displaced relative to the fixed lower ramp, the movement is transferred into an axial motion, depending on the ramp angle. Use of balls or rollers keeps the friction low.

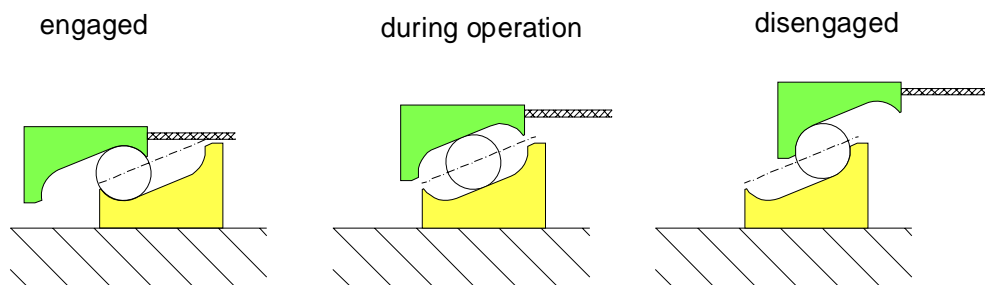


Figure 7: Ramp principle

This basic design can be executed in very different ways. Figure 8 shows a design presently in development. Here two ramp units are located between the release bearing and the transmission wall.

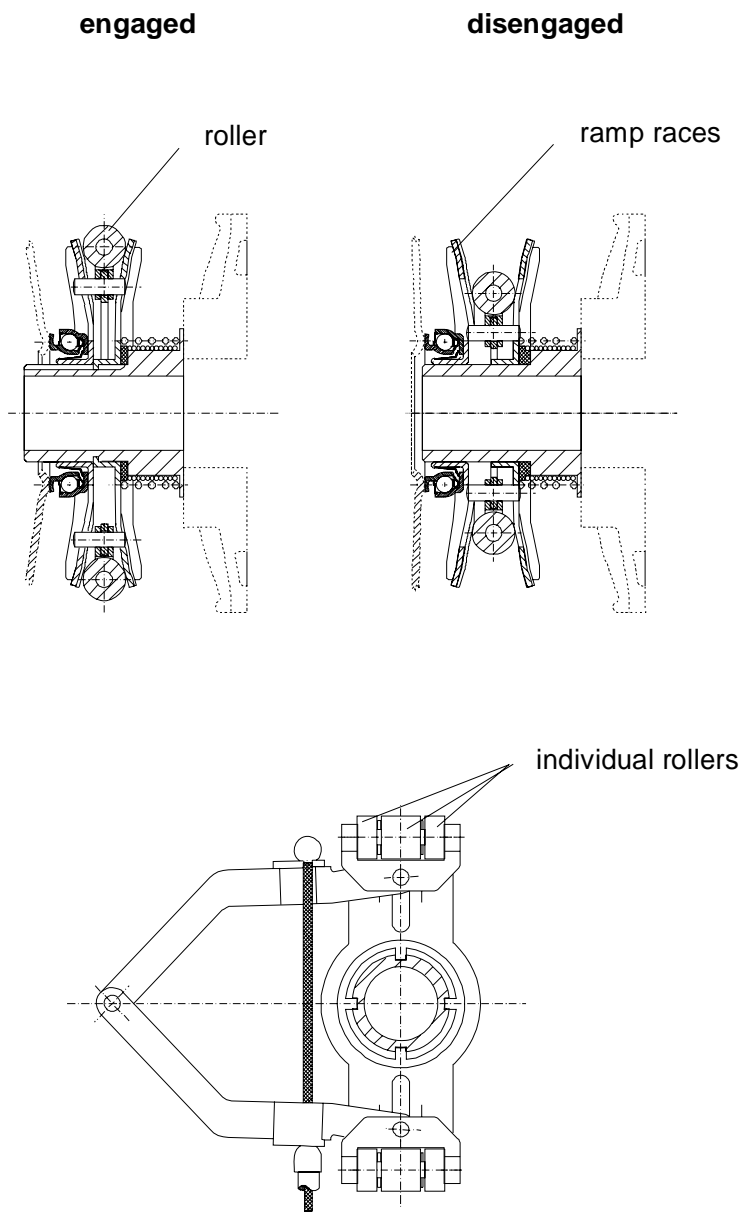


Figure 8: Radial ramp arrangement

When the cable is activated two opposing rollers are synchronously moved towards each other via a mechanical coupling. This spreads the ramp races and produces an axial movement of the release bearing.

In order to achieve a rolling motion and a symmetrical ramp load, each roller unit is divided into three individual rollers. The center roller rolls against one ramp race, and the two narrow outside rollers roll against the opposing ramp race.

Therefore, each ramp race is guided via a three-point support, which prevents a misalignment of the release bearing. This assumes a synchronous movement of the upper and lower rollers shown in Figure 8. Additional components must be added to the design to ensure this.

One further possibility for the configuration of ramp units is shown in Figure 9. Here three circular ramps in the form of asymmetrical grooves were situated in a fixed ramp ring and a rotating ramp ring. When the rotating ramp ring is turned, a screw-type motion occurs similar to the action of a triple-threaded screw; the balls minimize the friction and take over the radial as well as the axial guidance of the release bearing mounted to the upper segment. While the fixed ramp ring is mounted on the transmission wall, the rotating ramp ring can be actuated by a cable producing the axial release movement. This simple principle has proved reliable for a long time in the release system for motorcycle clutches.



Figure 9: Circular ramp arrangement

The three balls create a three-point support which clearly defines the position of both ramp rings with respect to each other. Besides torque, the cable also creates an unwanted transverse load, which, however, only amounts to approximately 40 % of the release bearing load, depending on the ramp angle. This transverse load is transmitted by two of the three balls.

When the ramp angles of both parts are constant, the release bearing will not tilt, even if one of the balls shifts. As shown in Figure 7, the ramps can be designed so that the balls at both ends of the ramp act as stops, which reliably prevents overtravel damage to the SAC and therefore does not require a stop-tab in the SAC cover.

The balls are repositioned each time they are used as a stop. A ball cage is therefore not necessary, even if varying ramp angles are used to reduce the maximum and to increase the minimum release load. In that case the ramps need to be designed so that the contact points of both ramps on the ball are located opposite each other over the complete travel. This allows the ball to easily follow the desired path because it prevents the creation of reactive loads (Figure 7).

The advantage of this ramp ring-type release system lies both in the compact concentric design and in the three-point support, which ensures reliable function with few parts.

In order to compete with hydraulic systems, a mechanical release system must be able to automatically adjust for changing diaphragm spring finger height as the facing wears.

In the SAC, unlike in a conventional clutch, as the facing wears the diaphragm spring fingers travel in the same direction as during disengagement. A relatively simple mechanical readjustment mechanism similar to the SAC-adjustment (Figure 10) can be designed to compensate for the change in diaphragm spring finger height. To accomplish this, ramp rings - preloaded with springs - compensate when a gap occurs between the diaphragm spring fingers and the release bearing. As in the SAC-design, the self-locking feature prevents a return to the previous ramp position by using a flat ramp angle. This mechanism operates automatically and continuously.

The mechanical central release system (MCR) combines this readjustment with the release concept shown in Figure 9.



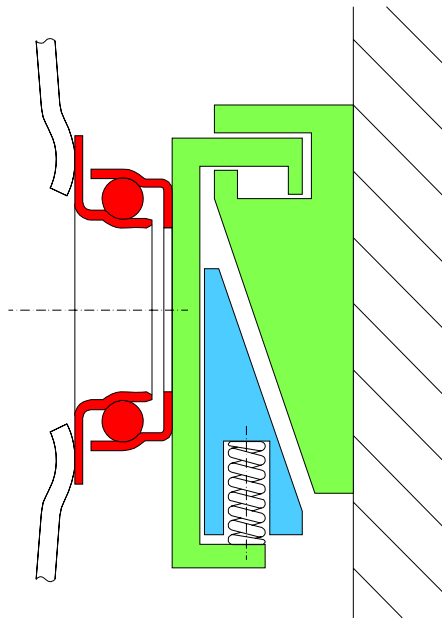


Figure 10: Finger height adjustment concept

## The mechanical central release system

Figure 11 shows a layout. The complete release system consists of a few, relatively small detail parts that are inexpensive to make. Besides the release bearing with its diaphragm spring, three formed sheet-metal parts, 3 balls, 2 plastic rings, one coil spring and a simple curved wire are needed. LuK can rely on its long experience in the production of clutches and dual mass flywheels when creating the tools for these stamped parts. How the individual parts work together is described in the following section.

The system can be divided into units with the following functions:

The fixed and rotating ramp rings are responsible for the release function.

The fixed ramp ring is fastened to the transmission via screws or grooved pins. When the rotating ramp ring turns, it moves axially over the three greased balls. At the end of the turning motion, the balls hit stops, which limits the release travel (Figure 12). A wire leading to the housing wall activates the ramp ring. Due to the hook form of the wire, the cable can be easily connected or disconnected from outside. This wire also protects the cable from contamination by facing particles and from excessive transmission-housing temperature.

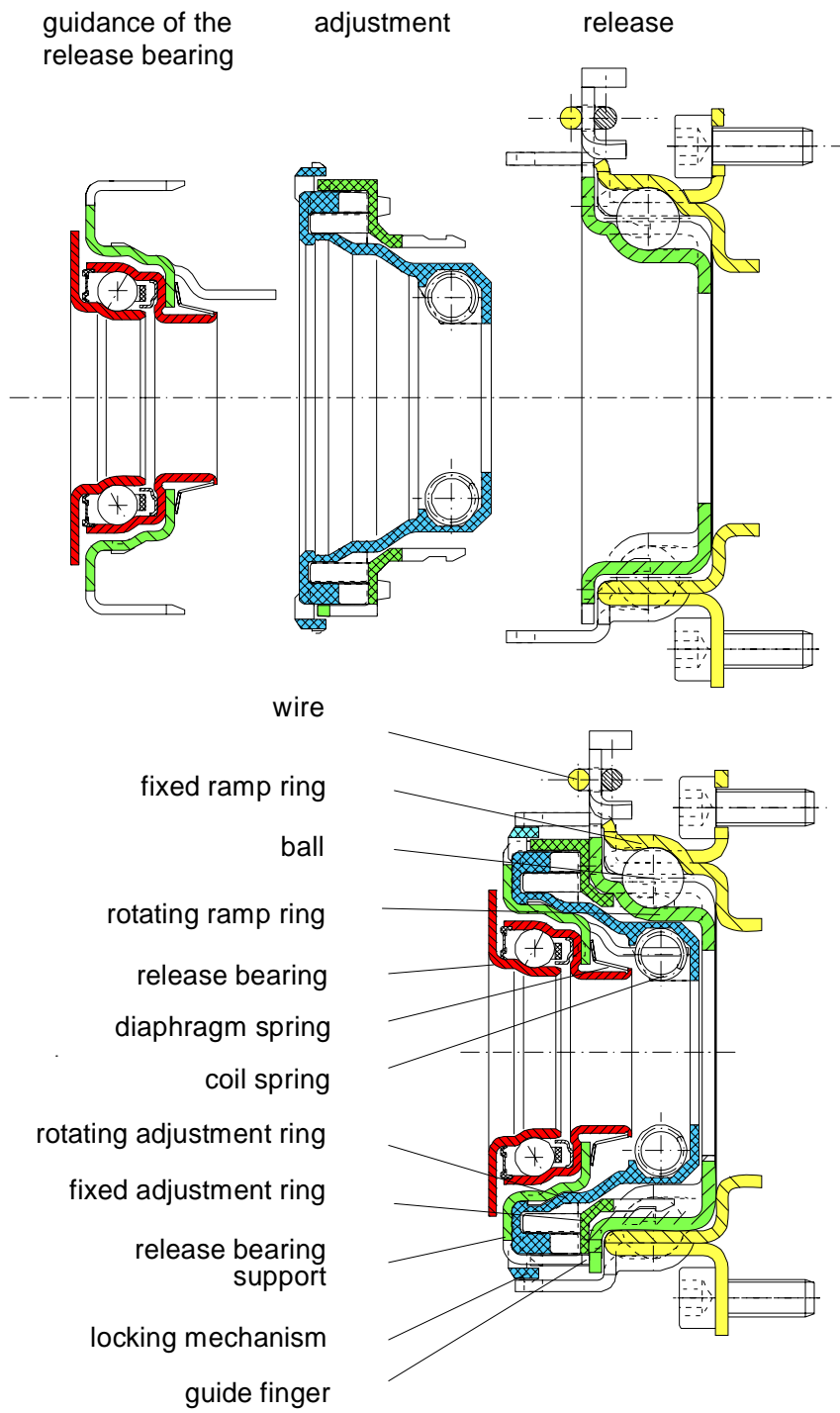


Figure 11: Mechanical central release system (MCR)

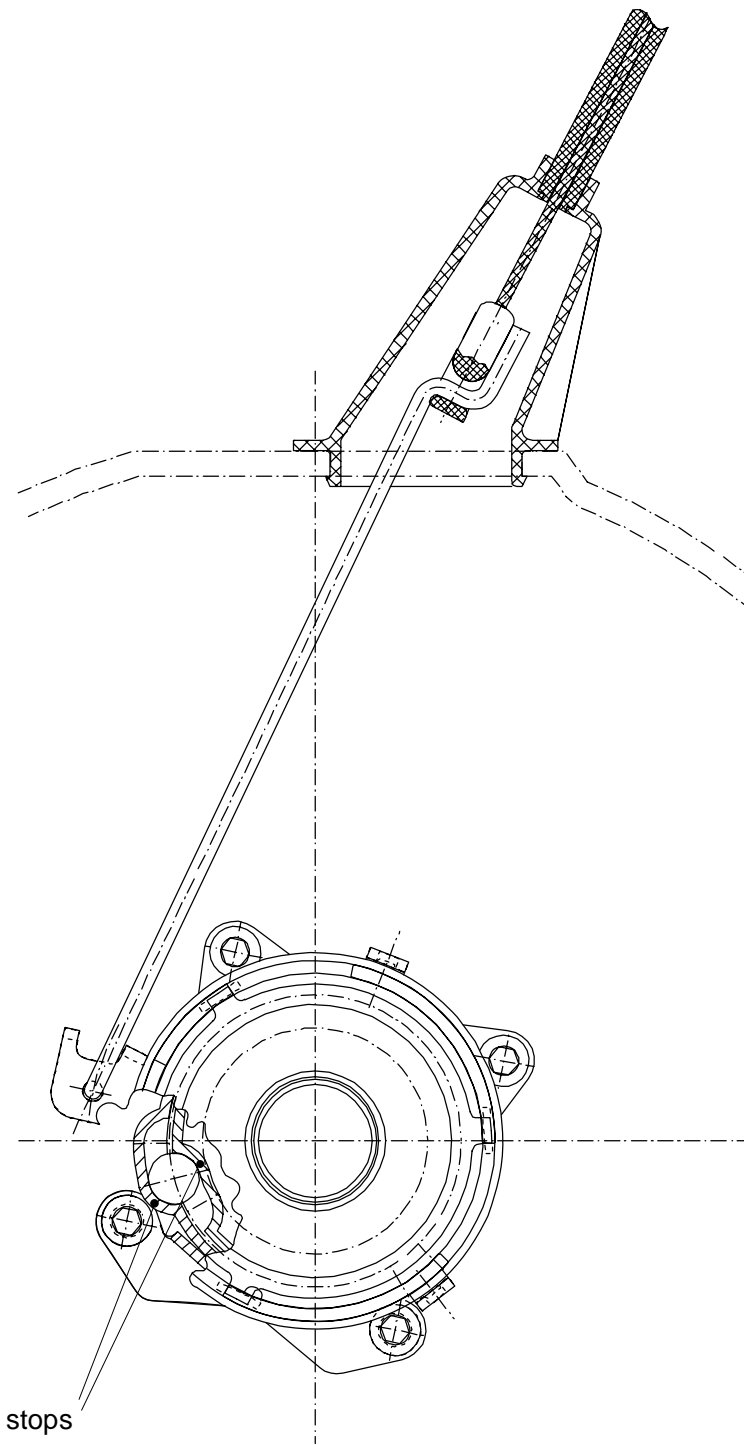


Figure 12: MCR cable connection

A ramp angle varying along the cable travel can be used to change the lever ratio over the release travel and, if necessary, compensate for the release load, which in the SAC typically drops considerably at the end of the release travel (Figure 13).

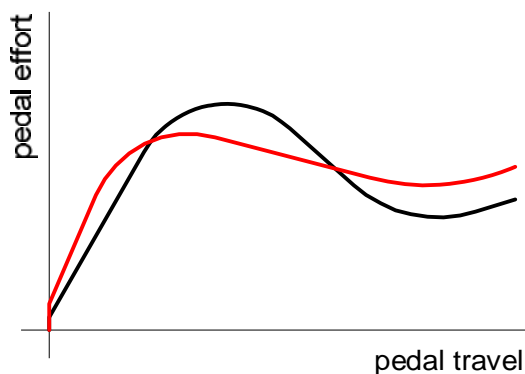
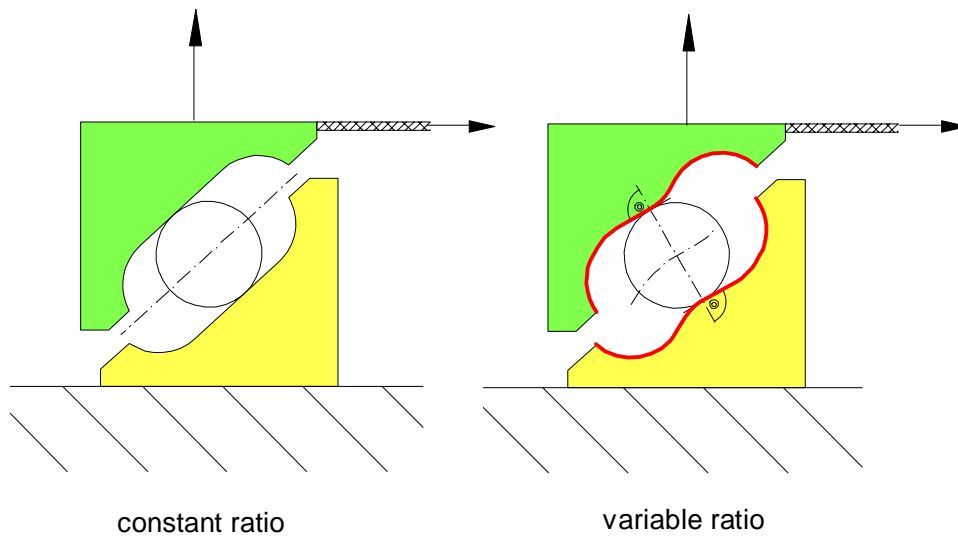


Figure 13: Ramp concept

The fixed adjustment ring is permanently connected with the rotating ramp ring (Figure 11), which together with the rotating adjustment ring provides the adjustment function via two concentrically situated ramp areas. The outer and inner ramp areas consist of two ramps, each extending over 180° with a self-locking ramp angle. After readjustment, each ramp area provides two contact areas separated from each other by 180°. Because

the outer and the inner ramp area are off-set by 90°, a stable four-point support is established.

A coil spring assists readjustment by exerting a force directly onto the rotating adjustment ring and via a flange onto the release bearing support. Depending on the available space, the spring can be placed inside, as shown here, or radially outside of the adjustment ramps. With a readjustment angle of approximately 100°, about 6 mm adjustment can be achieved.

The coil spring also produces a release bearing preload.

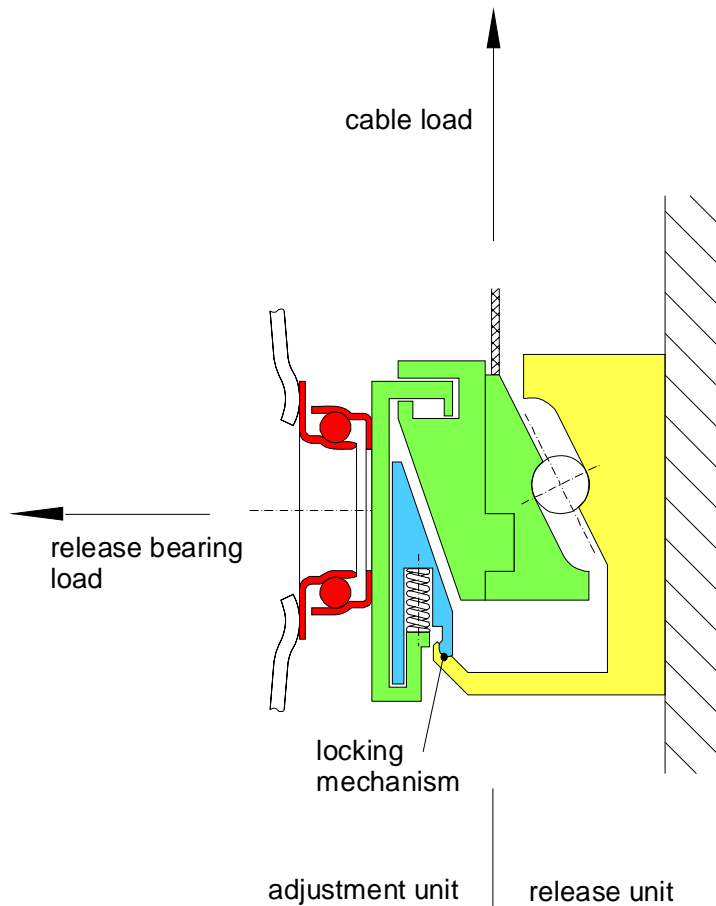


Figure 14: MCR block diagram

Prior to installing the MCR, the adjustment mechanism must be reset and locked (concept see Figure 14), which requires that the MCR be removed from the vehicle. The adjustment ring is turned back and then locked in the rotating ramp ring in order to block the axial movement of the rotating

adjustment ring. The MCR assumes its shortest axial length and can be installed in this position. After the clutch housing is installed, the mechanism unlocks automatically during the first clutch operation by separating the rotating ramp ring from the rotating adjustment ring, which releases the locked parts and frees the adjustment function.

Once activated, the ramp-ring reset mechanism functions to adjust for the installation tolerances. It moves the ramp ring away from the lock-up position and effectively prevents further lock-up. The mechanism can easily be locked again manually if the transmission housing is removed from the vehicle for service. In addition, the mechanism locks the release system during transport to the automotive plant.

The self-centering release bearing is mounted in the traditional fashion on the release bearing support via a small diaphragm spring. Because the three-point support on the three-ball ramp prevents the release bearing from tilting, the conventional quill can be eliminated. This means that the outer bearing diameter can be smaller, which reduces costs and bearing drag torque. The three guide fingers on the release bearing support directly transfer these drag torques onto the fixed adjustment ring, which in turn isolates the adjustment function of the rotating ring from the drag torque.

## **Tolerance compensation**

The axial length of the component is based on the crankshaft length, the flywheel height, the diaphragm spring height, the release system length, and distance to the transmission wall. The finger height adjustment assembly can also be used to compensate from tolerance of this axial length.

This reset mechanism cannot compensate for the tolerances of the cable length and its linkage, which produce a variation in pedal height. A separate initial adjustment mechanism is required, like the one that has been developed in cooperation with Küster (Figure 15).

Basically the design consists of two nested sleeves which are preloaded with a light spring and integrated into the cable sheath.

At installation the spring is pushed to solid. Serrations in a sliding sleeve form a positive locking function, which prevents the sleeves from being pulled apart. At minimum length, the sheath is shortened by more than 40 mm and permits easy connection of the protruding cable. After the transmission has been installed, the safety catch between the sleeves is released by activating the locking sleeve. Inside the sheath a spring-supported length adjustment is established. After the locking sleeve has been released, the serrations again lock with each other and are in operating condition. This process can also be easily accomplished during service.

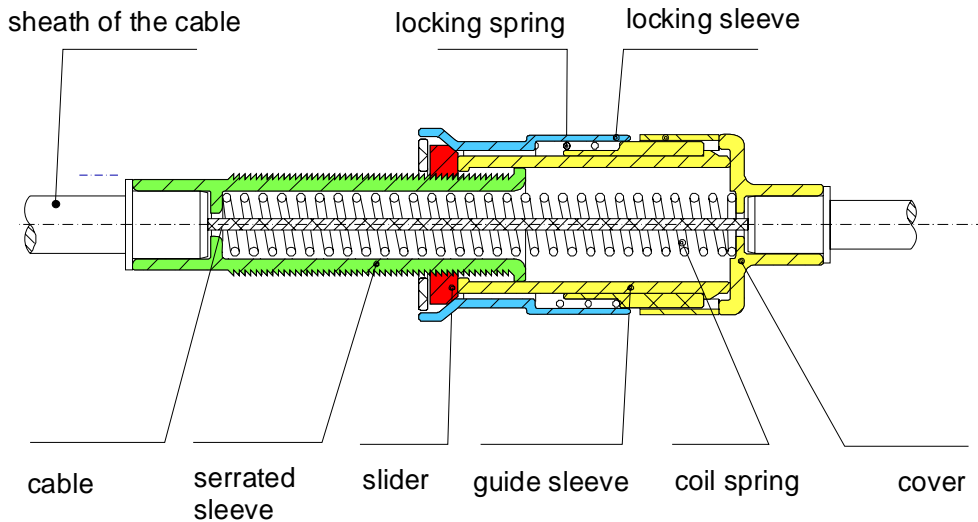


Figure 15: Initial cable adjustment mechanism, Küster design

This mechanism must be sealed against the somewhat lower air pressure inside the vehicle. Otherwise it will attract dirt particles, which in turn increases the friction inside of the cable.

Counter to popular belief, wear on cables causes less than one millimeter change in length, therefore the cable itself does not have to be readjusted during its lifetime, although this could be easily done using the initial adjustment mechanism.

It also is possible to adjust the pedal height tolerance with a locking mechanism placed between cable and pedal (Figure 16, Kirchhoff design).

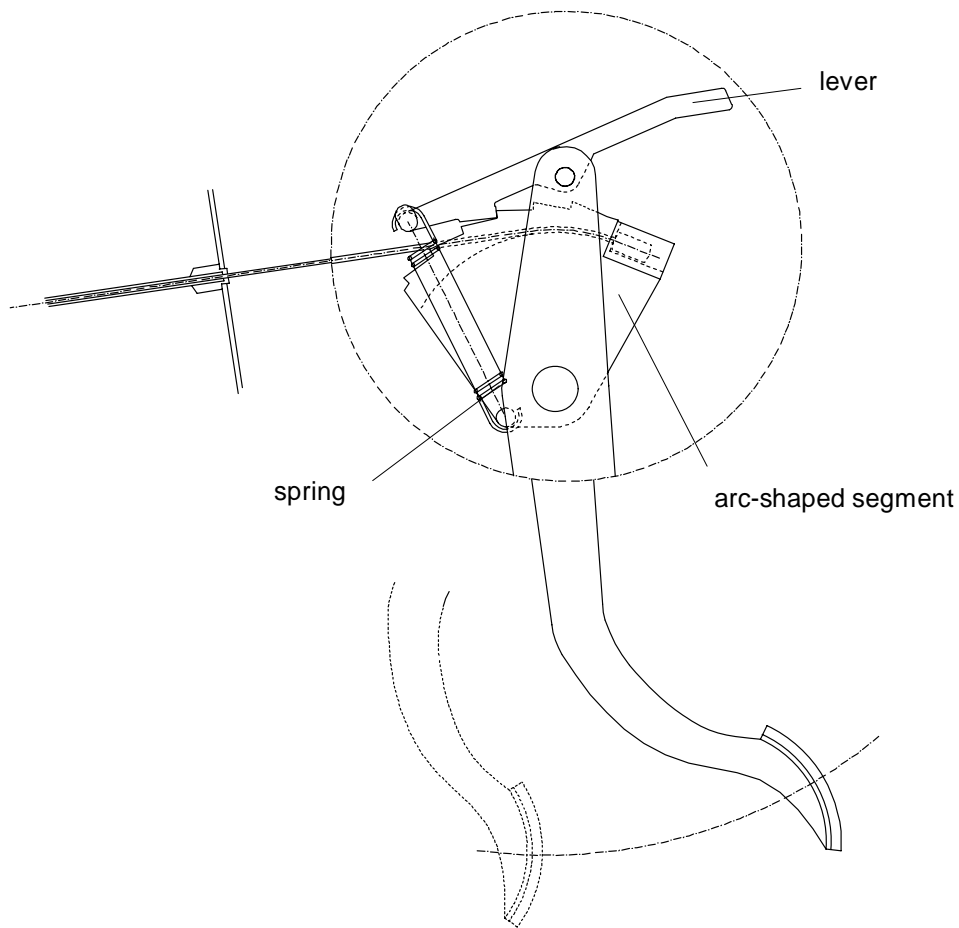


Figure 16: Initial pedal adjustment, Kirchhoff design

During installation, the cable is hooked into an arc-shaped segment. Interlocking teeth in the lever and the segment prevent rotation.

After the cable is attached, the lever is depressed to release the serrated teeth, and the attachment segment preloads the cable slightly via a spring. When the lever is released, the spring-loaded positive connection is reestablished and the original adjustment is completed. Because this mechanism can be installed inside the vehicle, it is not exposed to higher temperatures, as it would in the engine area. There are also no air pressure differences, which in turn reduces contamination of the cable by dirt particles.

There are various concepts for initial adjustment and easy attachment of the cable, as demonstrated with both previous examples. The vehicle type does influence the selection. In any design, the smallest possible distance



between serrations should be used in order to limit lash, which would translate into release system losses.

A sample MCR device was installed in a LuK-vehicle, where it functioned to full satisfaction (Figure 17).

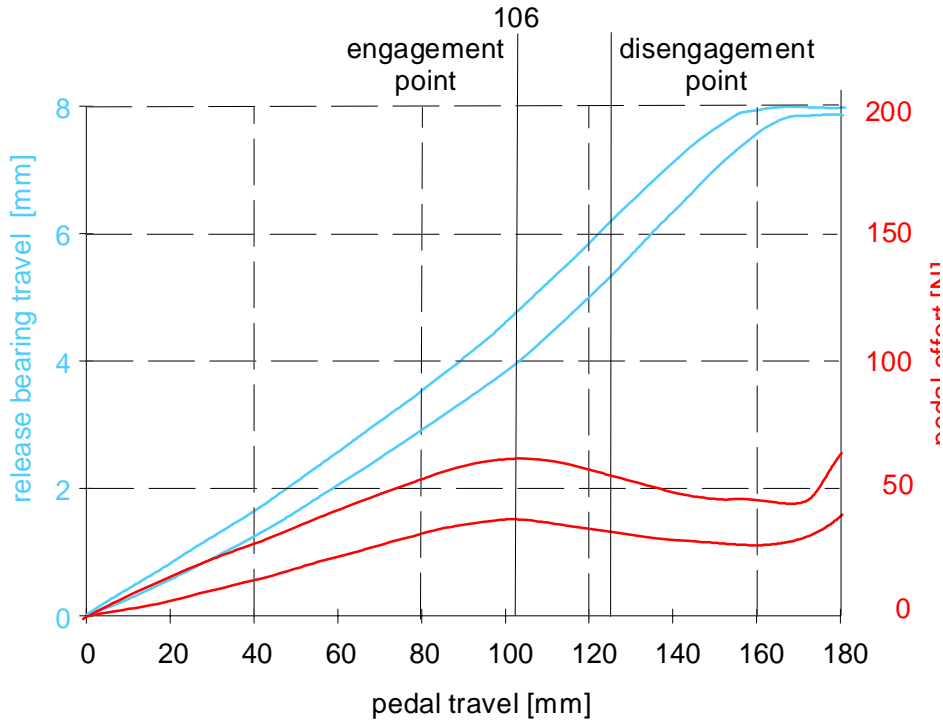


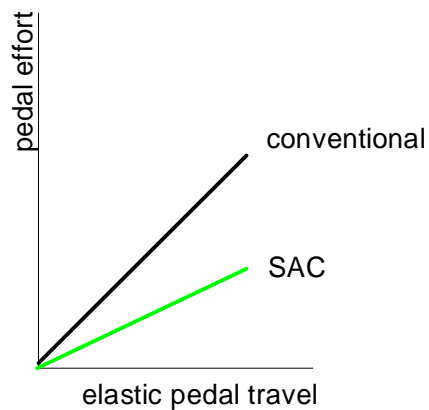
Figure 17: MCR function test in the vehicle

## Isolation of pedal vibrations

Pedal vibrations attract unfavorable attention by creating noises or a tingling sensation in the foot. Elimination of the release lever and installation of the SAC with MCR improves vibration isolation (Figure 18).

Eliminating the release lever gets rid of a relatively heavy part that has its own natural frequency. In addition, the lash-free three-point support prevents tilting, so the finger run-out of the clutch no longer causes pedal vibrations.

Remaining vibration sources include axial crankshaft vibrations and the resulting natural frequencies of the pressure plate.



- The release fork is eliminated from the vibration system
- Run-out of the diaphragm spring finger does not result in excitation because of release bearing guidance without free play
- Softer spring improves the isolation of vibrations

Figure 18: Influence of MCR with SAC on pedal vibrations

In conventional release systems, a rubber spring is often located between the release bearing and the pedal to reduce such vibrations. While the rubber spring makes it possible to achieve vibration isolation above the resonance frequency of the release system, the efficiency of the release system is reduced because the application of springs automatically leads to more flexible and therefore less efficient release systems. Application of the SAC, with its resulting 50 % reduction in release load, provides lower spring rates with increased vibration isolation at the same efficiency.

Figure 19 shows one possibility for integrating such a spring elegantly in the release system. No additional parts are required.

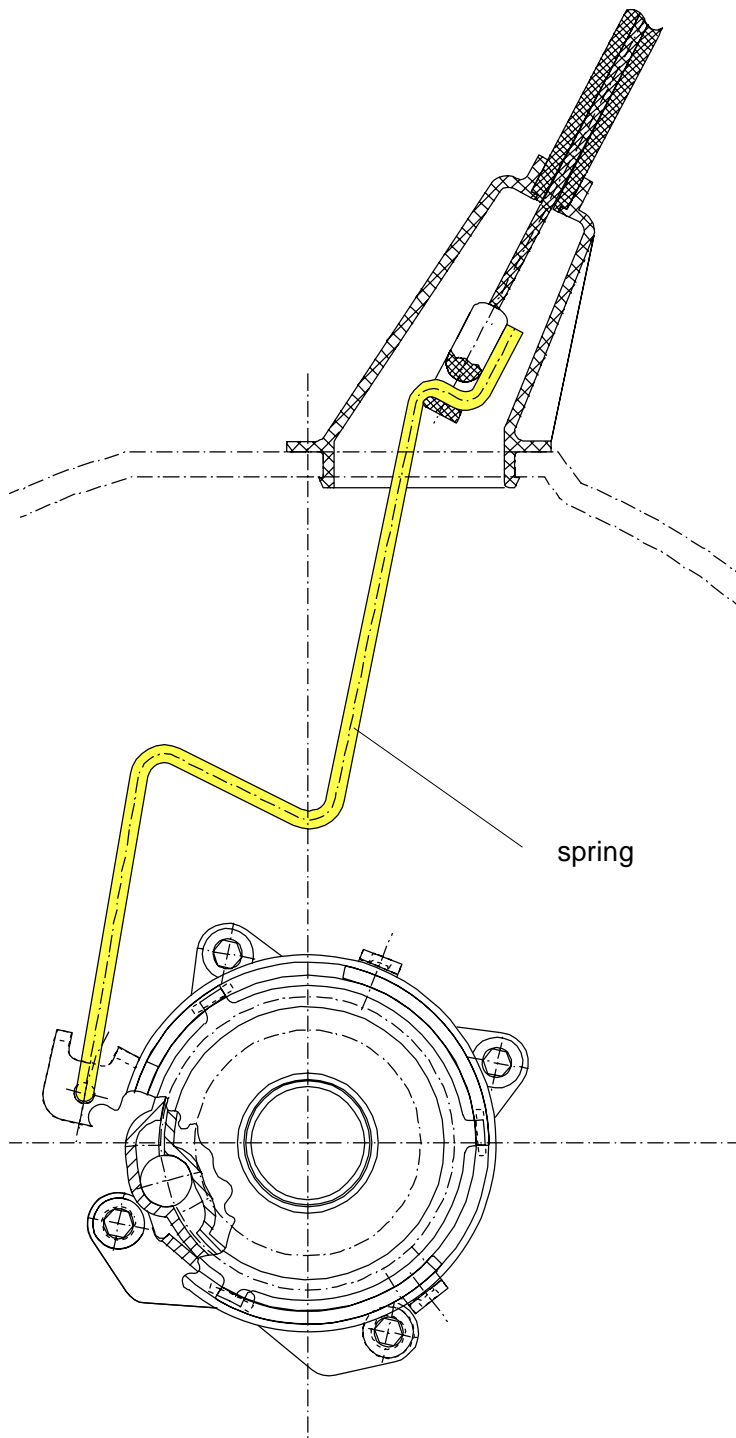


Figure 19: MCR with spring

Comparison of the mechanical central release system (MCR) with hydraulic systems. When comparing these very different systems (Figure 20), it is apparent that the functions achieved are almost the same. The MCR is prone to travel losses (without load) due to the mechanical lock feature in the initial adjustment, but so are hydraulic release systems due to the travel until the orifice connecting it to the reservoir closes

criteria	MCR	hydraulic systems
application	with SAC only	universally
travel losses	8 % (10 mm) (initial adjustment)	8 % (10 mm) (orifice)
losses in elasticity	10 %	5 - 10 %
friction, new friction, old	20 % 30 %	30 % 30 %
damping of pedal vibrations	possible	possible
complexity of design	few parts	few parts
cable routing	limited because of design requirements	free
functional reliability	simple mechanical system	seals represent a risk
costs	- 20 %	base

Figure 20: Comparison of MCR with hydraulic systems

Losses in elasticity are somewhat higher for the MCR, which does not matter in actual application. In new hydraulic systems, the friction produced by the seals is higher than in the MCR. With the cable, however, friction

can increase over the lifetime of the clutch, but it will be less than in conventional clutches because of the lower SAC release load.

One advantage of the CSC is the easy routing of the hydraulic lines. On the other hand, the piston seals are subject to higher risk because abrasive wear from dirt particles can endanger the seals and their function.

The difference in costs is significant. In comparison to the conventional hydraulic release system, the release fork, the bearing support for the release fork and the quill located on the transmission can be eliminated.

For obvious reasons the costs for the MCR will lie considerably below those for the conventional hydraulic release system and probably below the costs of a CSC as well.

## State of development and outlook

Durability tests have been performed with functional samples for  $10^6$  release operations (Figure 21). They provided information about suitable material combinations for the ball/ramp ring. C15 has high forming capabilities and in the case-hardened state achieves a suitable surface hardness and hardness penetration. When greased balls were used in tests, no significant wear was found on the ramps. Since the balls do not rotate, a costly grease seal was not required.

### Test stand experiments

Durability tests to  $10^6$  load cycles at 120°C to 165°C

- No wear between ramps and balls
- Wear of cable causes less than 1 mm change in length

### Vehicle tests

- Vehicle test reached 20 000 km - no problems
- Friction losses of 25 %

Figure 21: MCR - test stand experiments and vehicle tests

In the meantime, 20,000 km have accumulated in one vehicle test. The SAC reduced the maximum pedal load to about 70 N. Friction is still a bit high at 25 %, because the cable has not yet been optimized.

To summarize (Figure 22), it has been determined that application of the SAC has created a new range of requirements for the release system.

A new type of mechanical central release system has been introduced, which functions similar to the CSC. The elimination of the release fork and the quill clearly cuts costs when compared to conventional hydraulic systems.

- The SAC enables the development of new release systems.
- The new style of mechanical central release system functions as well as its hydraulic counterpart.
- The mechanical principle provides for simple, reliable function.
- A clear cost saving due to elimination of the release fork and the quill as compared to the conventional hydraulic system is achieved.

Figure 22: Summary MCR

For this new product, the first prototypes are planned for the end of 1995.